AGU Fall 2012
SM23A-2294

Auroral Oval Boundaries and Joule Heating/Poynting Flux Metrics Study

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Potential Validation Methodology

Physical quantities: Equatorward boundary

Poleward boundary

Define the boundary: not trivial

Method 1: a threshold in flux (50 eV - 20 keV) as in Hardy model

Method 2: Newell et al. approach, where different identified regions have physical meanings

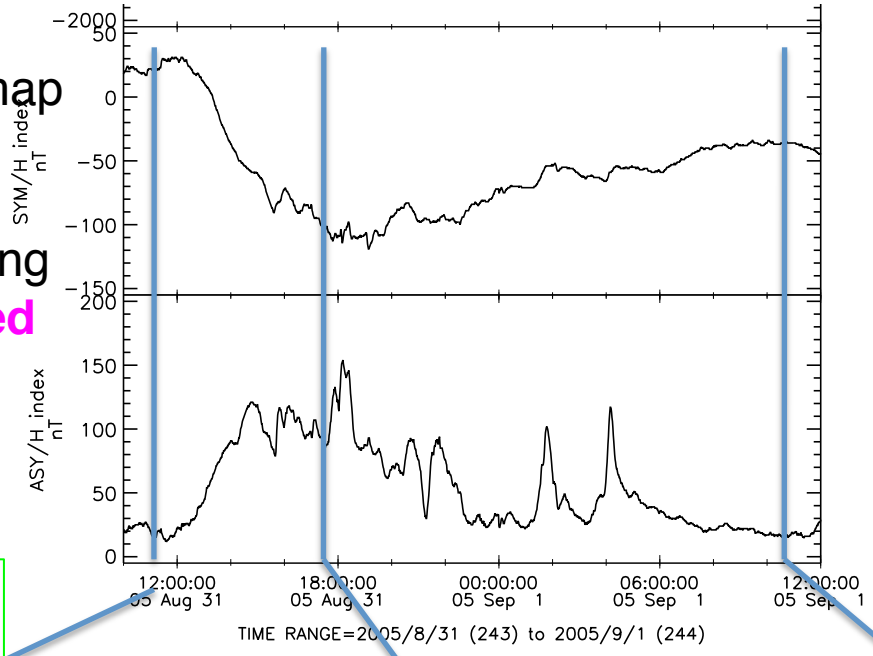
Method 3: Redmond et al approach, constant value in flux (sub energy range of DMSP: 1.39 keV -30 keV) as a threshold

http://ccmc.gsfc.nasa.gov/RoR_WWW/presentations/boundary_options.pdf

Different Measure of Performance

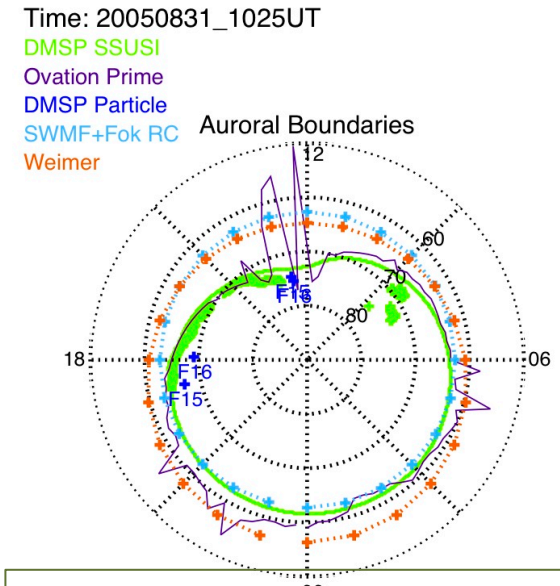
- Models' capability in capturing MLT feature/ characteristics at a specific time or during a period
  - Use standard deviation of the offset
  - correlation in all MLT binned by activity level or for a specific time - auroral imaging
- Model performance at a fixed local time
  - How well model performs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

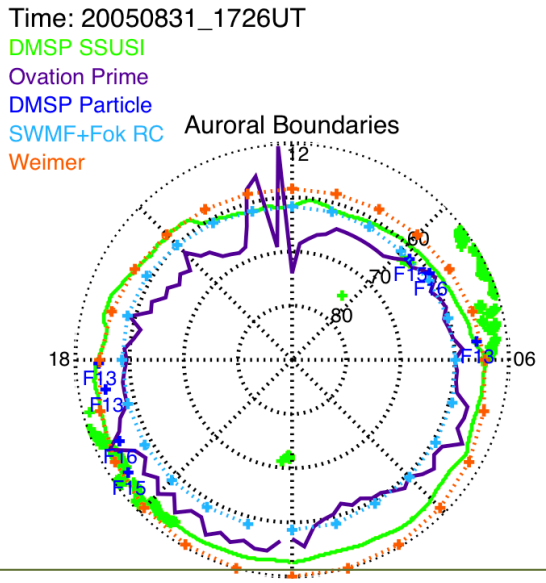
With global or partial map of auroras, we can measure model performance in capturing **MLT features at a fixed time instance or time interval**

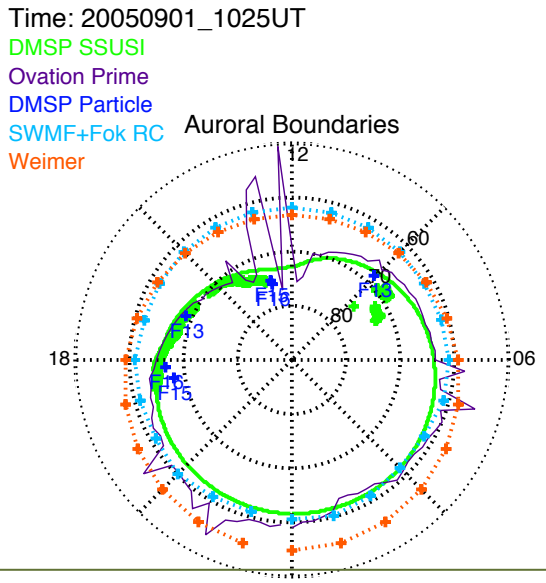


Event: 31 August 2005

Green clusters – DMSP/SUSSI obs.
Green continuous circle – DMSP/ SUSSI model (Zhang et al., 2007)



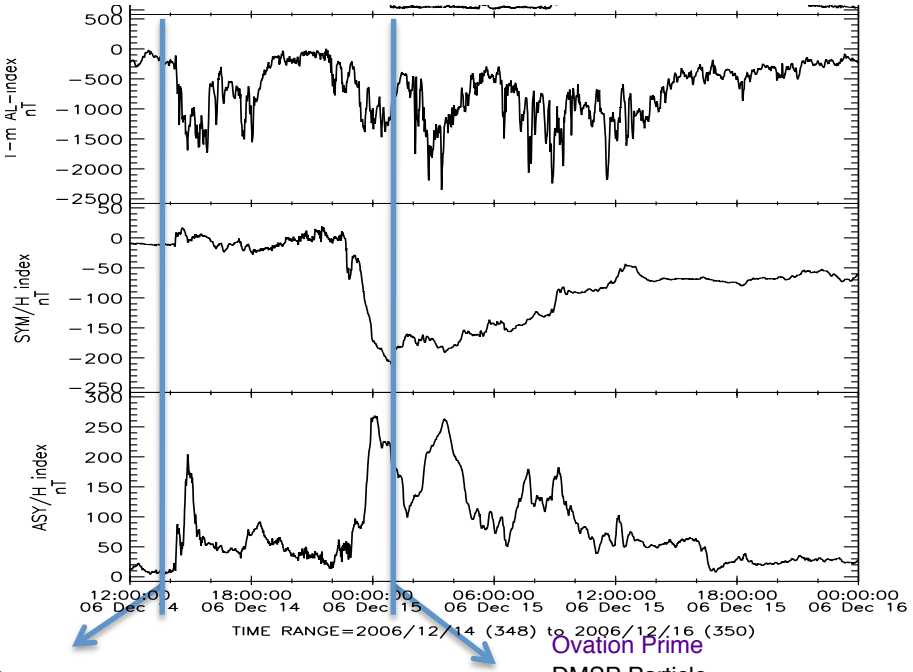




➔ Ovation Prime, the model based on DMSP SUSSI perform better in capture MLT features

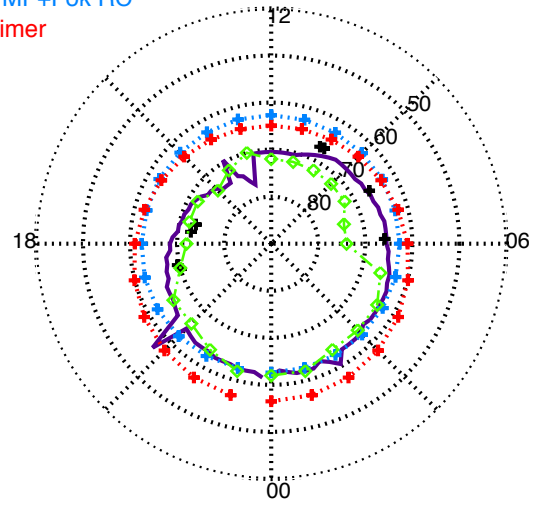
MLT distribution at different activity levels

Event:
14-16 December 2006



Ovation Prime
DMSP Particle
SWMF+Fok RC
Weimer

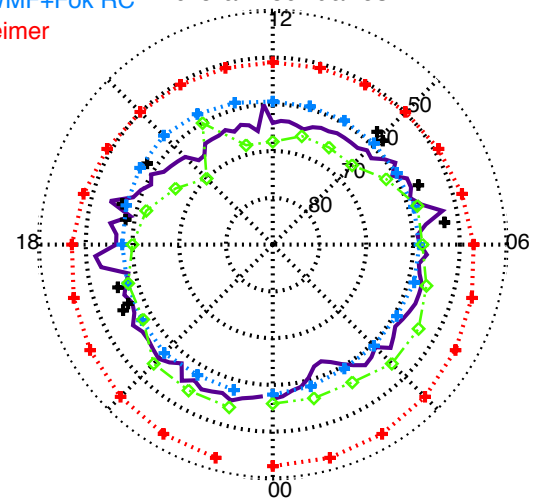
Auroral Boundaries



AMIE

Ovation Prime
DMSP Particle
SWMF+Fok RC
Weimer

Auroral Boundaries



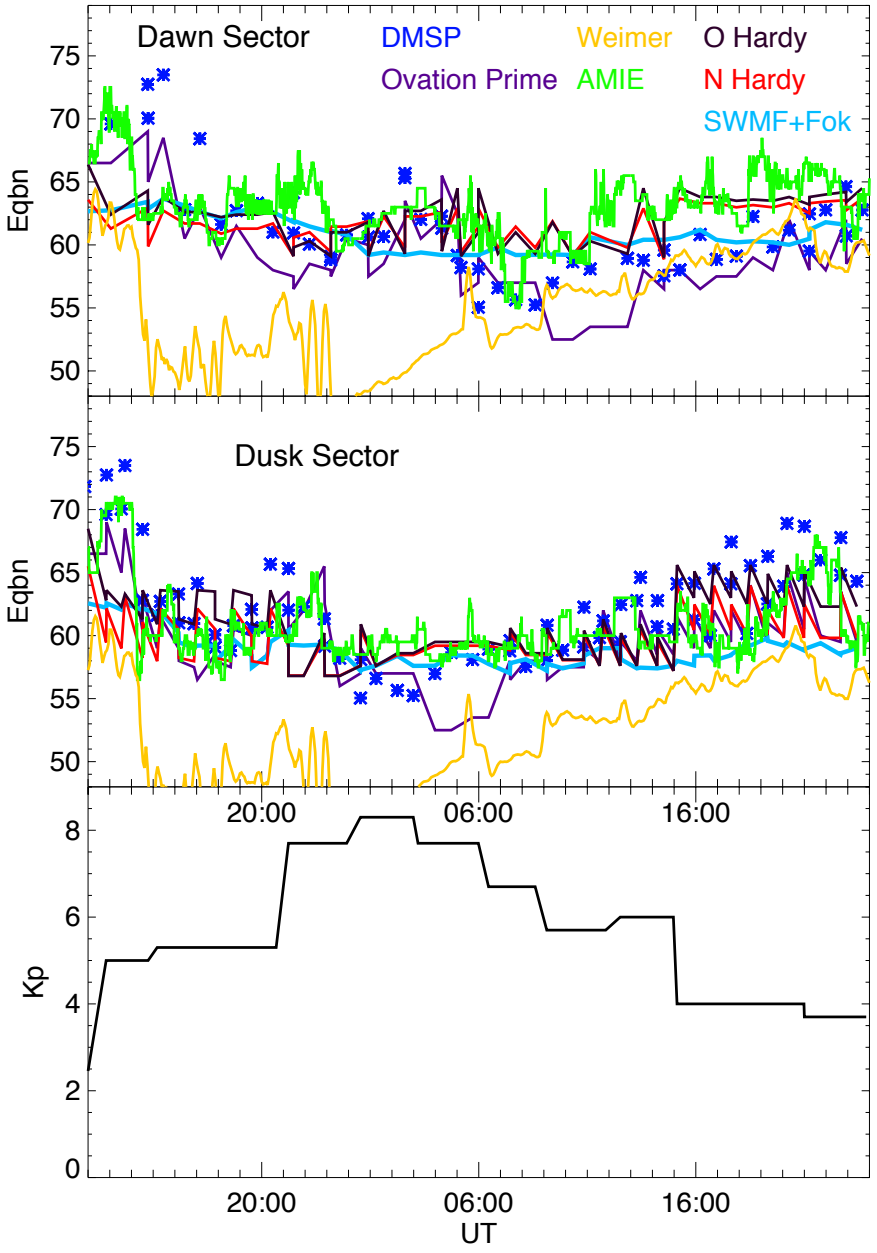
AMIE

➔ **Ovation Prime, AMIE perform better in capture MLT features**

Measure the model performance at fixed MLT

Event: 14-16 December 2006

- Equatorward expansion during geomagnetically active times (high Kp)
- Most-equatorward expansion at Dusk leads that at Dawn



Metrics

- Analysis Formulas
  - Prediction Efficiency
    - 1 is perfect
    - 0 is worst
  - Skill Score
    - 1 is perfect
    - 0 is “no advantage”
    - Negative values indicate worse than reference (but not necessarily a bad result)
  - RMSE / DE / RE
  - MAE

$$PE = 1 - ARV$$

$$ARV = \frac{\sum_{i=1}^{n}(x_i - \hat{x}_i)^2}{\sum_{i=1}^{n}(x_i - \bar{x}_i)^2}$$

$x_i \rightarrow observations\ (DMSP)$

$\hat{x}_i \rightarrow predictions\ (model)$

$$\sum_{i=1}^{n}(a_i - x_i)^2 / n$$

$$SS = 1 - \frac{\sum_{i=1}^{n}(a_i - x_i)^2 / n}{\sum_{i=1}^{n}(b_i - x_i)^2 / n}$$

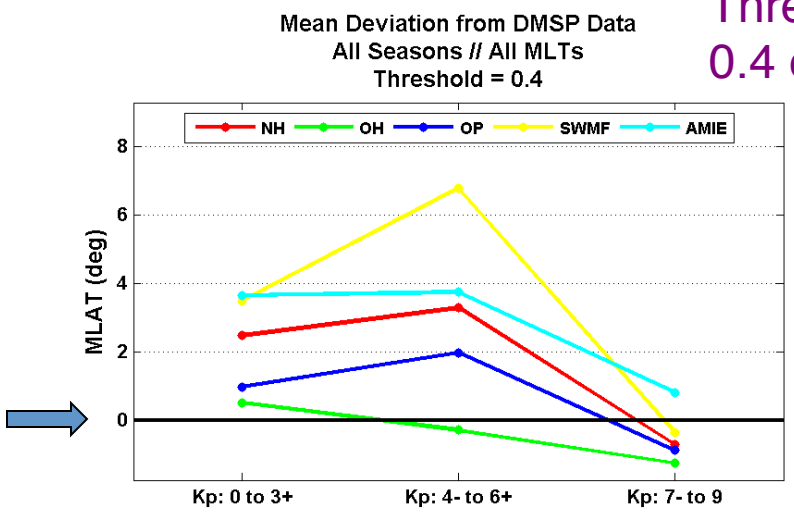
$x_i \rightarrow observations\ (DMSP)$

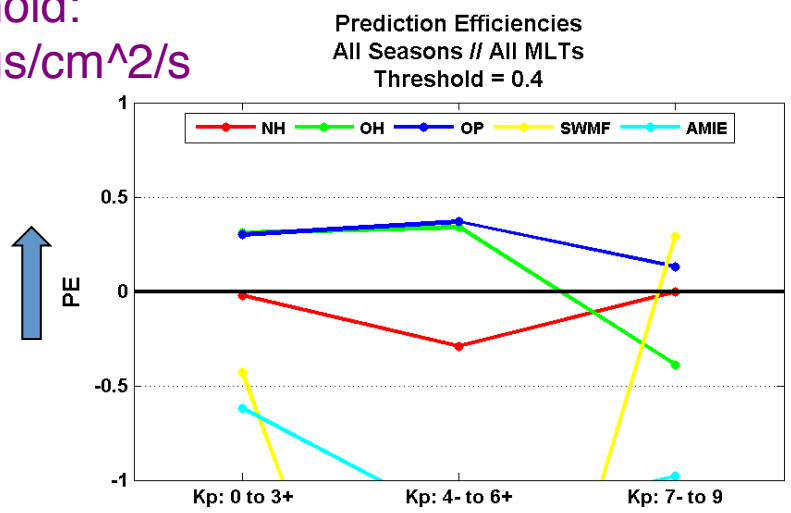
$a_i \rightarrow forecast\ (OP)$

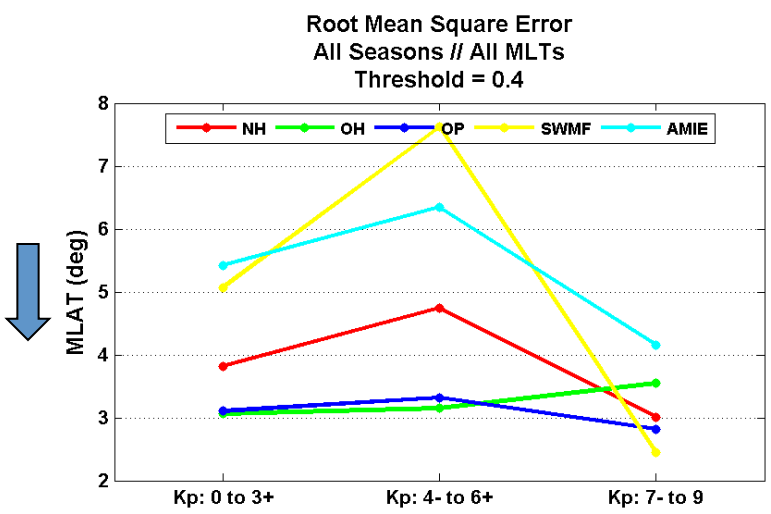
$b_i \rightarrow reference\ (OH)$

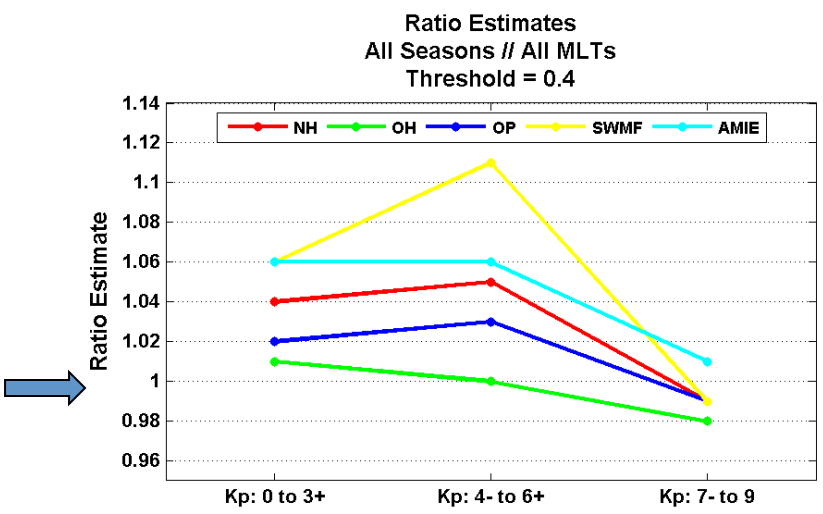
Metrics – All Models

Threshold:
0.4 ergs/cm^2/s









Results Summary

- OP has the best Prediction Efficiency and OH closely follows.
- OH has a regression line that closely approximates 1:1.
- The SS 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.

Next Step

- Broader community participation by submitting more model runs
- 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

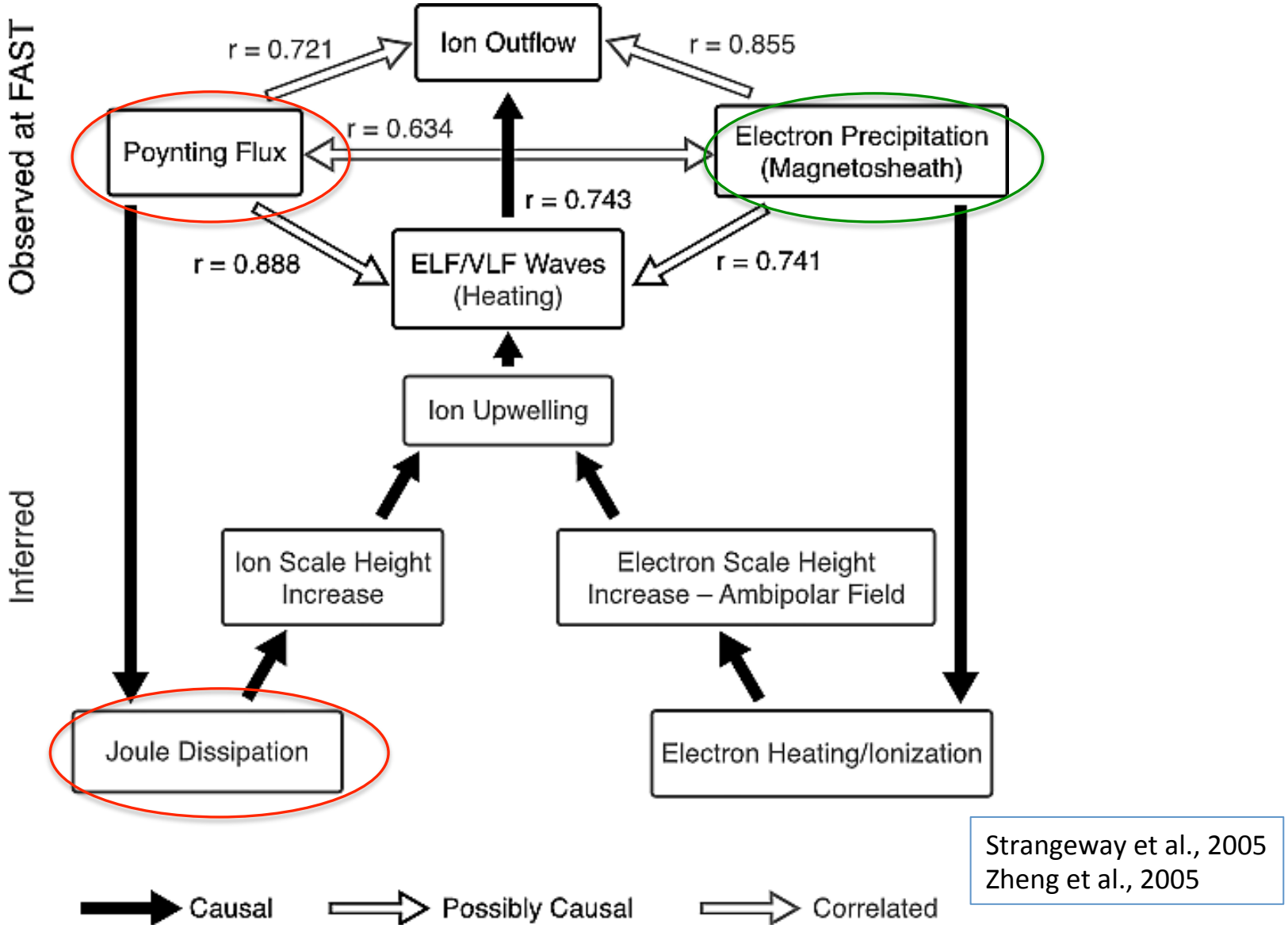
Why Poynting Flux/Joule Heating

- 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

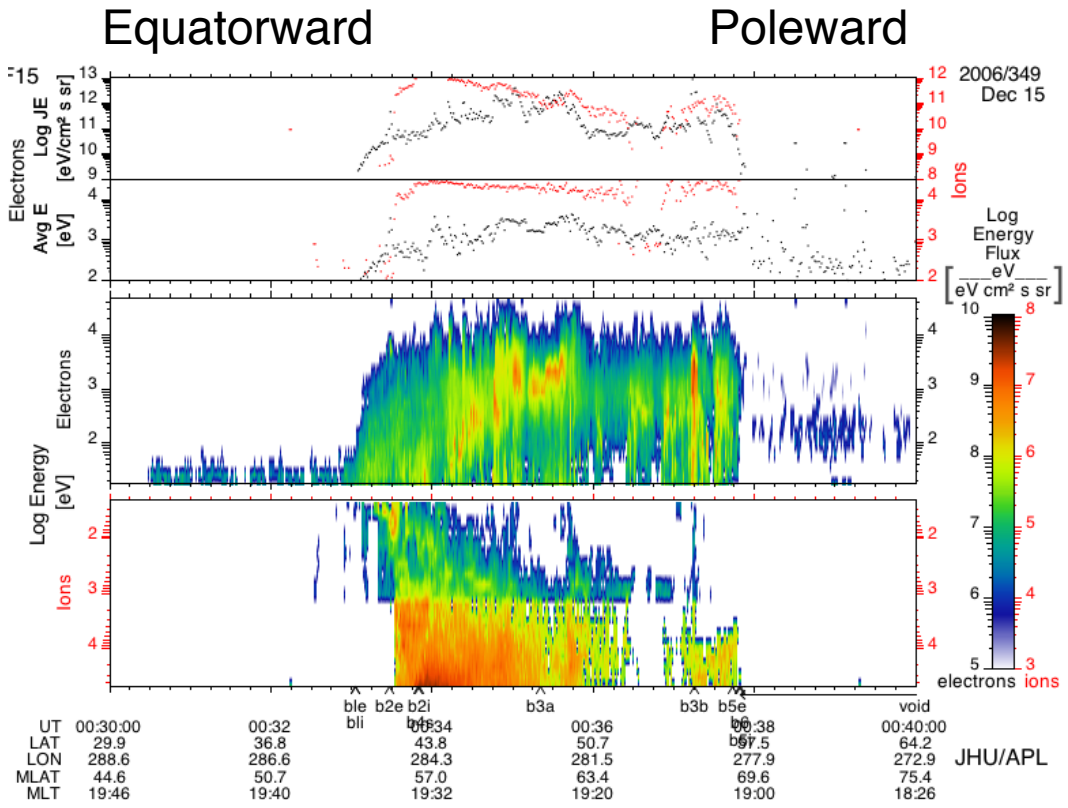
- ✓ Poynting flux: input of electromagnetic energy into the ionosphere
- ✓ Mainly dissipated as heat (Joule Heating) in the ionosphere

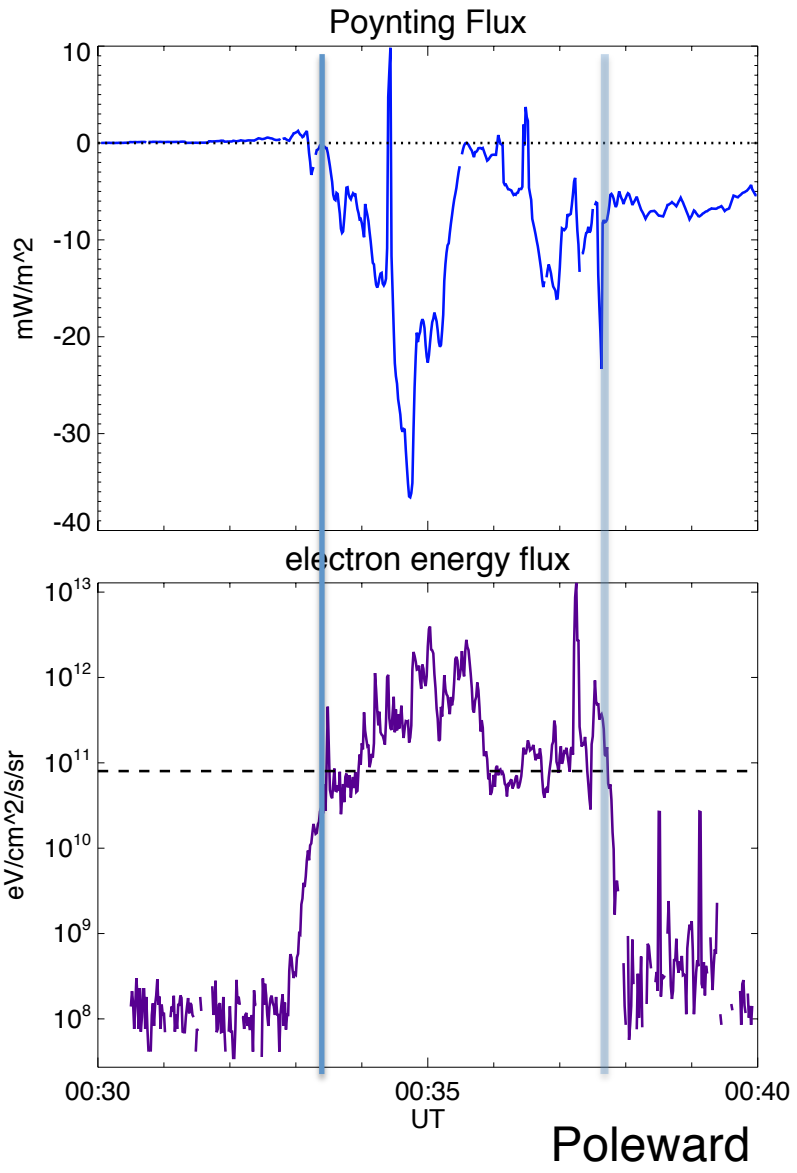
Why Poynting Flux/Joule Heating



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

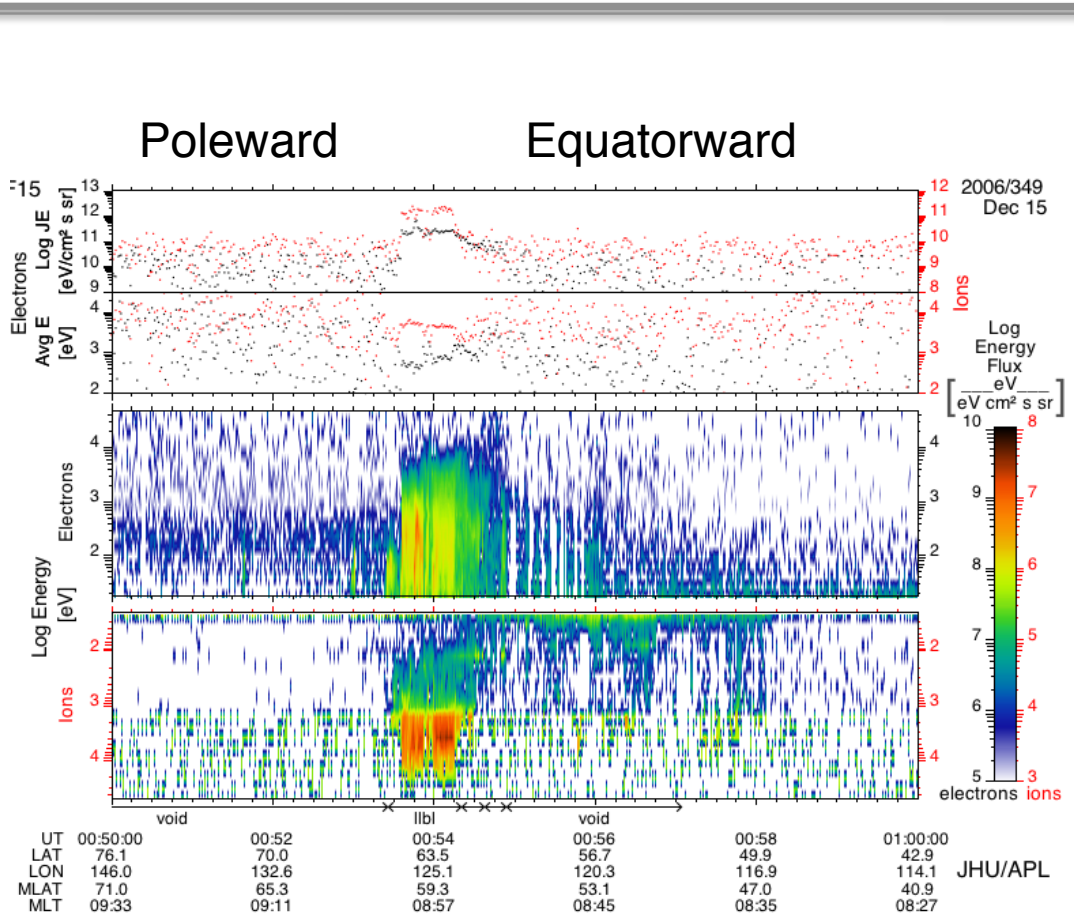
Poynting Flux vs Aurora Precipitation

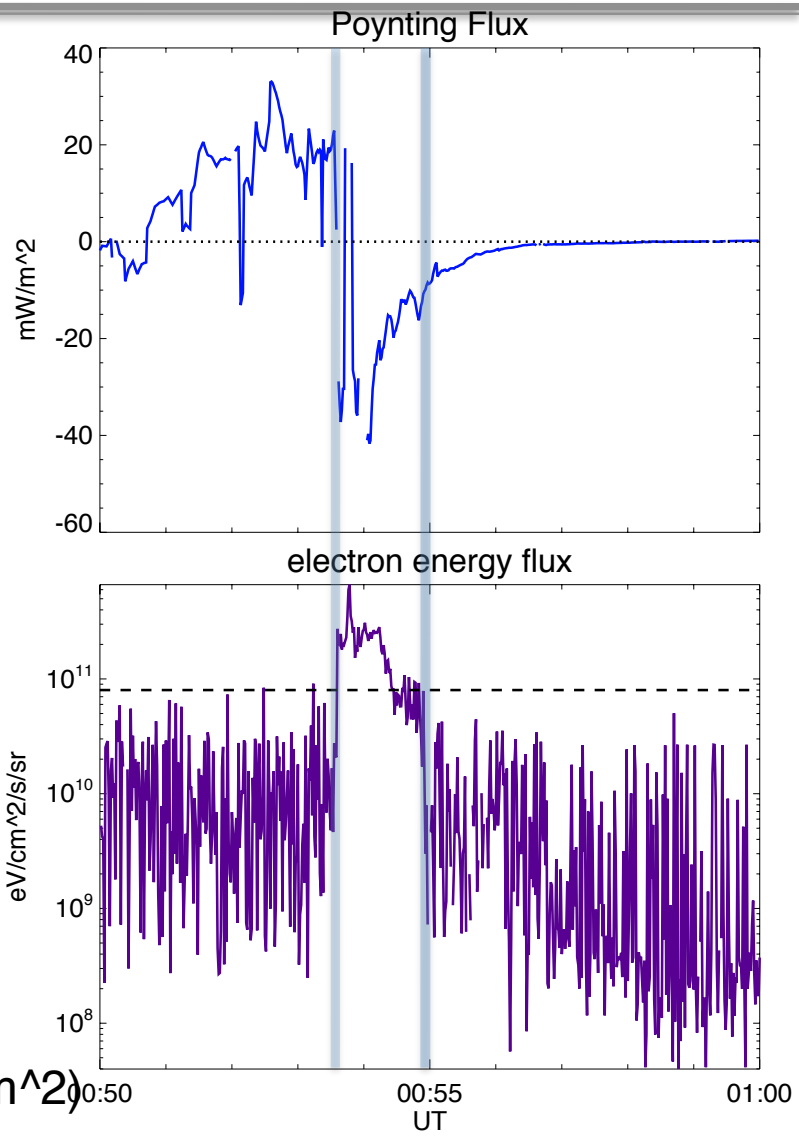




Dusk:
Eqbn: equatorward disturbance of Poynting flux
Pobn: last local maximum on the poleward side

Poynting Flux vs Aurora Precipitation





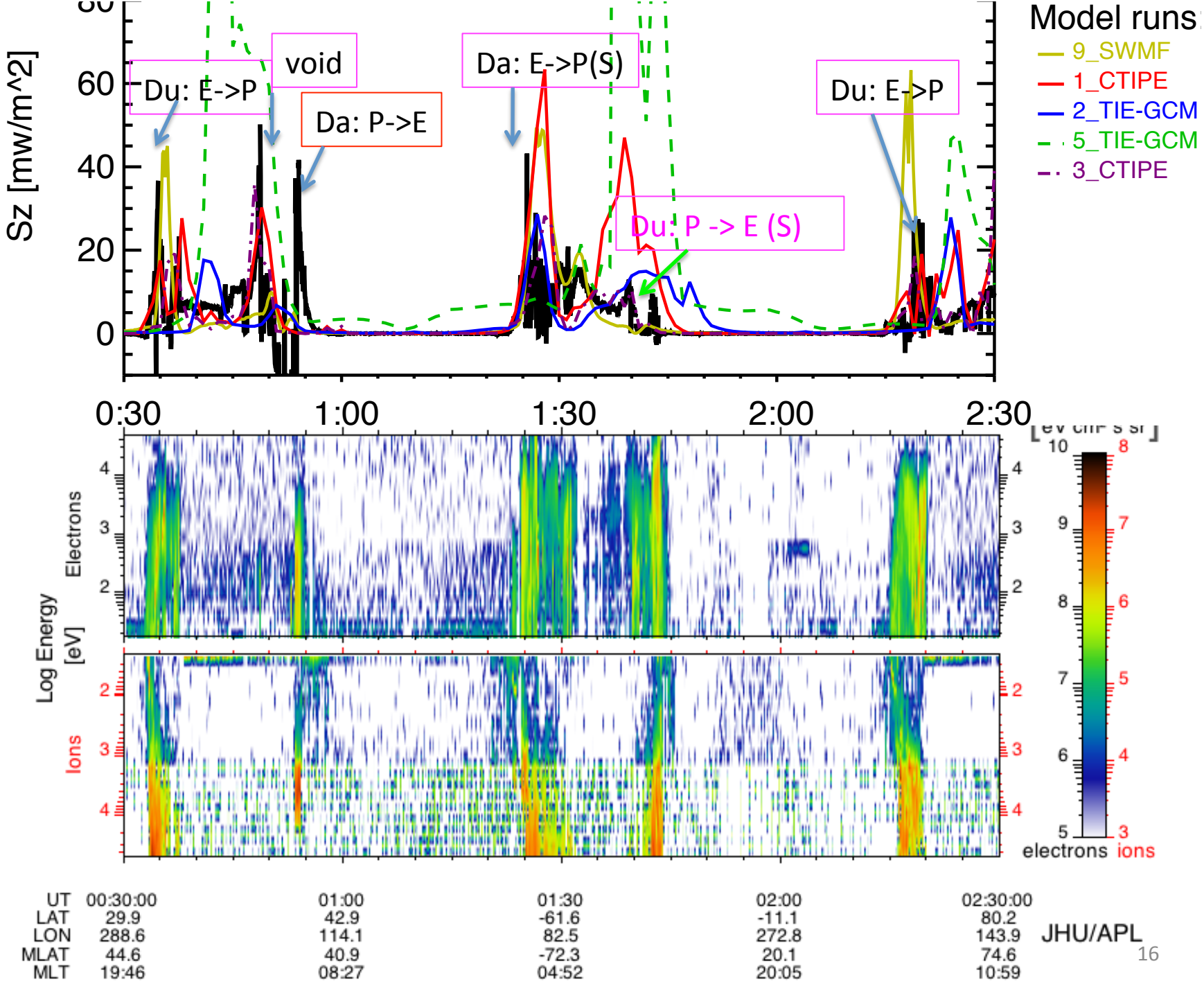
Dawn:
Eqbn: Poynting flux exceeds a threshold (3 mW/m^2)
Pobn: last local maximum on the poleward side

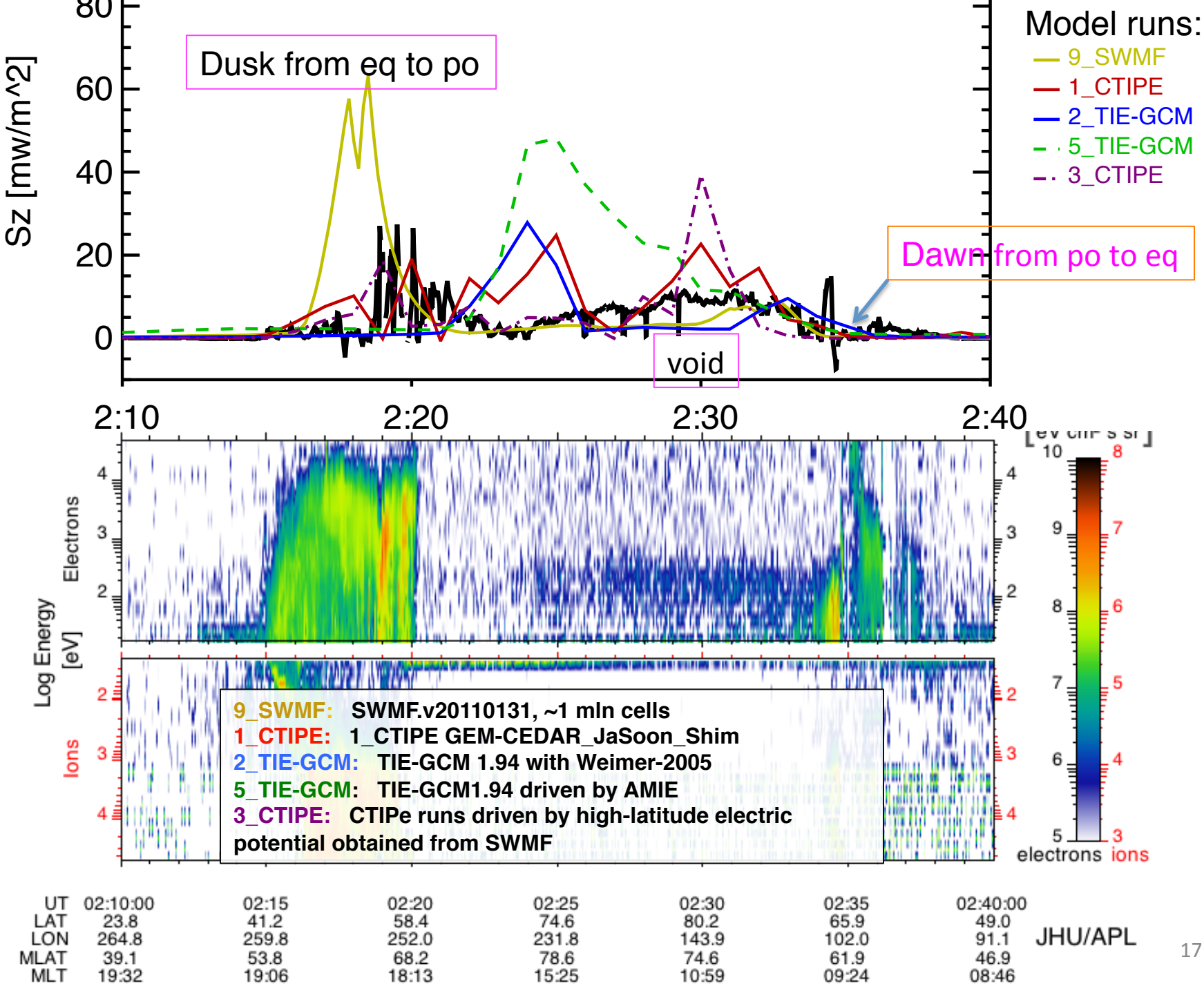
Poynting Flux vs Auroral Precipitation

- ✓ Examining their relationship by looking at more DMSP passes
- ✓ Finding a rule (if solid) for defining auroral boundaries using Poynting flux behaviors

Related Poster: Showing different model performance in calculating Joule heating
SA33A-2183. Shim et al., Effects of high-latitude drivers on Ionosphere/ Thermosphere parameters
Dec 5, Wednesday, 1:40pm - 6:00pm, Poster Hall, Moscone South

9_SWMF: SWMF.v20110131, ~1 mln cells
1_CTIPE: 1_CTIPE GEM-CEDAR_JaSoon_Shim
2_TIE-GCM: TIE-GCM 1.94 with Weimer-2005
5_TIE-GCM: TIE-GCM1.94 driven by AMIE
3_CTIPE: CTIPe runs driven by high-latitude electric potential obtained from SWMF


Sz [mw/m^2]
0
20
40
60
Du: E->P
void
Da: P->E
Da: E->P(S)
Du: P -> E (S)
Du: E->P
Model runs
9_SWMF
1_CTIPE
2_TIE-GCM
5_TIE-GCM
3_CTIPE
0:30
1:00
1:30
2:00
2:30
Log Energy [eV]
Electrons
Ions
electrons
ions
UT 00:30:00 01:00 01:30 02:00 02:30:00
LAT 29.9 42.9 -61.6 -11.1 80.2
LON 288.6 114.1 82.5 272.8 143.9
MLAT 44.6 40.9 -72.3 20.1 74.6
MLT 19:46 08:27 04:52 20:05 10:59
JHU/APL


Sz [mw/m^2]
80
60
40
20
0
Dusk from eq to po
Model runs:
9_SWMF
1_CTIPE
2_TIE-GCM
5_TIE-GCM
3_CTIPE
Dawn from po to eq
void
2:10
2:20
2:30
2:40
Electrons
Log Energy [eV]
Ions
9_SWMF: SWMF.v20110131, ~1 mln cells
1_CTIPE: 1_CTIPE GEM-CEDAR_JaSoon_Shim
2_TIE-GCM: TIE-GCM 1.94 with Weimer-2005
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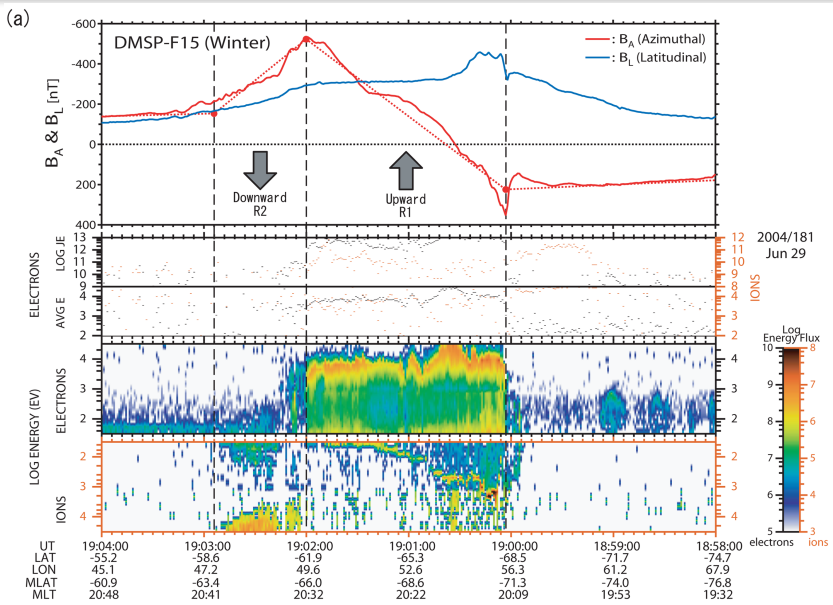
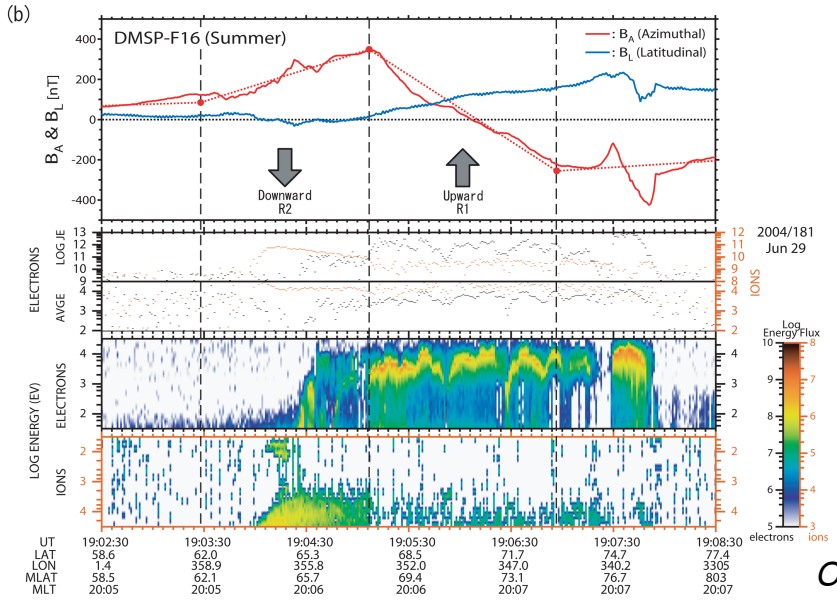
electrons
ions
UT 02:10:00 02:15 02:20 02:25 02:30 02:35 02:40:00
LAT 23.8 41.2 58.4 74.6 80.2 65.9 49.0
LON 264.8 259.8 252.0 231.8 143.9 102.0 91.1
MLAT 39.1 53.8 68.2 78.6 74.6 61.9 46.9
MLT 19:32 19:06 18:13 15:25 10:59 09:24 08:46
JHU/APL

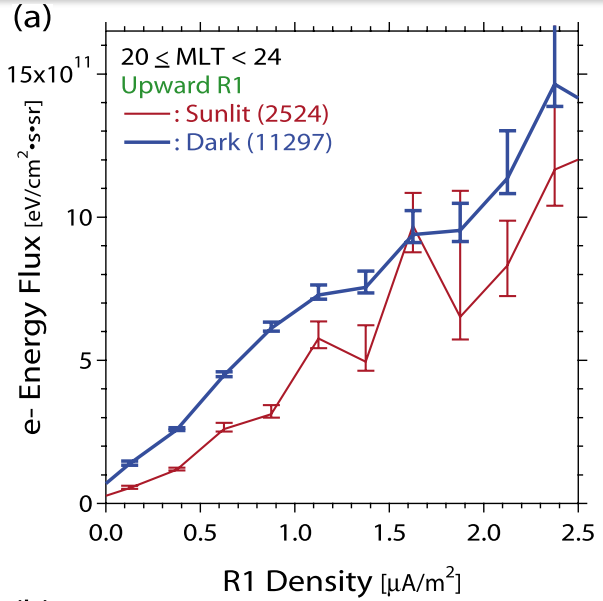
What Is Next: Region 1 FACs

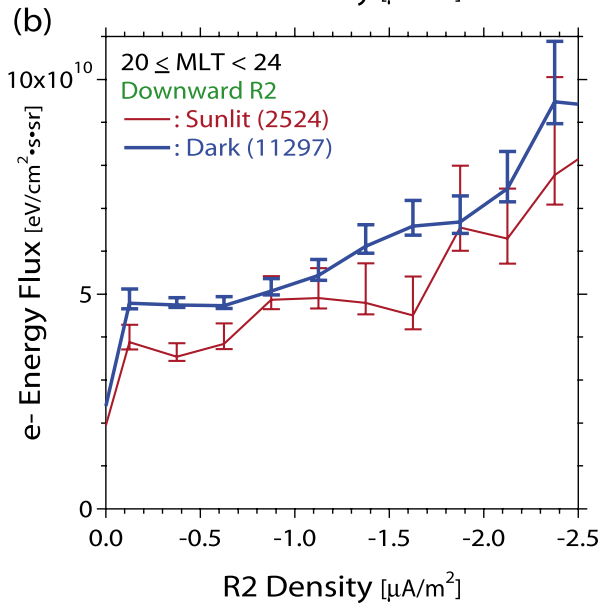
- ✓ Upward region 1 field-aligned currents correlate nicely with precipitating electron energy flux
- ✓ Can be used as a proxy for auroral precipitation
- ✓ Can be a nice physical parameter to validate models with

Nightside: Region 1 FAC vs Aurora Precipitation









Ohtani et al., 2009, JGR

Future Direction/Community Effort

- 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