Auroral Model V& V Results/Efforts

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Overview

- Motivation
- What has been done (Cory)
- Future plan

Motivation

- Auroral precipitation models have been valuable both in terms of space weather applications and space science research. Since aurora represents one type of spectacular displays from the nature, an accurate auroral prediction model is also being sought after in order to help support auroral tourism in high latitude countries.
- Aurora, as manifestation of solar wind – magnetosphere - ionosphere coupling, can be used as a remote sensing tool for magnetospheric processes.
- Ionospheric conductance, field-aligned currents (FACs), Poynting flux, Joule heating and ion outflow are a few very important physical parameters or physical processes playing critical roles in auroral generation/evoluiton process and in global connections of the magnetosphere and ionosphere.
- As for the space weather effects, particles in the auoral region can cause surface charging of spacecraft, its associated currents can result in geomagnetically induced currents on the ground. During geomagnetically active times, it has potential of disrupting radio communications, affecting GPS accuracy, radar operations and so on.
- A variety of auroral models are available, including empirical models that are parameterized by geomagnetic indices or upstream solar wind conditions, nowcasting models that are based on satellite observations, or those derived from physics-based, coupled global models.
- Yet very limited testing has been performed regarding model performance.

Challenges

- What physical quantity/quantities to choose
- How to define the physical quantify/ quantities from model and data
- Which data sets to use

Validation already been done

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

Physical parameter: Nightside **Precipitating power**

Instantaneous	**Hourly averages**
1. Brautigam IMF model (r=0.68)	1. Brautigam IMF model (r=0.69)
2. Evans nowcast model (r=0.70)	2. Hardy Kp model (r=0.74)
3. Hardy Kp model (r=0.72)	3. Ovation Prime (r=0.76)
4. Ovation Prime (r=0.75)	4. Evans nowcast model (r=0.77)

better

Using Polar/UVI during 1996 -1997

Validation already been done

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 Poiar 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

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

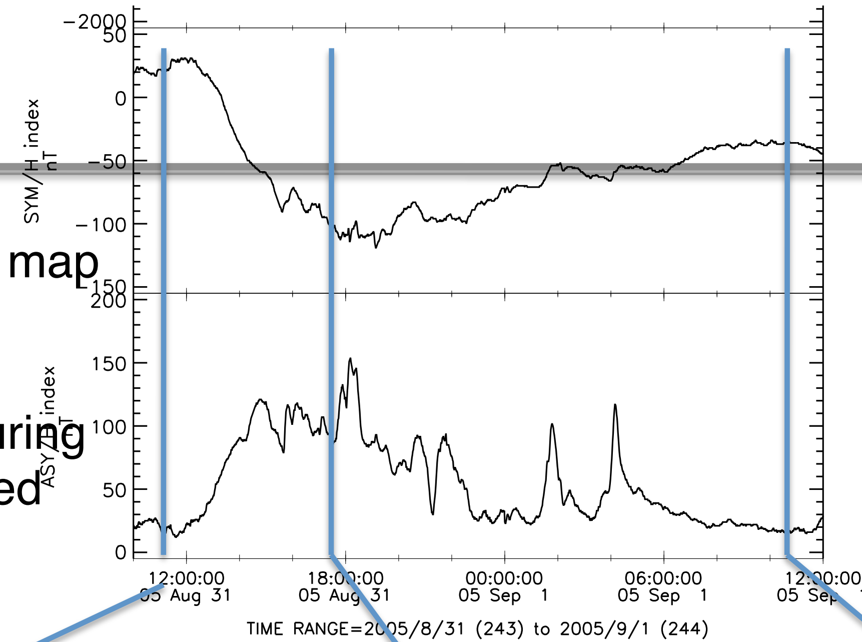
http://ccmc.gsfc.nasa.gov/RoR_WWW/presentations/boundary_options.pdf

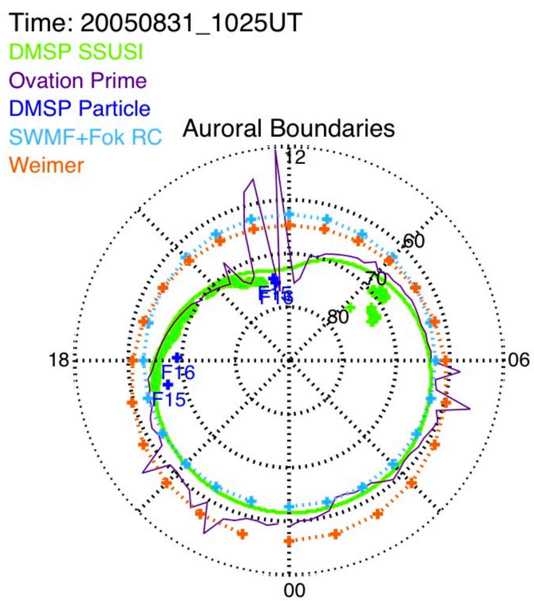
Different Measure of Performance

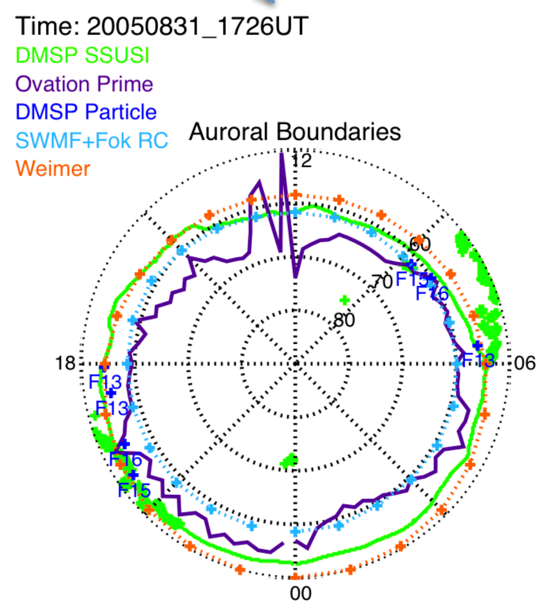
- PE for a fixed local time (PE)
  - How well model performs in terms of temporal revolution
- Divided into different local time sectors – such as the dusk side
- Whether the deviation in all local time is uniform or not – a measure of whether the model captures the MLT feature
  - How well models do

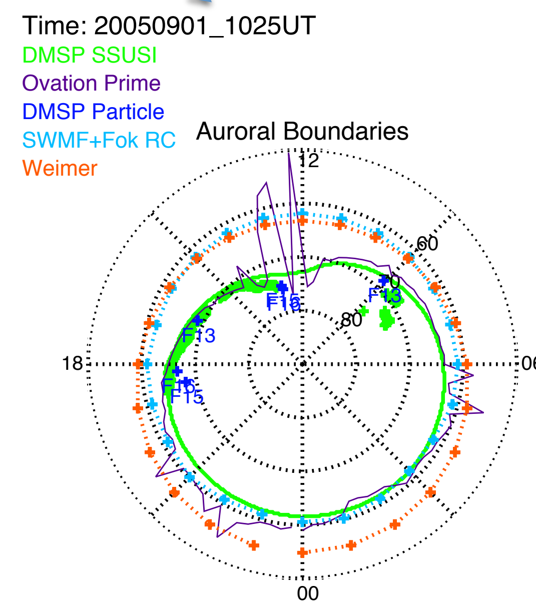
correlation in MLT binned by activity level or for a specific time - auroral imaging

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

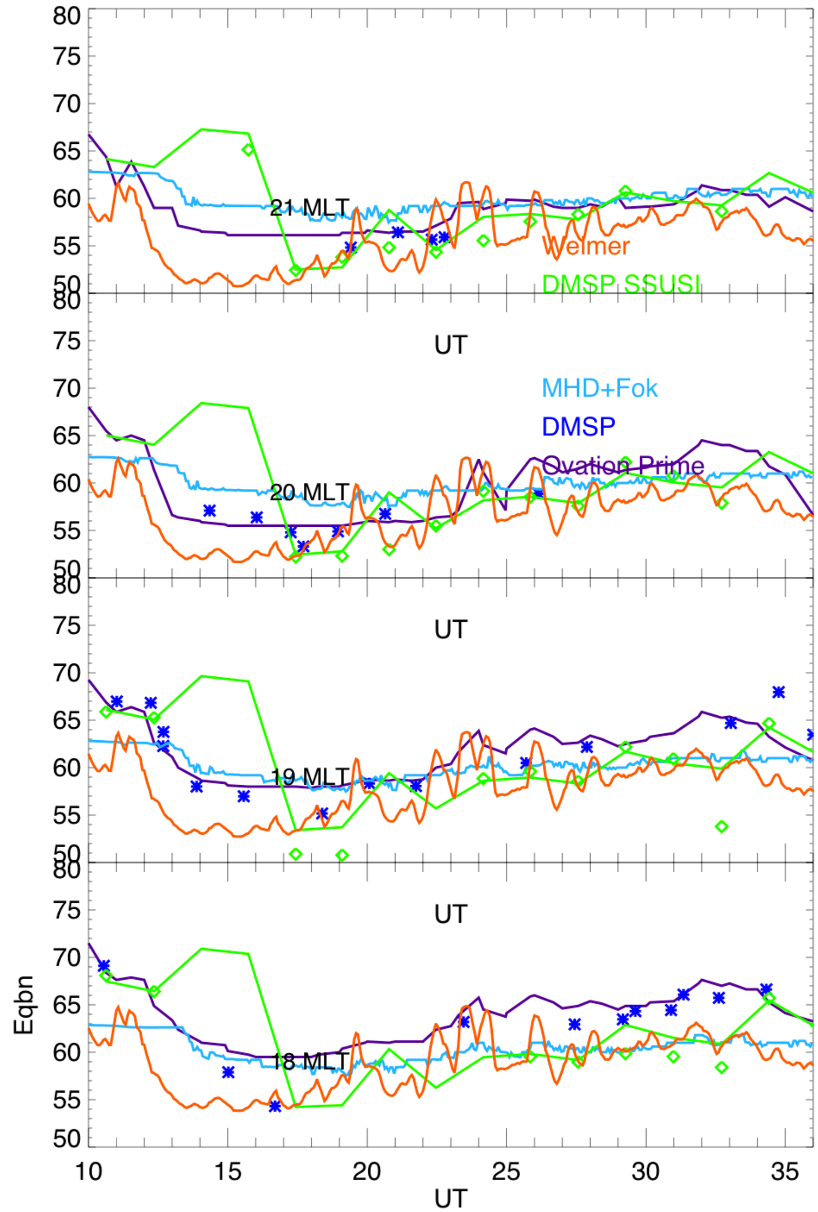








Measure the model performance at fixed MLT



Research Objective

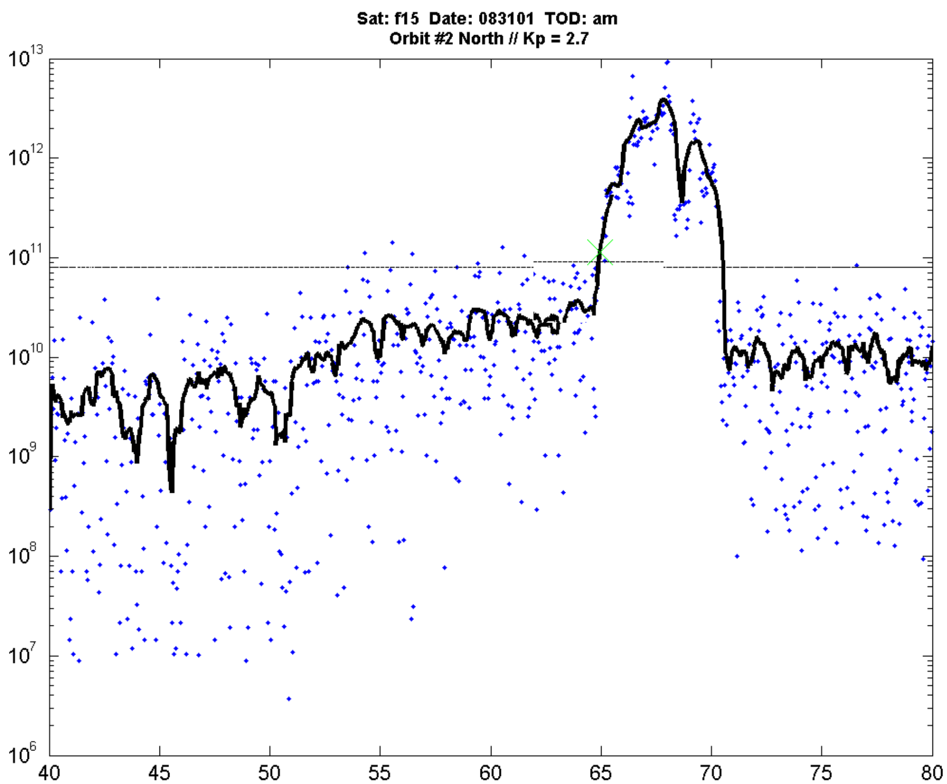
Maj. Lane’s master thesis work

- Develop and execute a meaningful comparison between DMSP energy flux measurements (in situ) and the calculated spatial and temporal energy outputs of various computational auroral models to include Ovation Prime, (Old & New) Hardy, SWMF/Fok-RC, and AMIE.

- Investigate the effect of geomagnetic activity and seasons on these results.

- From these comparisons, assign quantitative performance scores, utilizing various statistical measures (e.g., PE, Skill Score).

DMSP



- <u>DMSP satellite "pass"</u>
- Northern Hemisphere
- Threshold is set to 0.4 ergs/cm^2/s, 0.6 ergs/cm^2/s, and 1.0 ergs/cm^2/sec/
- 15-sec moving average is used (black line) for smoothing (all 0's removed)
- Green X represents crossing point
- More than 5800 of these passes have been collected…

…and individually validated "by hand."

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

$$PE = 1 - ARV$$

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

$x_i \longrightarrow observations\ (DMSP)$

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

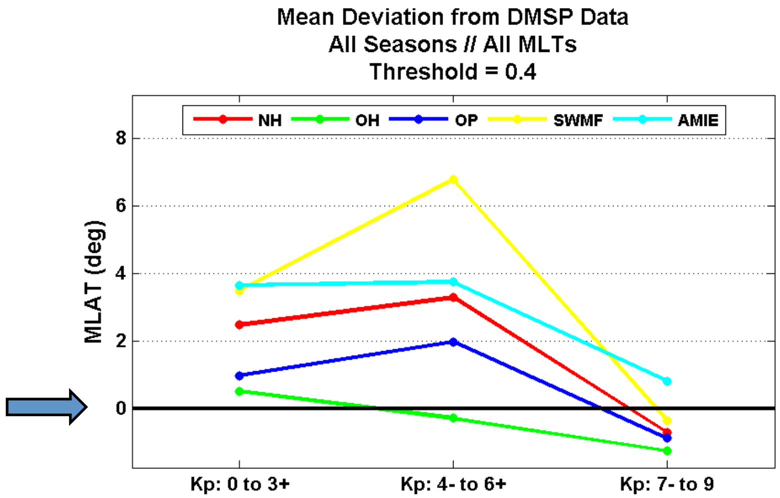
$$SS = 1 - \frac{\sum_{i=1}^{n}(a_i - x_i)^2 / n}{\sum_{i=1}^{n}(b_i - x_i)^2 / n}$$

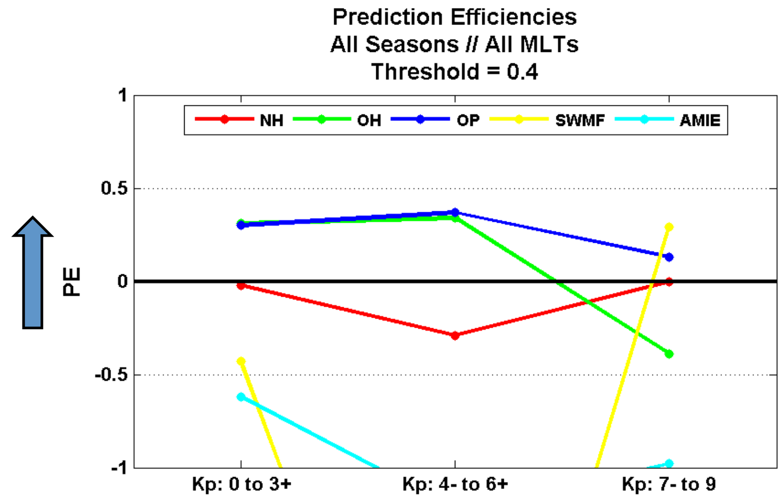
$x_i \longrightarrow observations\ (DMSP)$

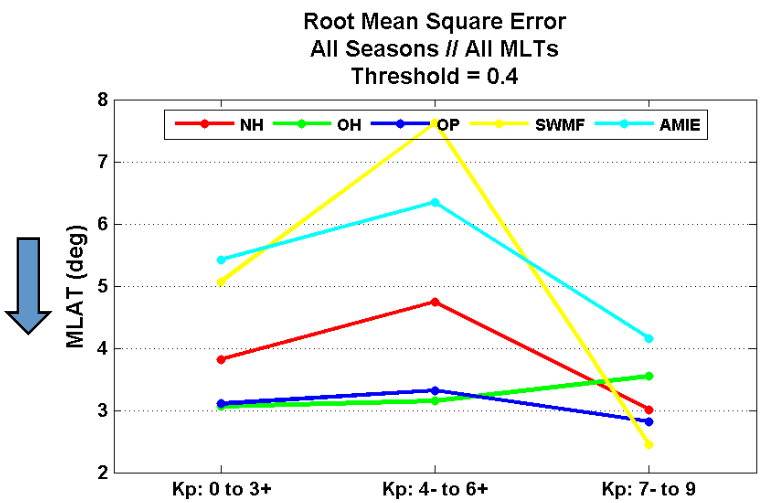
$a_i \longrightarrow forecast\ (OP)$

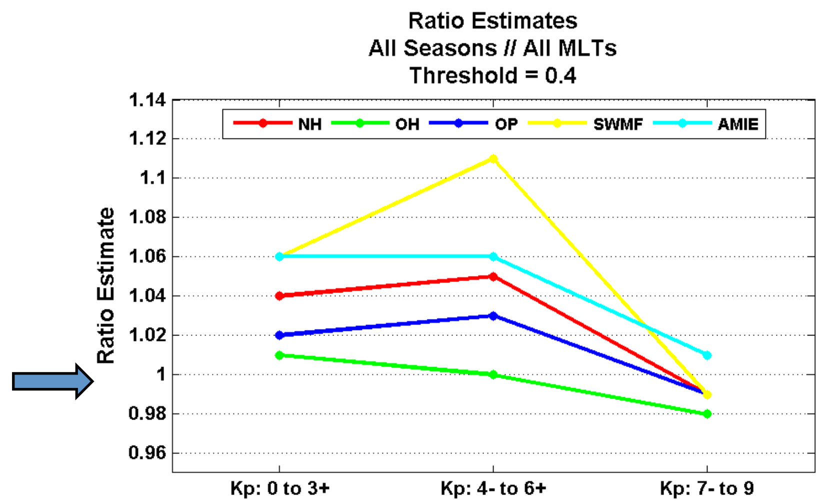
$b_i \longrightarrow reference\ (OH)$

Metrics – All Models









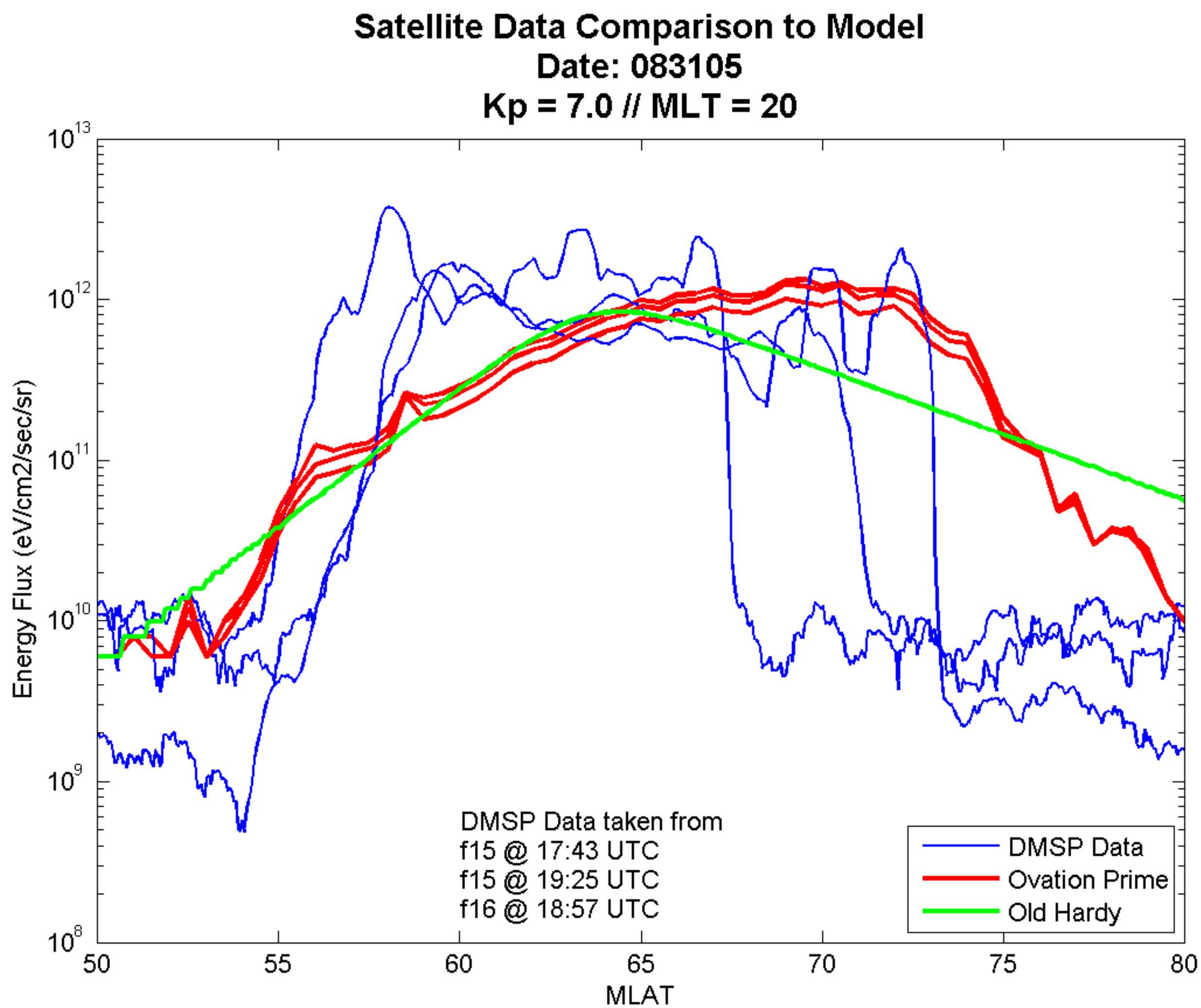
Results Summary

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

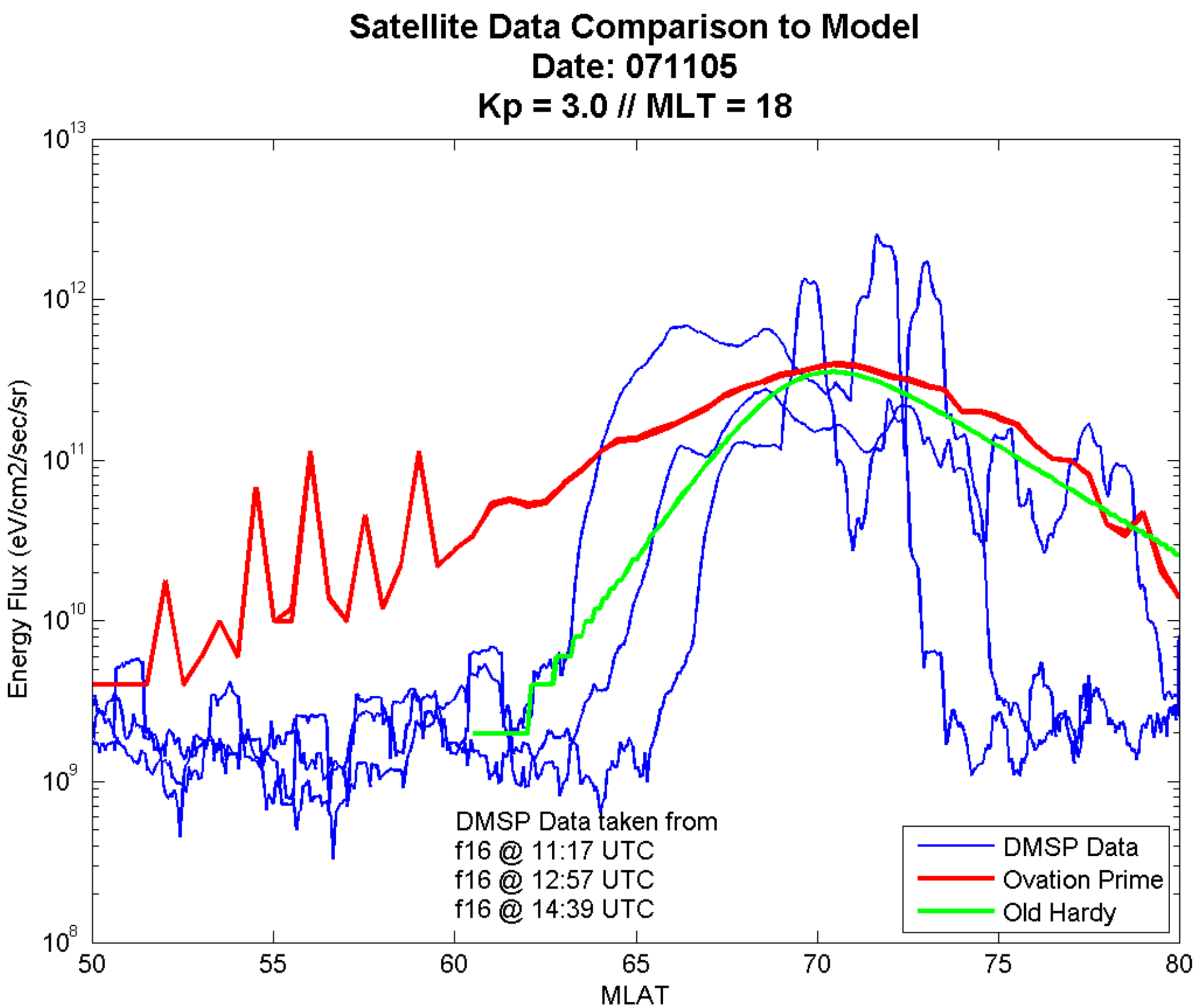
Model Performance along the satellite track

aurora with clean boundaries

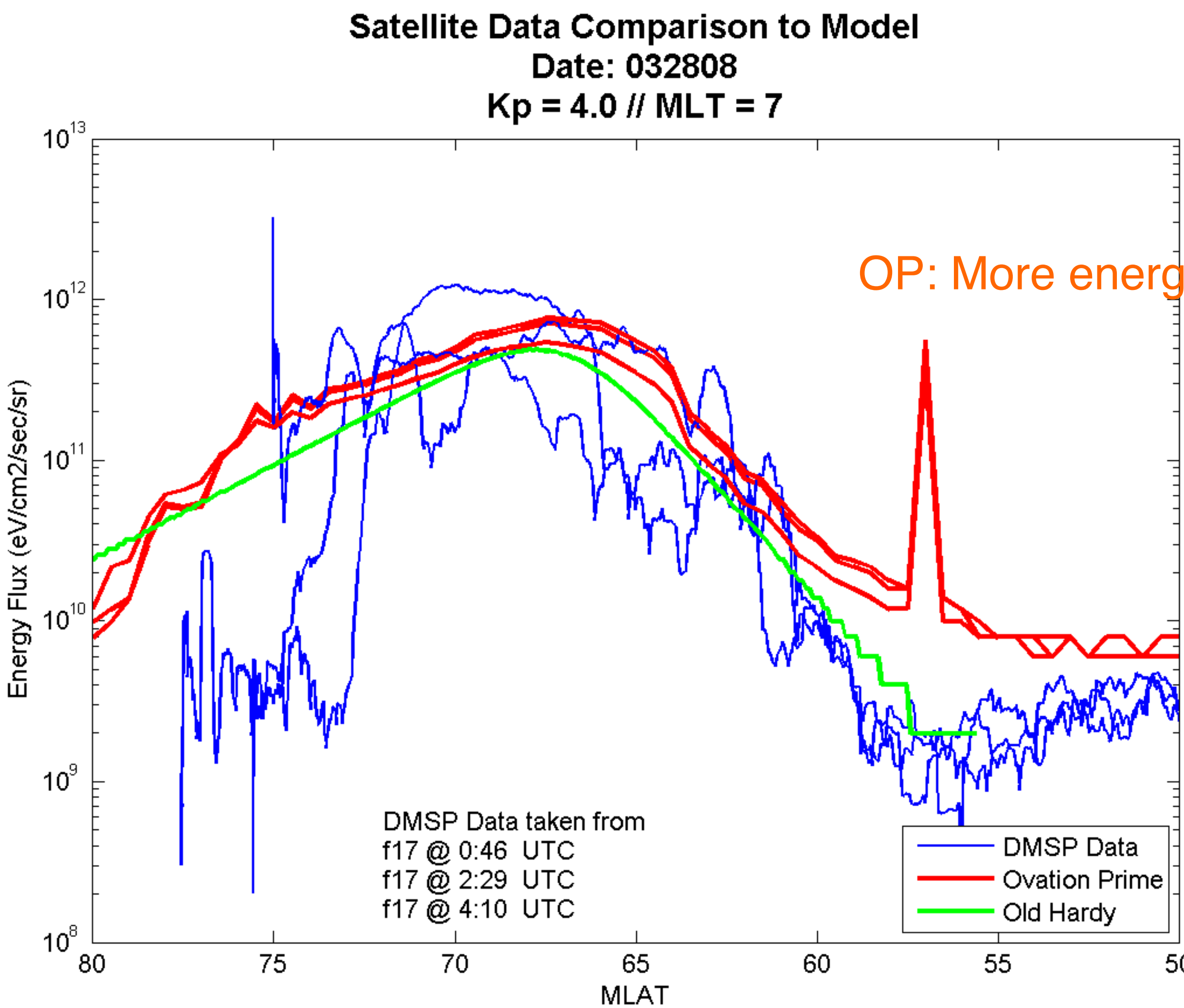


Model Performance along the satellite track

aurora with clean boundaries



Model Performance for a specific crossing



OP: More energy flux at high-lat

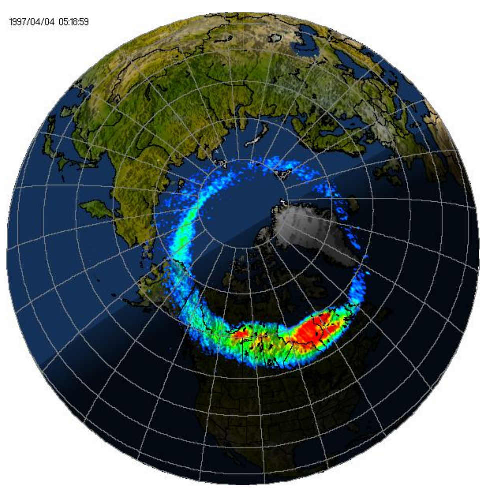
Measure of Performance future direction

- How well models do in capturing spatial features for a fixed time?
  - e.g., the MLT feature

correlation in MLT binned by activity level or for a specific time

standard deviation of the boundary offset

Observations: auroral imaging



Take advantage of auroral imaging datasets
Polar UVI, IMAGE/FUV, DMSP/SSUSI,

Measure of Performance future direction

- Explore better definition of the equatorward auroral boundary from global simulation results