# DMSP Overview and Opportunities for Model Validation

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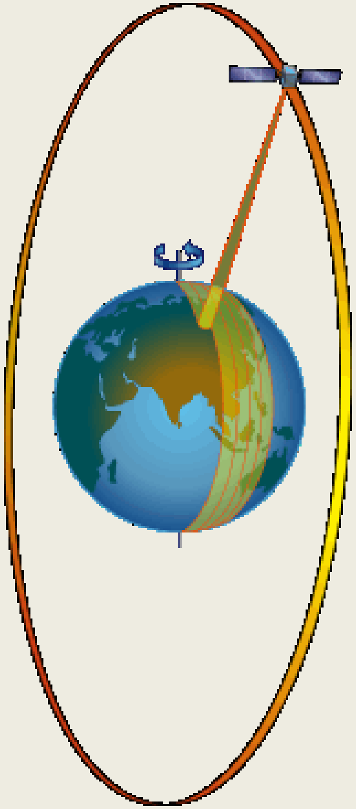
We would like to thank and acknowledge our Department of Defense collaborators for their contributions of data and advice

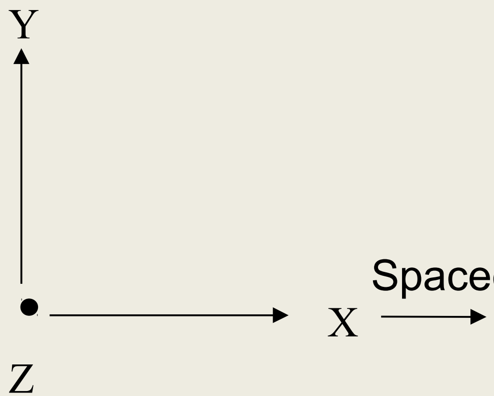
# Roadmap

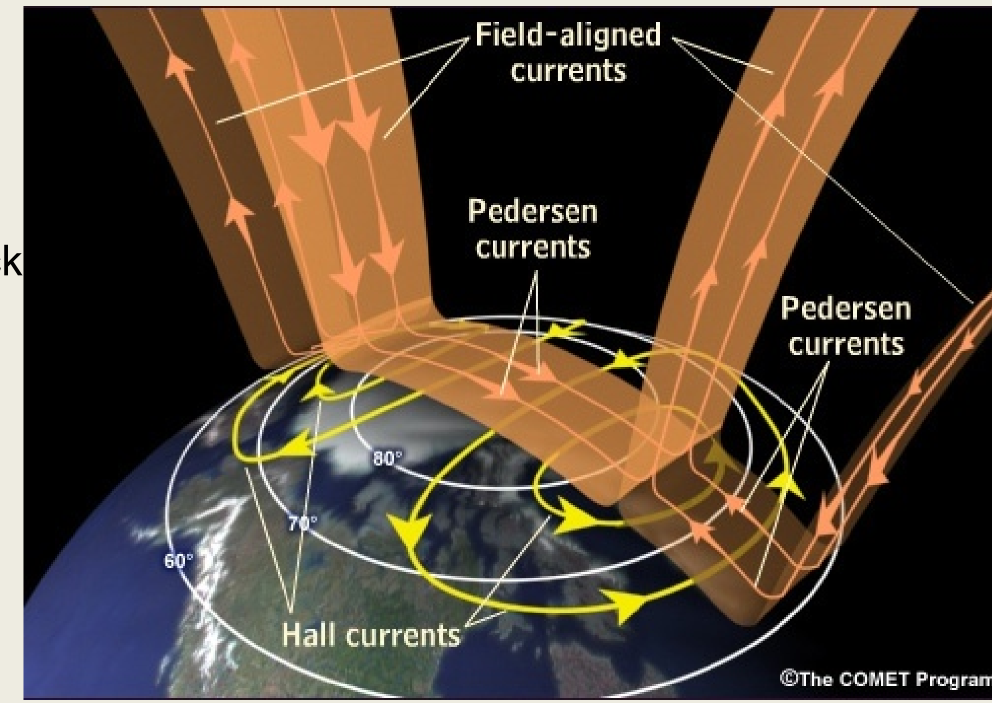
1. **Overview of Recent DMSP Poynting Flux Studies**
2. Sensitivity of Poynting Flux To Single Velocity Component Approximation
3. Status Update on DMSP Level 2 CDF Project
4. SSM Field Aligned Currents



# Poynting Vector from Defense Meteorological Satellite Program S/C

DMSP instruments sense Electric and Magnetic Fields




$$S = \left(E \times \delta B_{DMSP\ Horizontal}\right) / \mu_0$$

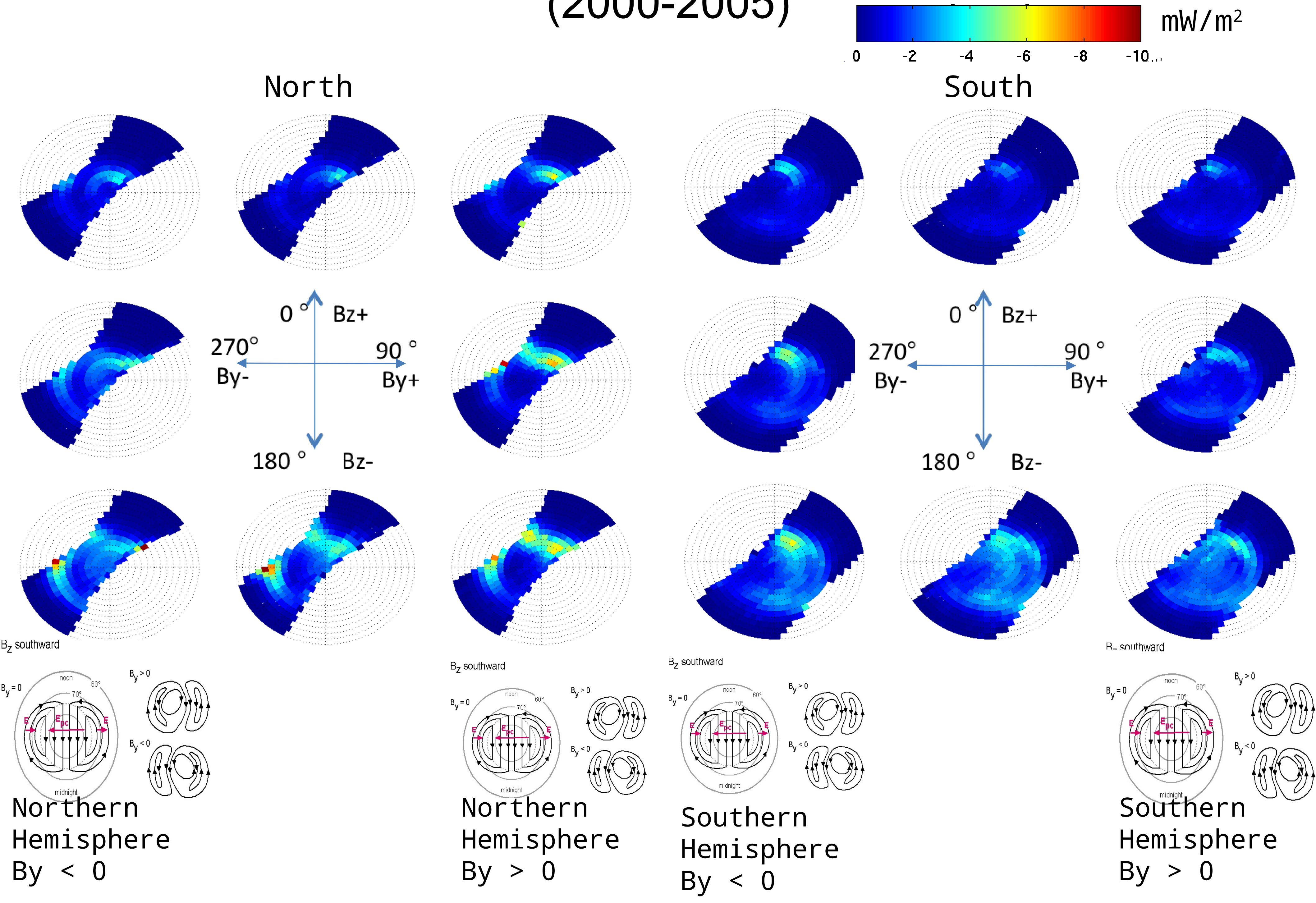
$$S_{||} = \left(E_x \delta B_y - E_y \delta B_x\right) / \mu_0$$

*where*

$$E = -V \times B_{IGRF} \quad \text{and} \quad \delta B_{DMSP\ Horizontal} = B_{DMSP} - B_{Main}$$

D. Knipp, L. Kilcommons, T. Larson
DMSP Measurements of Poynting Flux

# DMSP F15 IMF Binned Hemisphere Poynting Flux
(2000-2005)



# F-15 Poynting Flux Comparison 2000-2005
# IMF By Influence

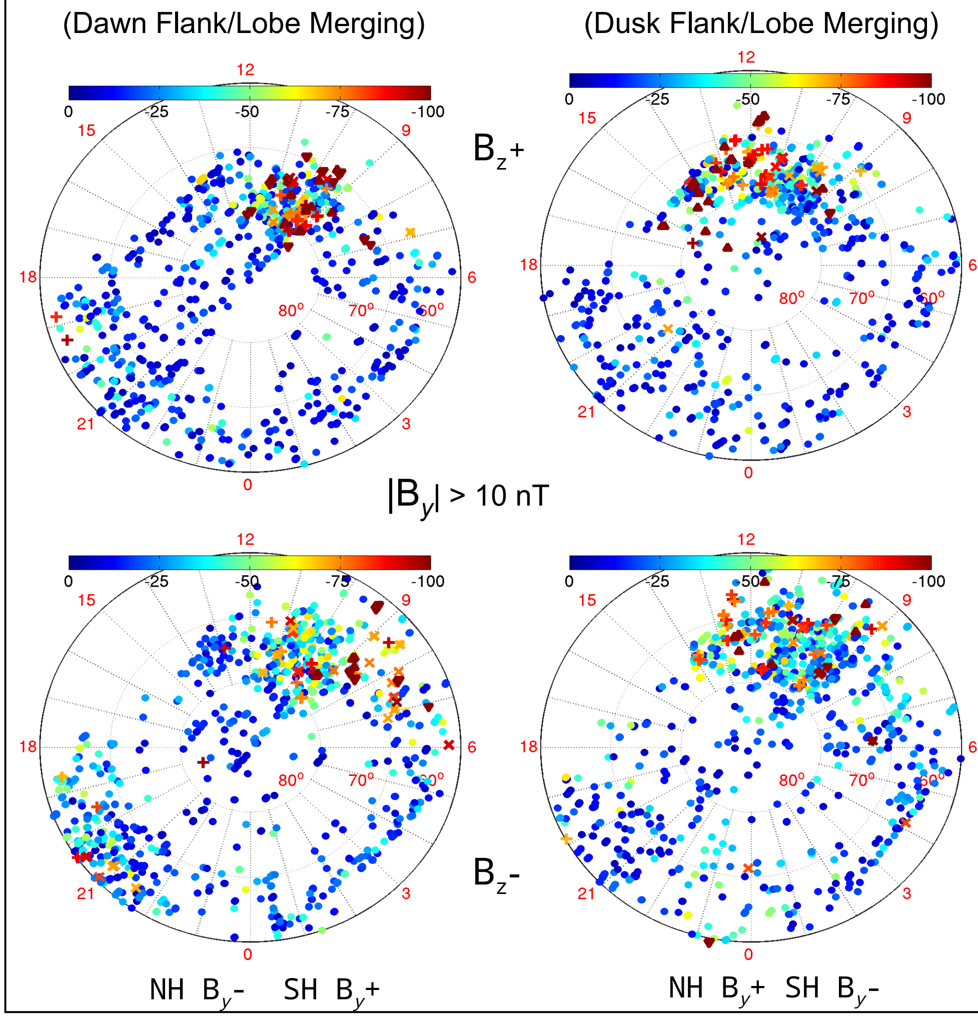
-Combined DMSP F-15 Poynting flux data from 2000-2005, in NH and SH according IMF By

-When the IMF By component is large, significant Poynting flux is deposited in the dayside. Deposition may exceed 170 mW/m$^2$—an order of magnitude above typical auroral values.

-Empirical Joule heat models do not capture this result.

*Extreme Poynting Flux in the Dayside Thermosphere: Examples and Statistics* [Knipp et al., 2011, GRL]

Intervals of large IMF By produce enhanced, and even extreme, Poynting flux deposition into the dayside thermosphere. These events have now been simulated to good agreement with the OpenGGCM MHD model.




Each dot represents the maximum value of the of the pass

Colored dots show Poynting flux in excess of 75 mW/m$^2$

~ 1500 passes are shown

# Poynting Flux
# Sawtooth Oscillations vs Steady Magnetospheric Convection

*McPherron et al., 2008*

<u>Sawtooth Oscillation/Injection:</u>

- •Steady solar wind input, but typically stronger than SMCs
- •Periodic  GEO particle injections
- •Large periodic substorms
- •Intense Poynting flux deposition

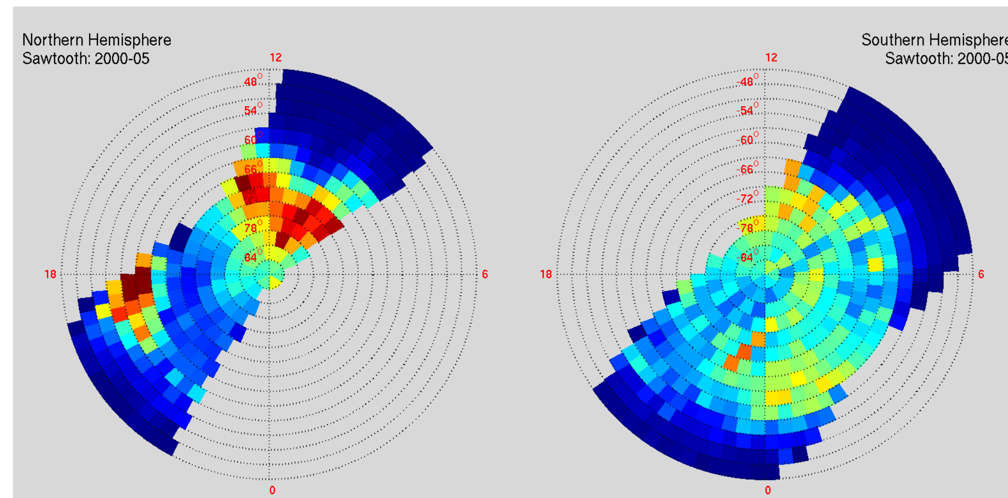
*Event List From Cia*

<u>Steady Magnetospheric Convection:</u>

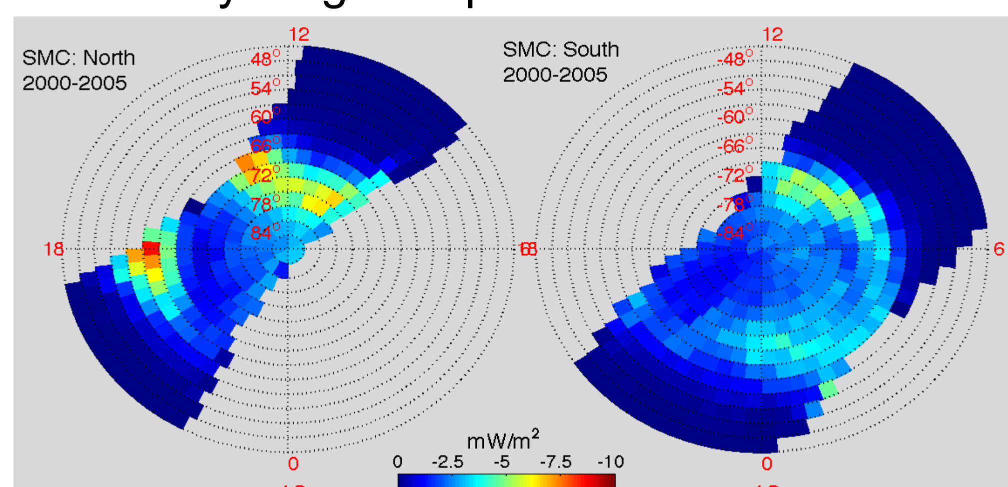
- •Steady  and relatively slow, solar wind input
- •No substorm activity (but often before or after)
- •Relatively constant auroral diameter
- •Moderate Poynting flux deposition in/near auroral oval
- •~Three time more prevalent than Sawtooth events

*Event List From Kissinger*

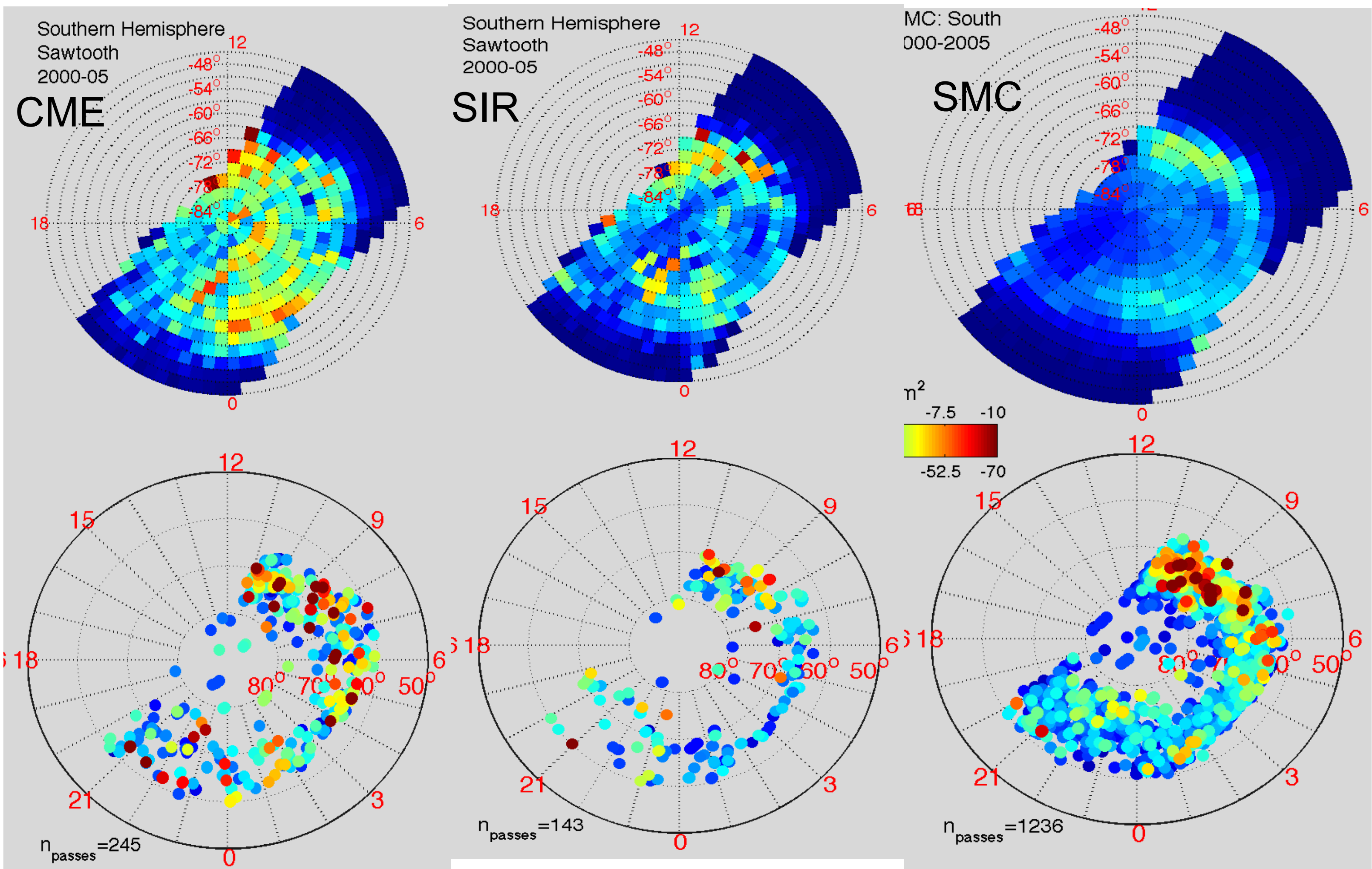
Sawtooth_Oscillation



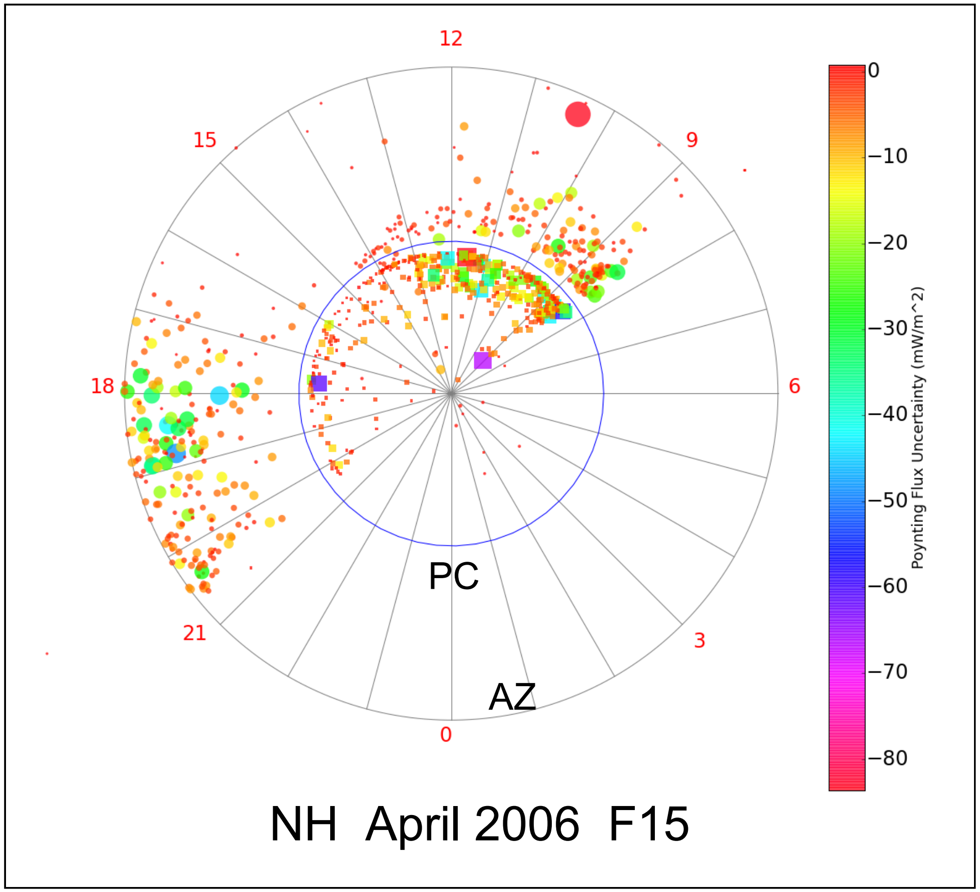

Steady Magnetospheric Convection

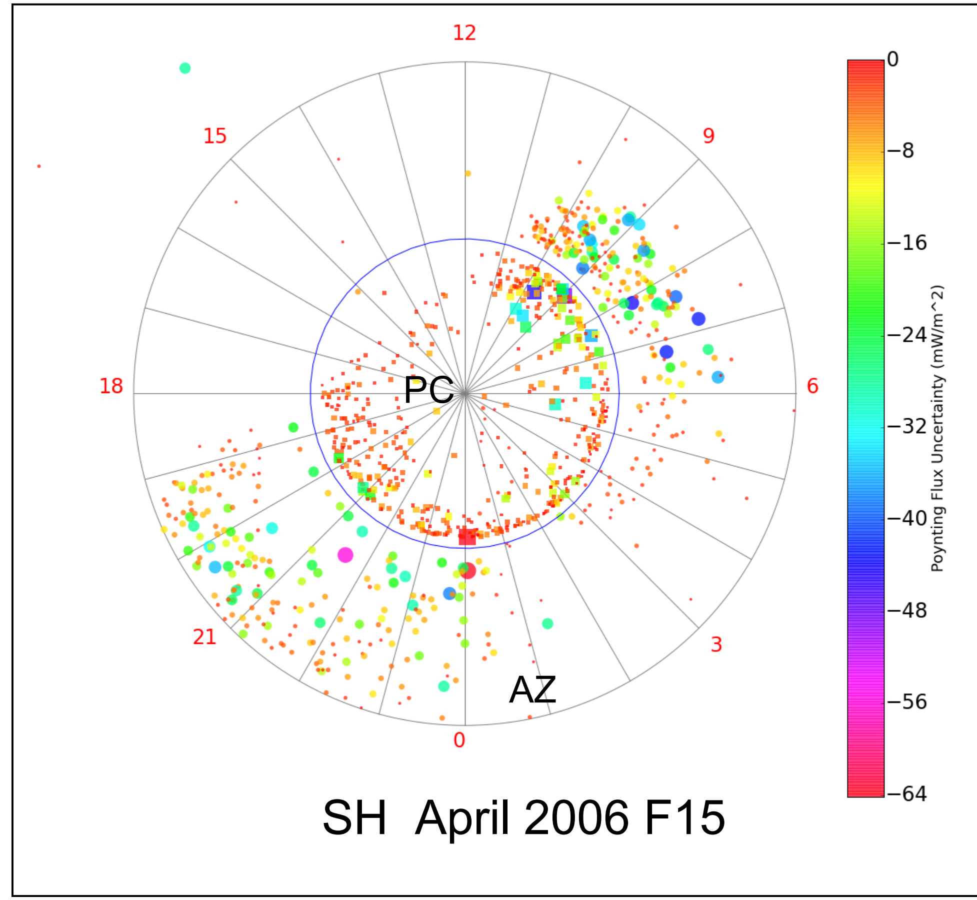


# Poynting Flux
# Sawtooth Oscillations Driver
# vs Steady Magnetospheric Convection



# DMSP Poynting Flux in Auroral Boundary Coordinates




*Each dot represents the maximum value of the of the pass

During this relatively quiet month long interval there is:

- Ubiquitous low level polar cap Poynting Flux
- Concentration of Poynting flux in mid morning hours in PC and AZ

Auroral Boundary Coordinates defined by Redmon et al. (2010)

- Determined by particle flux characteristics from DMSP
- PC = polar cap; AZ = Auroral Zone

# Limitations

Using DMSP F15 data only—WHY?

- Need across and along **E** and **dB**
  - Reliable or at least Quality Flagged for F15 only
  - Along track E for F16 and beyond is uncharacterized

- Need uncertainty estimates for F15
  - ✓ **E** from Univ of Texas Dallas
  - ✓ **dB** from Knipp et al 2014 and 2015
  - ✓ **PF** from Rastatter et al 2016

- Uncertainty estimates For F16 and beyond
  - ✓ **dB** from Knipp et al 2014 and 2015
  - ✓ Single component **E** thus single component **PF**

# Roadmap

1. Overview of Recent DMSP Poynting Flux Studies
2. **Sensitivity of Poynting Flux To Single Velocity Component Approximation**
3. Status Update on DMSP Level 2 CDF Project
4. SSM Field Aligned Currents

# DMSP Poynting Flux

'Spacecraft'
Coordinate Frame

X – along track
Y – across track
Z – radial (up)

$$S_z = \frac{1}{\mu_0}(E_x dB_y - E_y dB_x)$$

SSM Magnetometer

$$S_z = \frac{1}{\mu_0}(-[v_y B_z]dB_y - [v_x B_z]dB_x)$$

SSIES Cross Track Velocity
From Ion Drift Meter

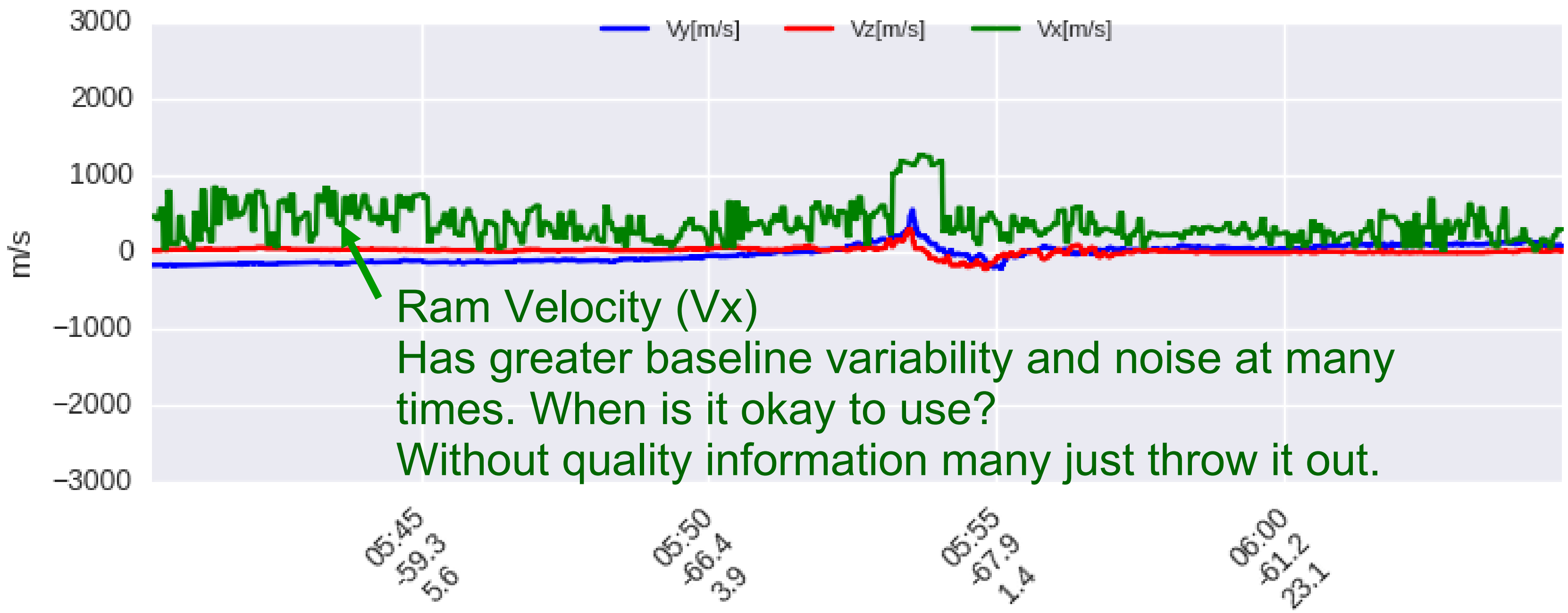
SSIES Ram Velocity
From Retarding
Potential Analyzer

******for simplicity, the terms vz*Bx,y in the electric field expressions have been neglected. They are usually are 5 – 10 times smaller than the Bz terms*

# The Ram Velocity (Vx) from RPA has Often Been Considered Questionable And It's Contribution Removed

## Resulting In the Approximation:

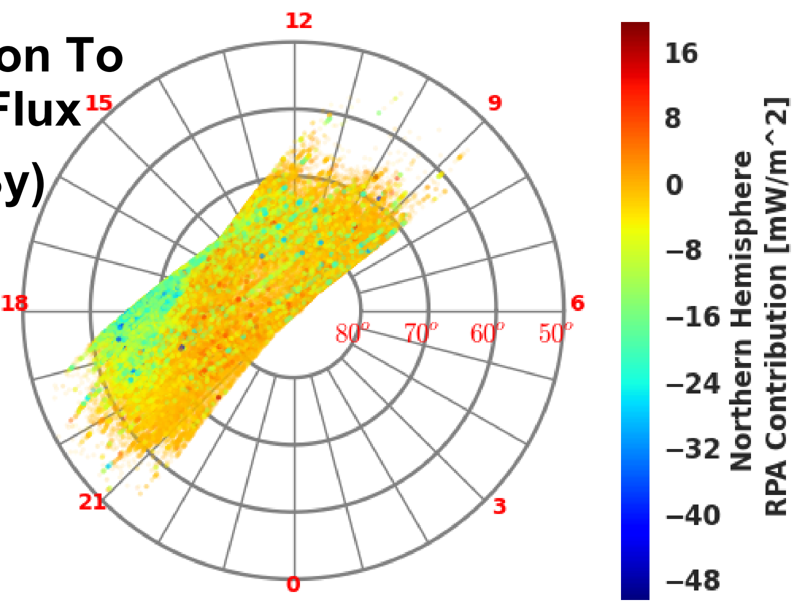
$$S_z \approx \frac{1}{\mu_0}(-[v_y B_z]dB_y)$$

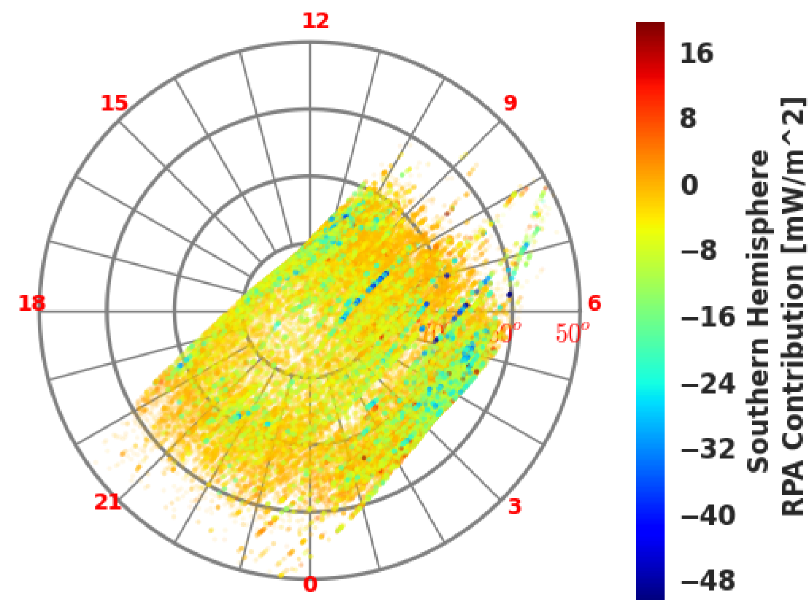


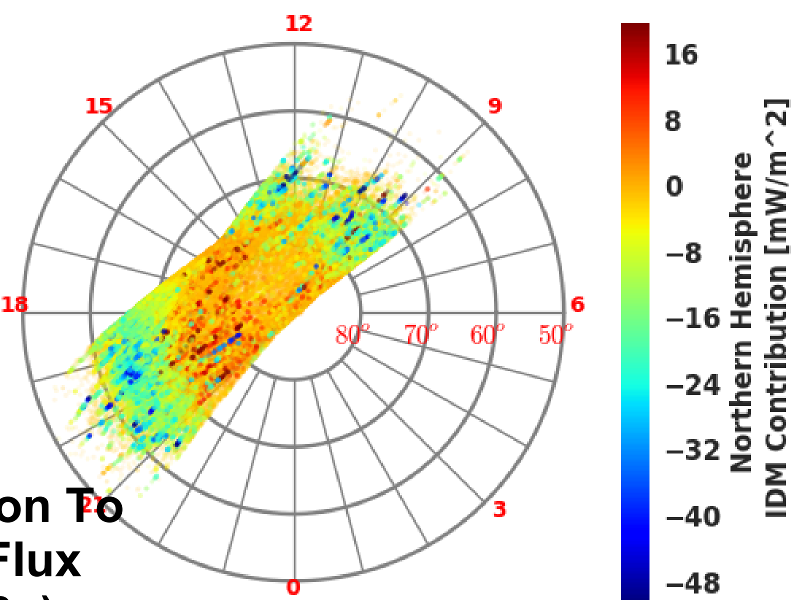
# Poynting Flux Separated Into Components

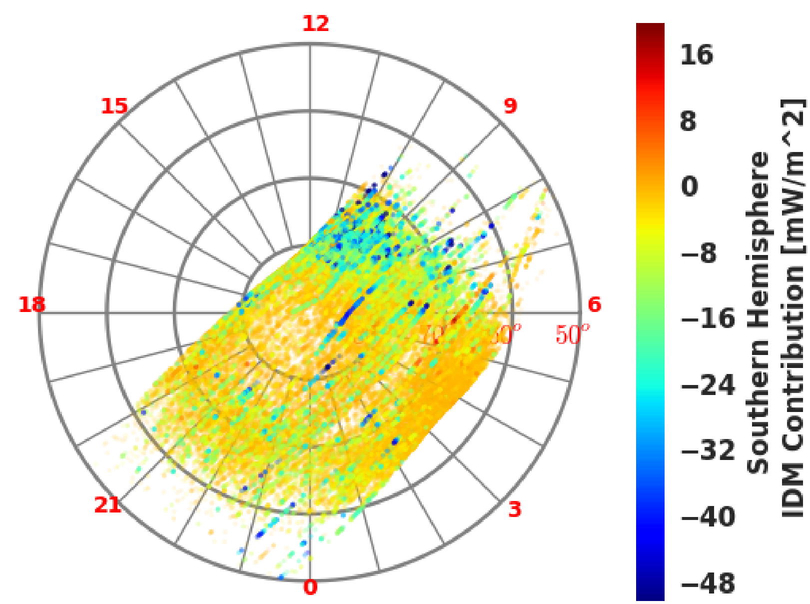
(Example from Winter of 2005)

**RPA Contribution To Poynting Flux (-Vx*Bz*dBy)**



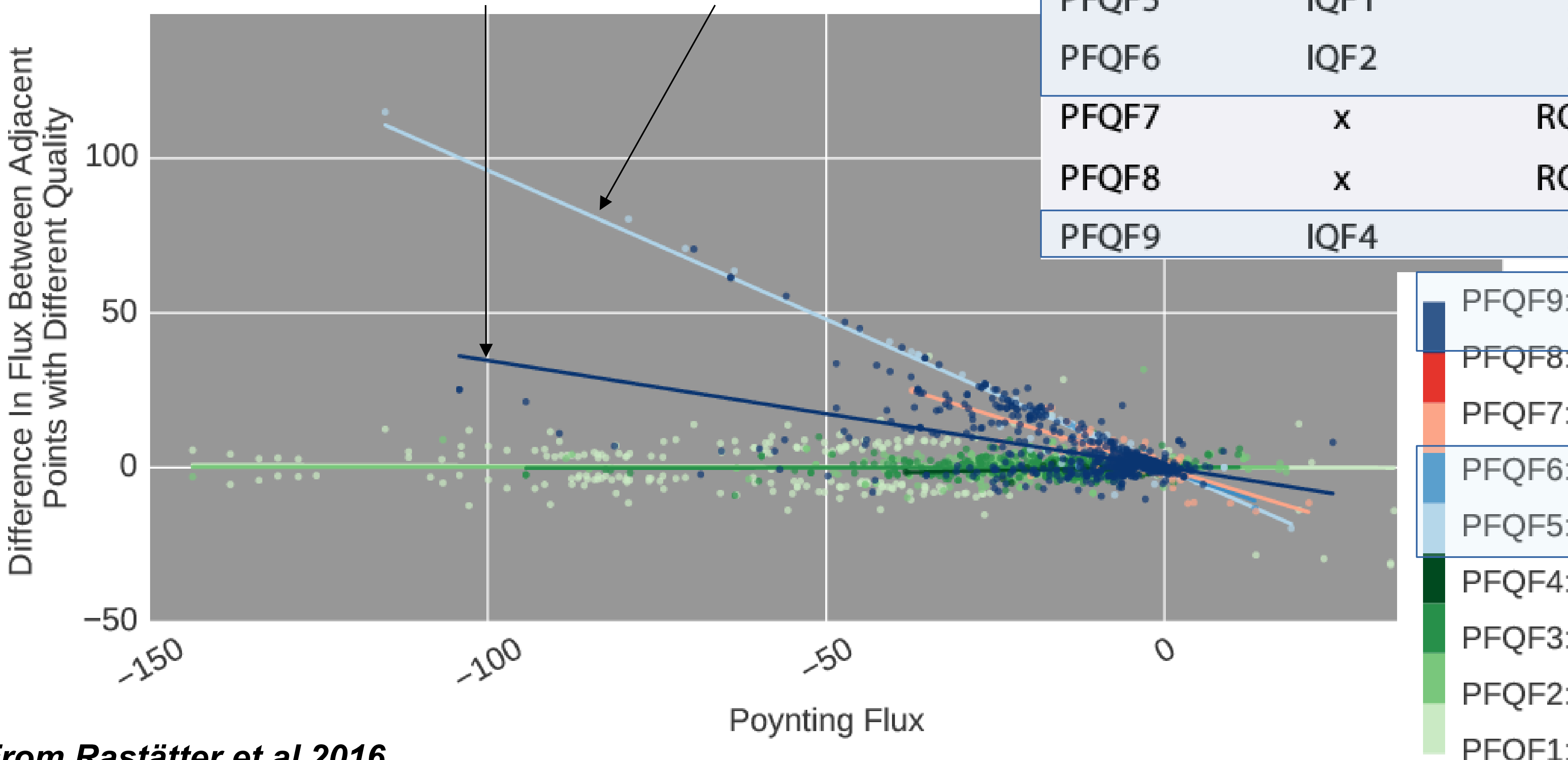




**IDM Contribution To Poynting Flux (-Vy*Bz*dBx)**

# A Study of Change in Second-To-Second DMSP Poynting Flux

- Examines deviation from stationarity when information going into the calculation is changed
- Shows the largest effects when a component of the velocity is neglected (PFQF 9,6 and 5)

| | IDM QF | RPA QF |
|---|---|---|
| PFQF1 | IQF1 | RQF1 |
| PFQF2 | IQF2 | RQF1 |
| PFQF3 | IQF1 | RQF2 |
| PFQF4 | IQF2 | RQF2 |
| PFQF5 | IQF1 | x |
| PFQF6 | IQF2 | x |
| PFQF7 | x | RQF1 |
| PFQF8 | x | RQF2 |
| PFQF9 | IQF4 | x |




***From Rastätter et al,2016***

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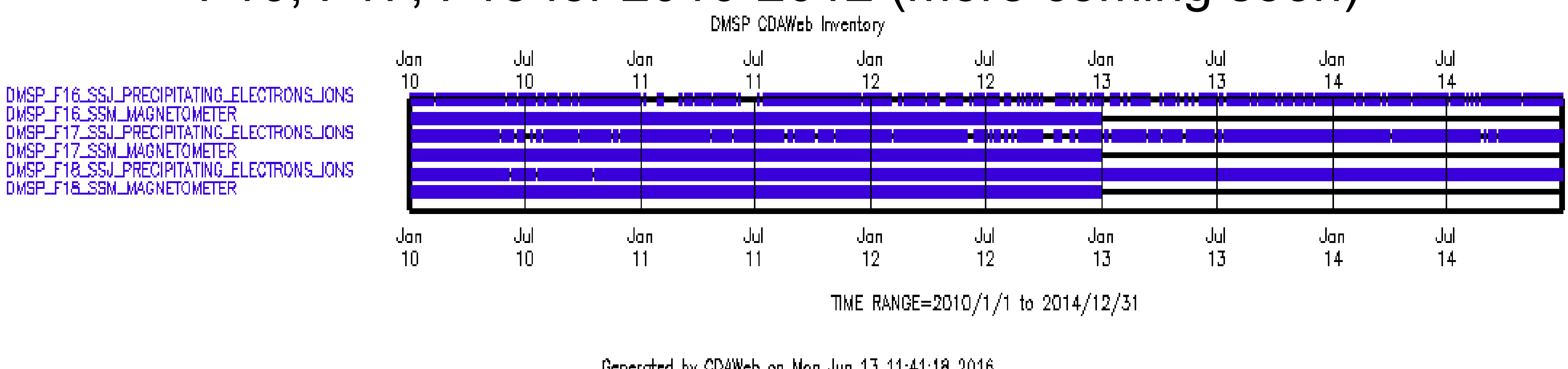
# SEDA Group DMSP Reprocessing Project

- **NASA-funded project to reprocess DMSP particles and fields data into Level 2 data products**
  - Addition of best estimate of uncertainty
  - Archival at virtual observatory

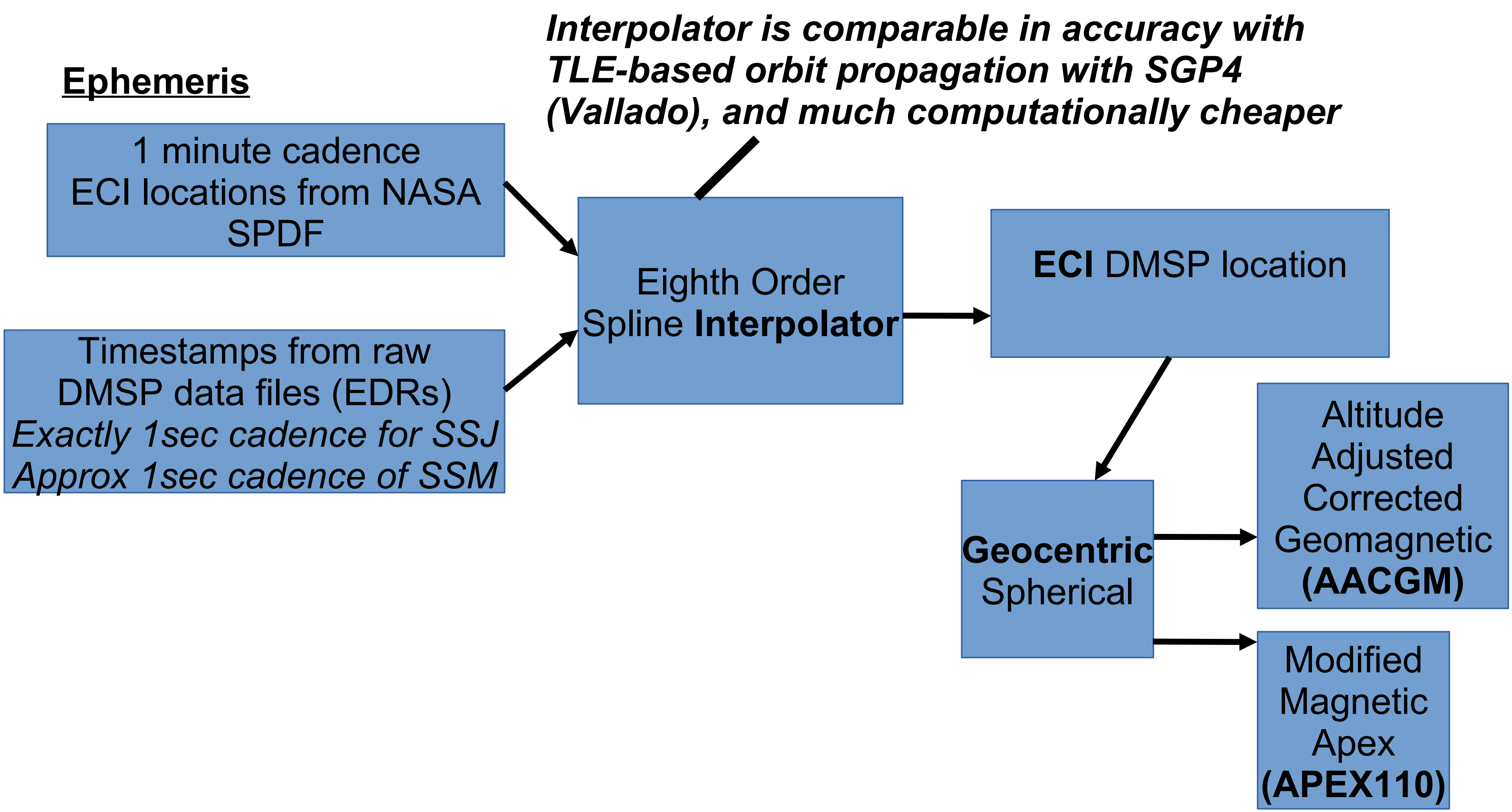
- **SSJ Precipitating ions and electrons data now available at NASA CDAWeb**
  - F16, F17, F18 for 2010-2014

- **SSM Magnetometer data now available at NASA CDAWeb**
  - F16, F17, F18 for 2010-2012 (more coming soon)



# All Instruments (SSM,SSJ,SSIES)

## More Accurate Spacecraft Locations in Geocentric and Magnetic Coordinate Systems

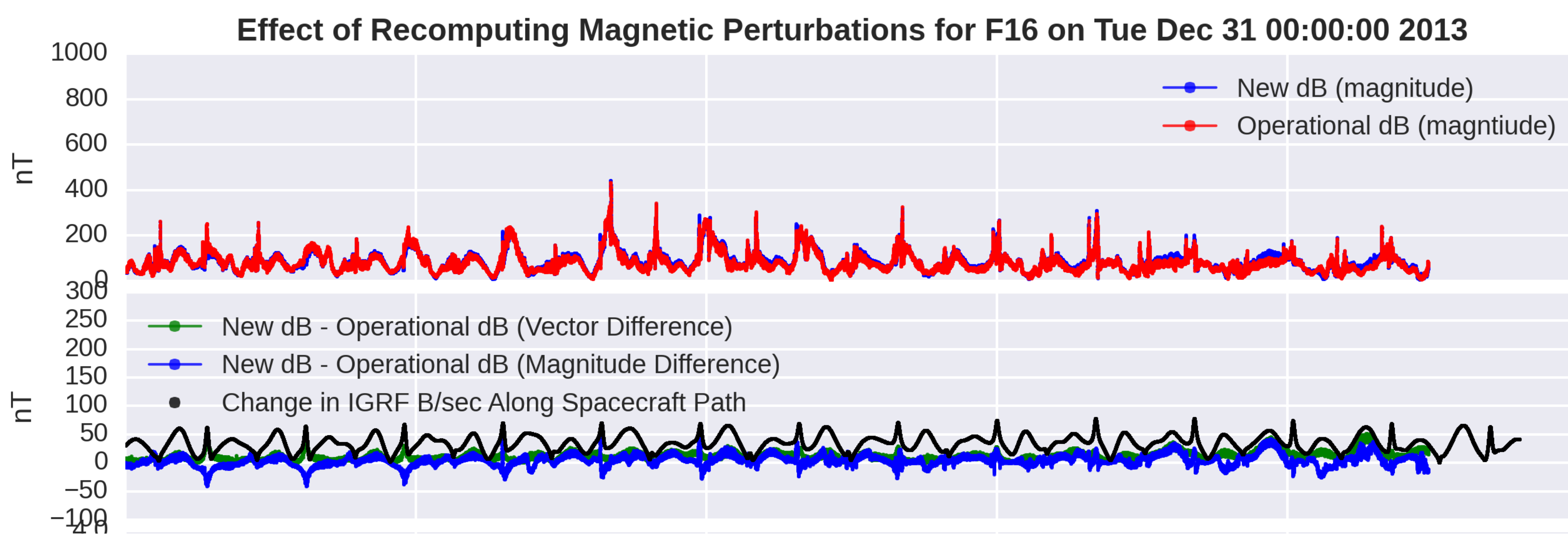


# SSM Magnetometer

## Level 2 CDFs (3 years now at CDAWeb)

### Improvement 1:

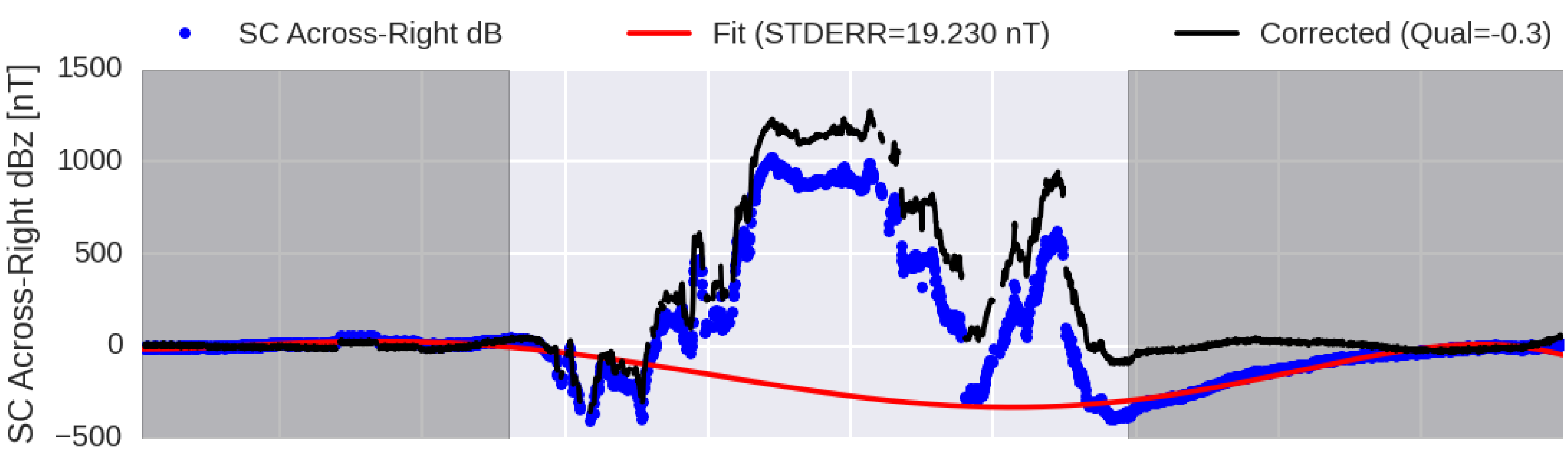
Recomputed magnetic perturbations (**$dB = B_{DMSP} – B_{IGRF}$**) with proper IGRF for new, more accurate s/c locations



# SSM Magnetometer
## Level 2 CDFs (3 years now at CDAWeb)

### Improvement 2:

Residual baseline removal, leaving only magnetic perturbations from ionospheric current systems (MFIT process)

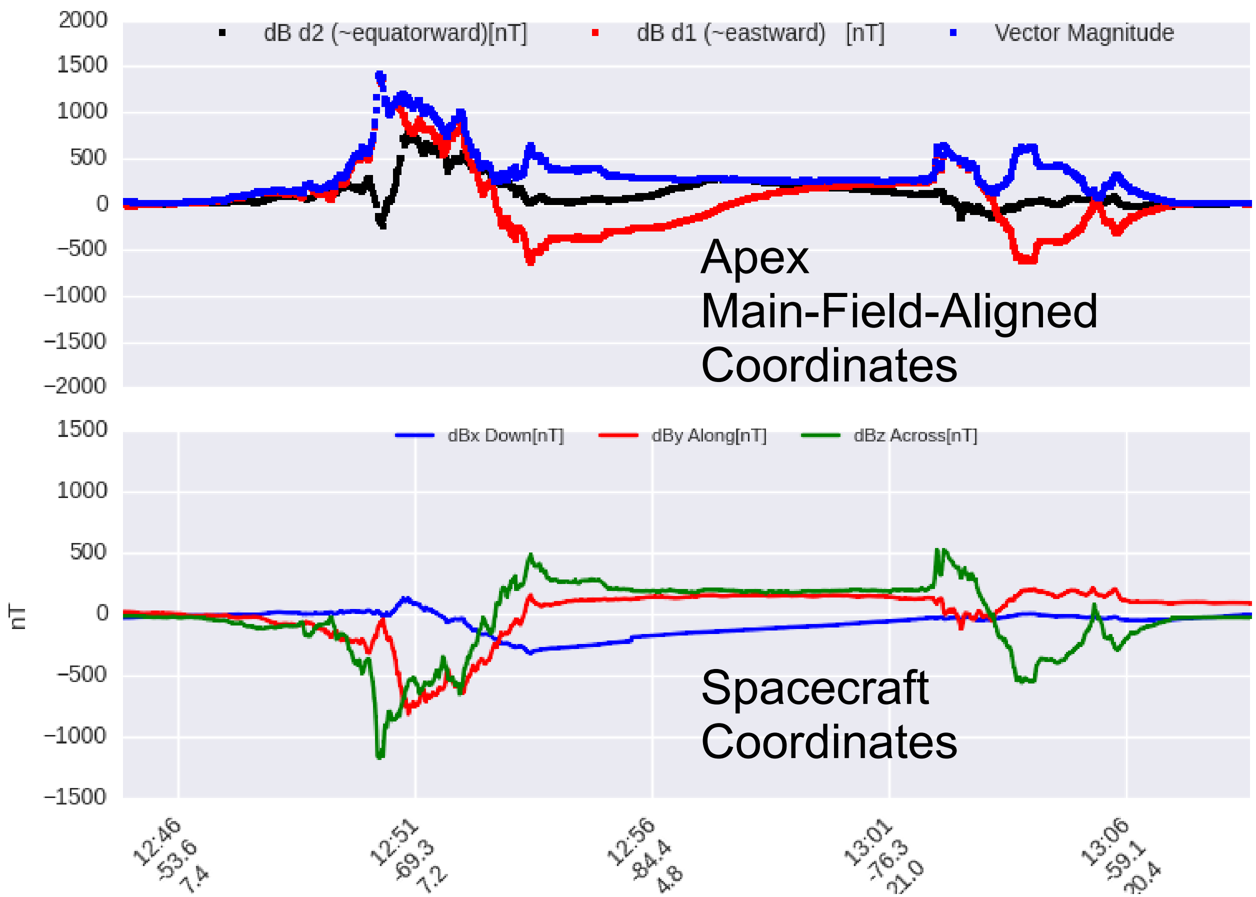


# SSM Magnetometer

## Level 2 CDFs (3 years now at CDAWeb)

### Improvement 3:

- Rotated vector measurements from spacecraft aligned coordinates to geocentric and main-field-aligned coordinate systems (Apex)

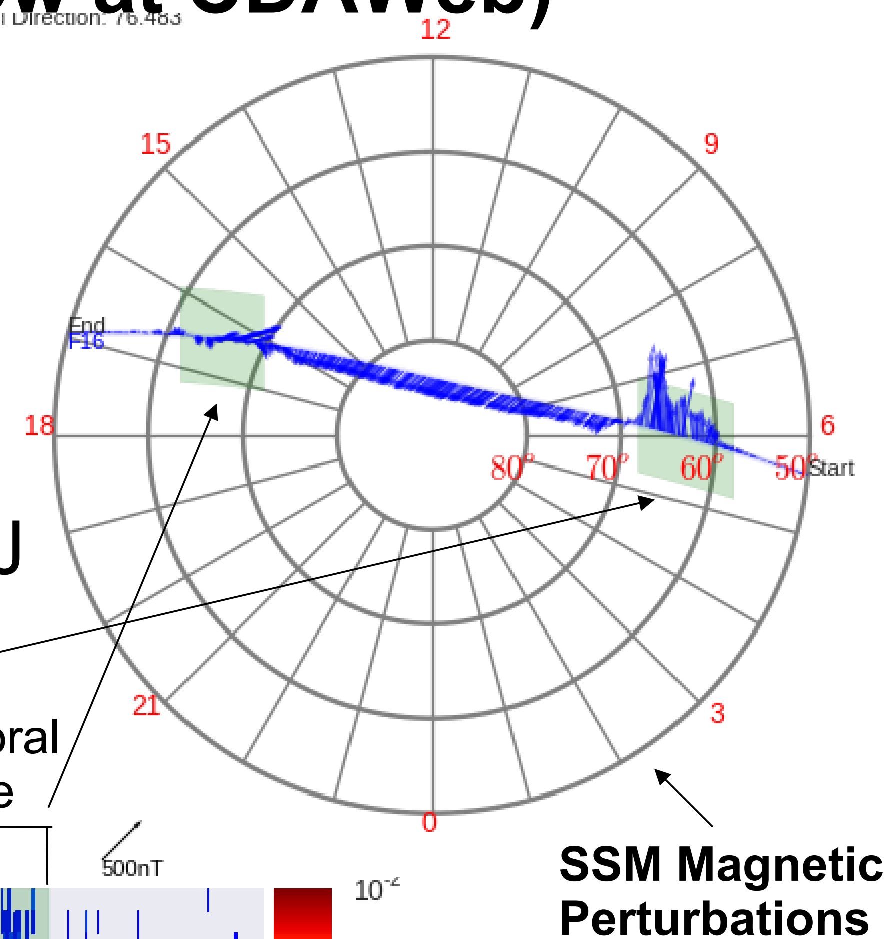


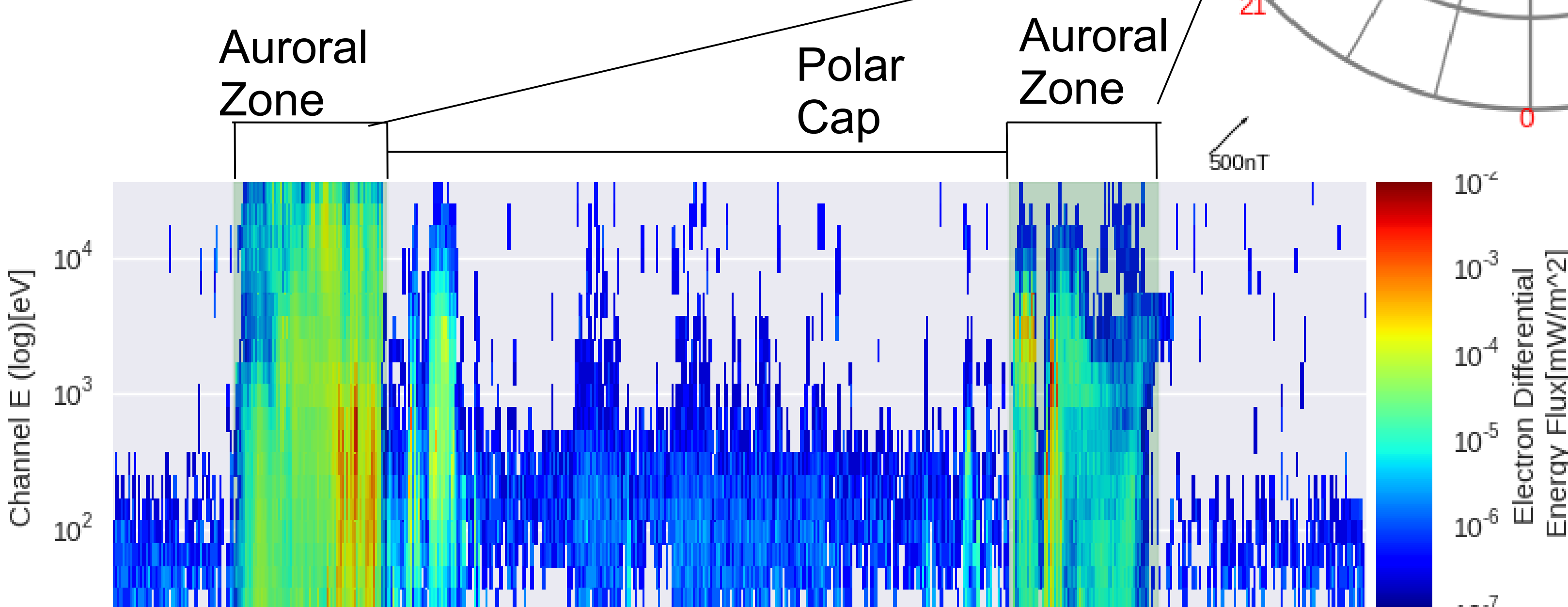
# SSM Magnetometer

## Level 2 CDFs (3 years now at CDAWeb)

### Improvement 4:

- Automated Auroral Boundaries From SSJ Instrument
- Based on Redmon et. al. 2010 method, now incorporating uncertainty information in new SSJ CDFs




**Southern Hemisphere F16 SSJ Electron Spectrogram**

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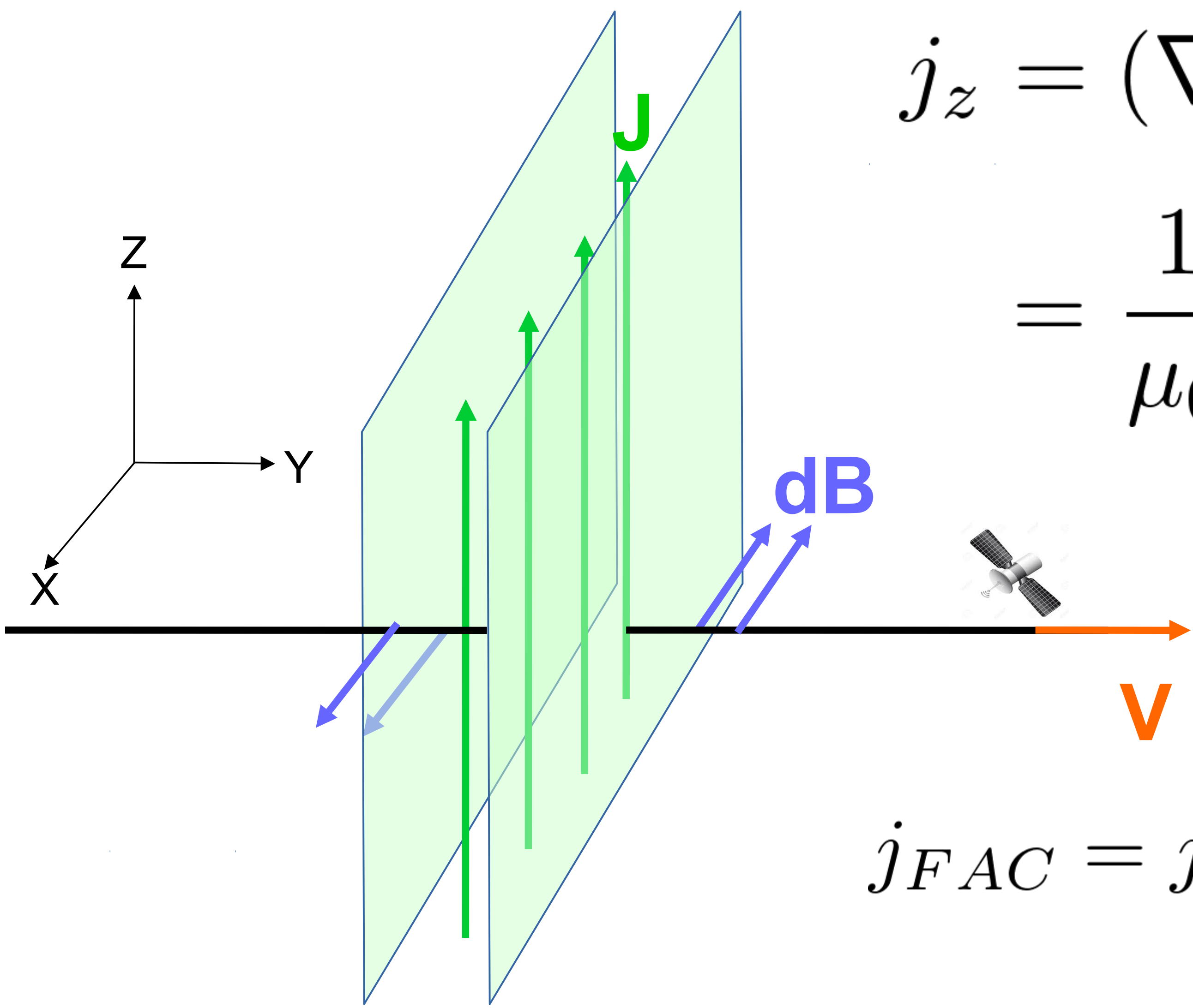
# Single Spacecraft FAC Estimation

Typical Assumptions for Single Spacecraft FAC estimation:

1. Current Sheet of finite width, but infinite length
2. Spacecraft crosses current sheet perpendicular to it's long direction




$$j_z = (\nabla \times B)_z$$

0 by assumption 1

$$= \frac{1}{\mu_0}\left(\frac{\partial dB}{\partial y} - \frac{\partial dB}{\partial x}\right)$$

Estimate partial derivative with finite difference

$$j_{FAC} = j_z = -\frac{1}{\mu_0}\frac{\Delta dB_{across}}{v\Delta t}$$

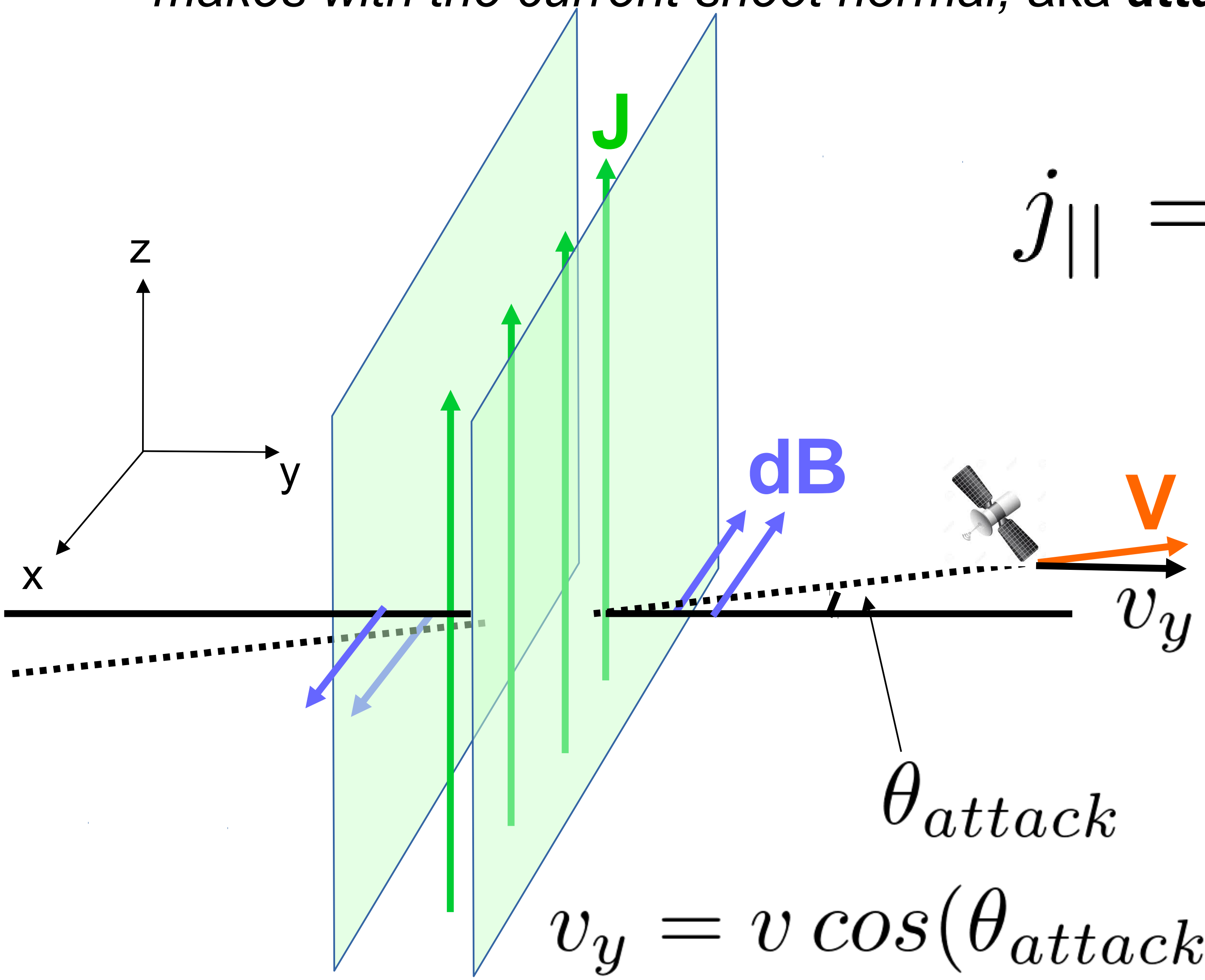
# SSM Magnetometer

## Minimum Variance Analysis (MVA)

Minimum Variance Analysis Technique Goal:

**Estimate Spacecraft Crossing Current Sheet Geometry**

*(precisely: estimate the angle that the spacecraft velocity vector makes with the current sheet normal, aka* ***attack angle***




$$j_{||} = \frac{1}{\mu_0} \frac{\Delta dB_x}{v_y \Delta t}$$

$$v_y = v\, cos(\theta_{attack})$$

*Rotation of* ***dB*** *vector that gives dB in x,y,z coordinates must be estimated statistically, via principal component analysis (PCA)*

# SSM Magnetometer: MVA Process

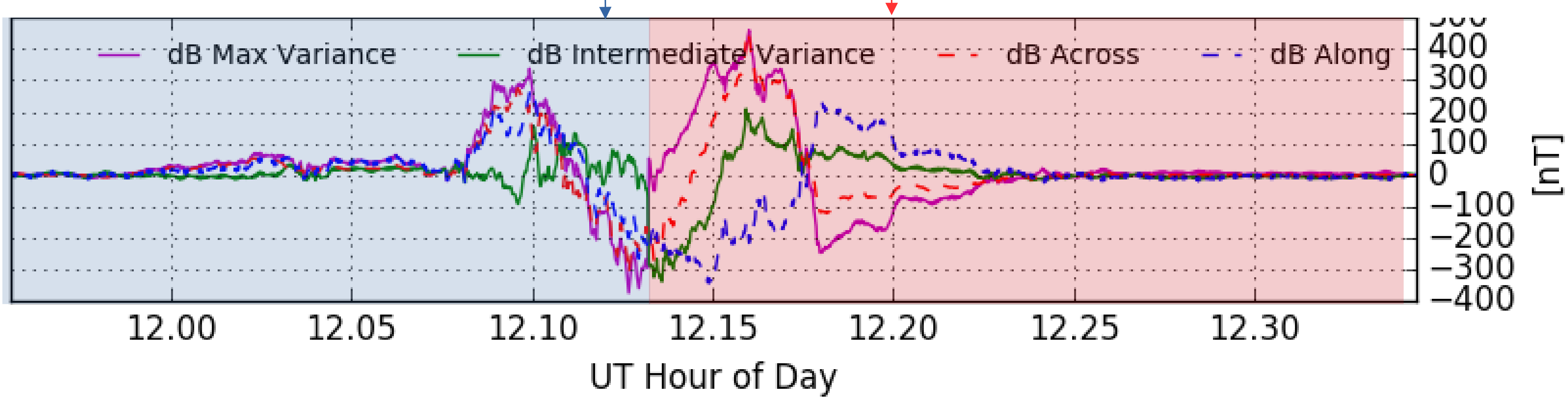
**½ orbit (equator to equator) SSM dB**
*Recomputed and Baseline Corrected*

***Duskside Leg of ½ Orbit***

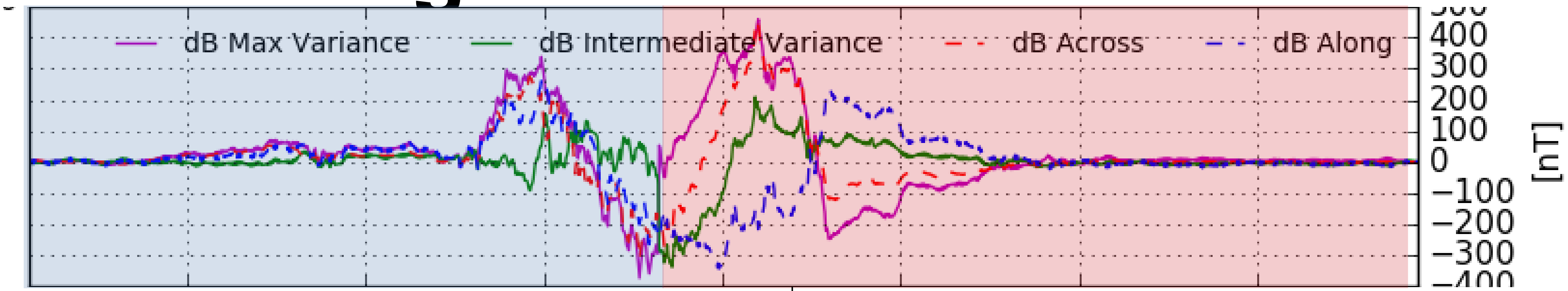
***Dawnside Leg of ½ Orbit***

**45 second (~300 km scale size @110 km altitude)**
**Digital Lowpass Filter**

**Principle Component Analysis of dB**
Determine rotation from spacecraft frame to Maximum,Intermediate,Minimum Variance Basis



# SSM Magnetometer: FAC Process

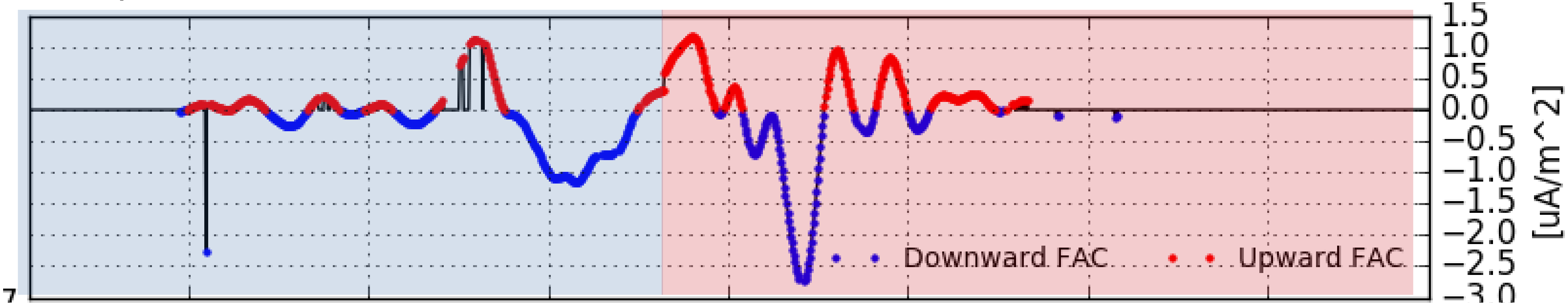



**X** – Max Variance Direction, Along Long Axis of Current Sheet

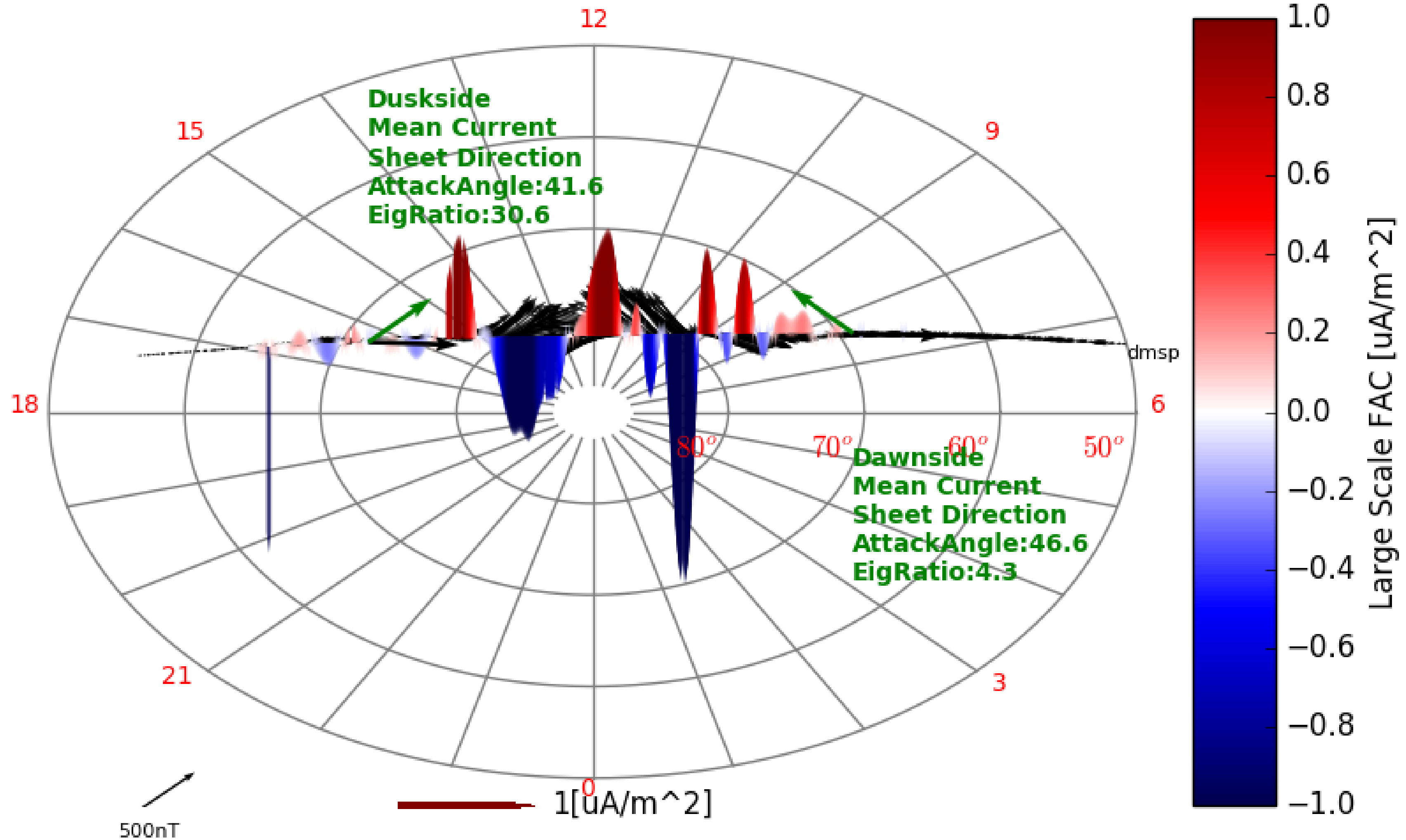
**Y** – Intermediate Variance Direction, Along Short Axis of Current Sheet

**Z** – Main Field Aligned Direction, ideally no perturbations at all in this direction

$$j_{||} = \frac{1}{\mu_0} \frac{\Delta dB_x}{v_y \Delta t}$$



# SSM Magnetometer: FAC Example

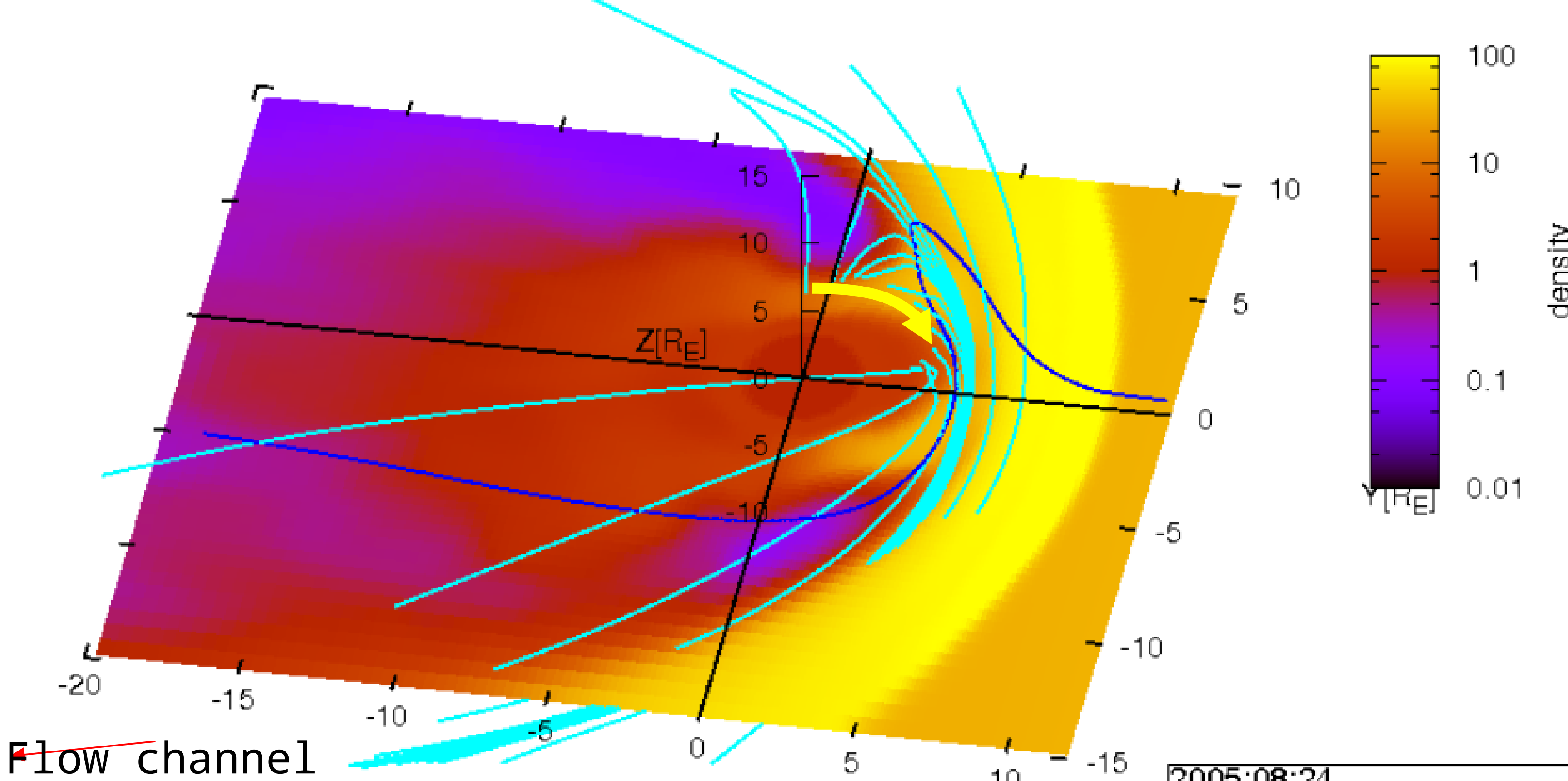


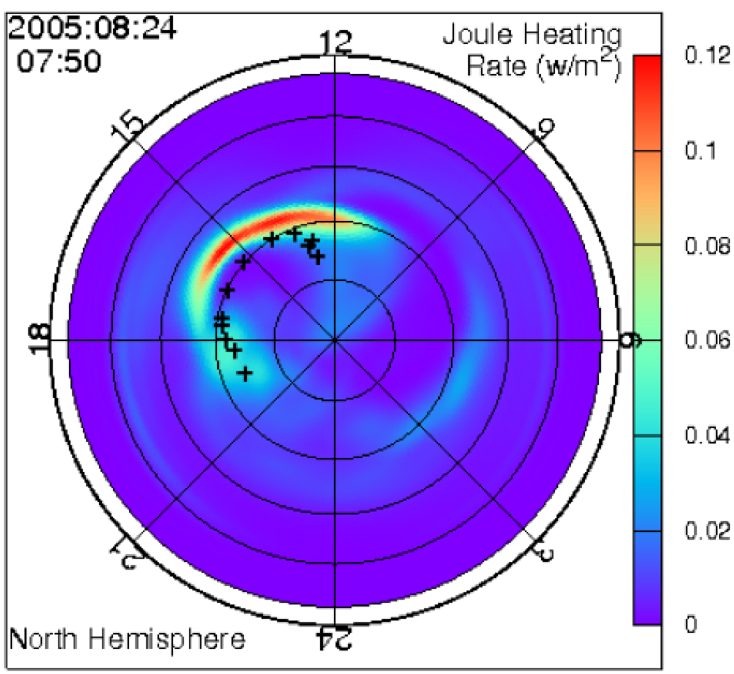

MVA shows that the FACs here have their long axis northward of magnetic east-west direction (attack angle is about ~40 degrees)

# Thank You!

# Questions?

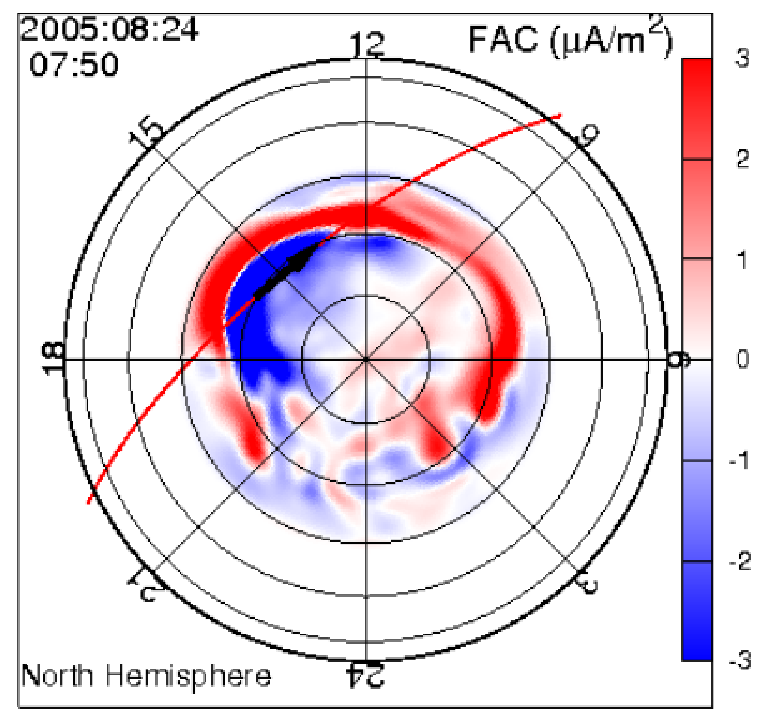
# Backup



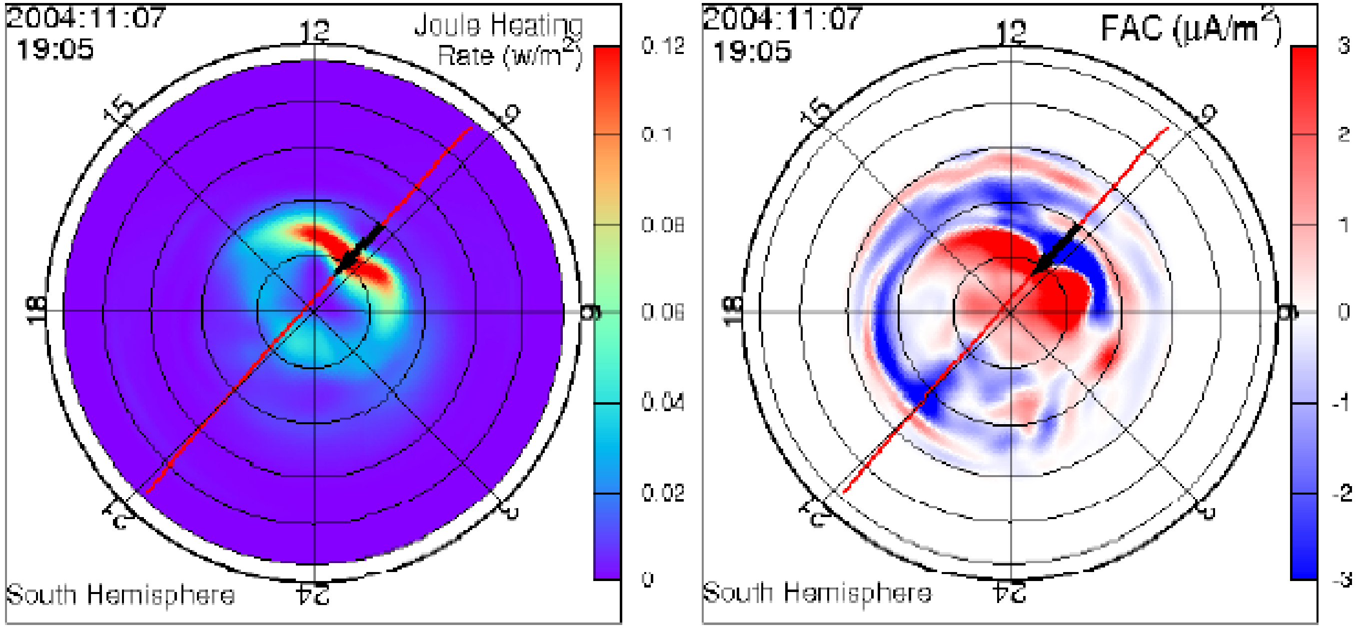

**Localized energy associated with intense FAC and plasma flow channels and dayside Poynting flux**

**Li et al., (2011)**



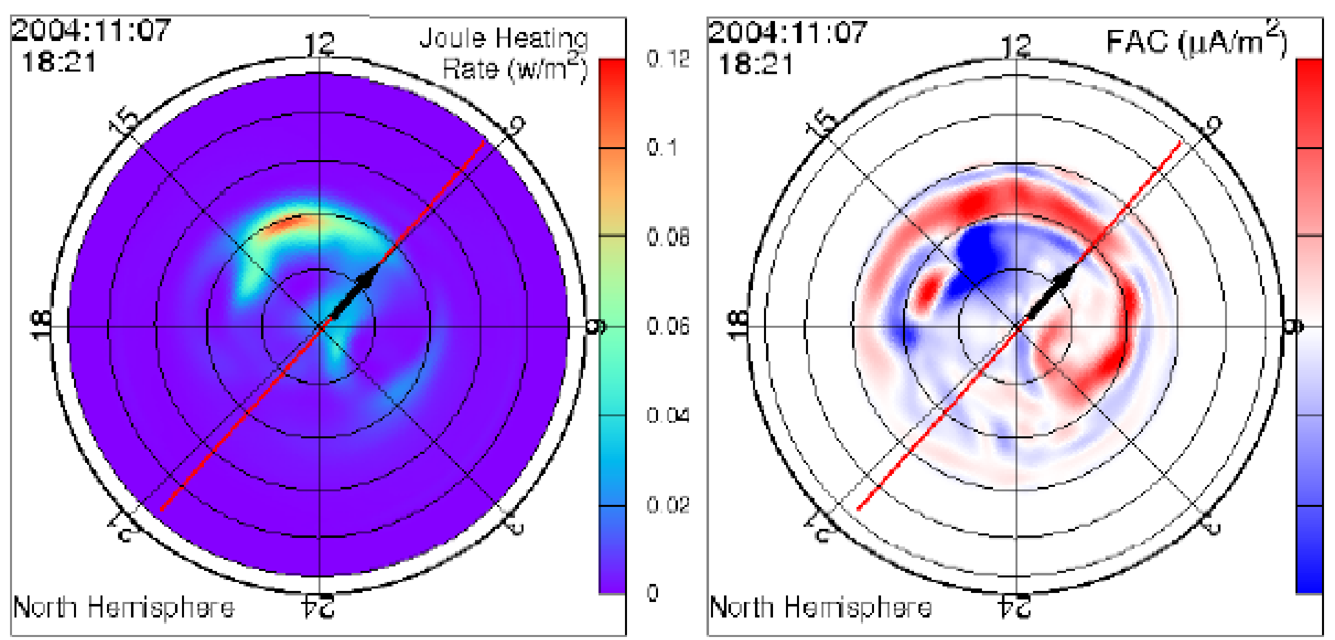
# Hemispheric Asymmetries

Southern Hemisphere




IMF By + Nov 7 2004
Li et al submitted 2011

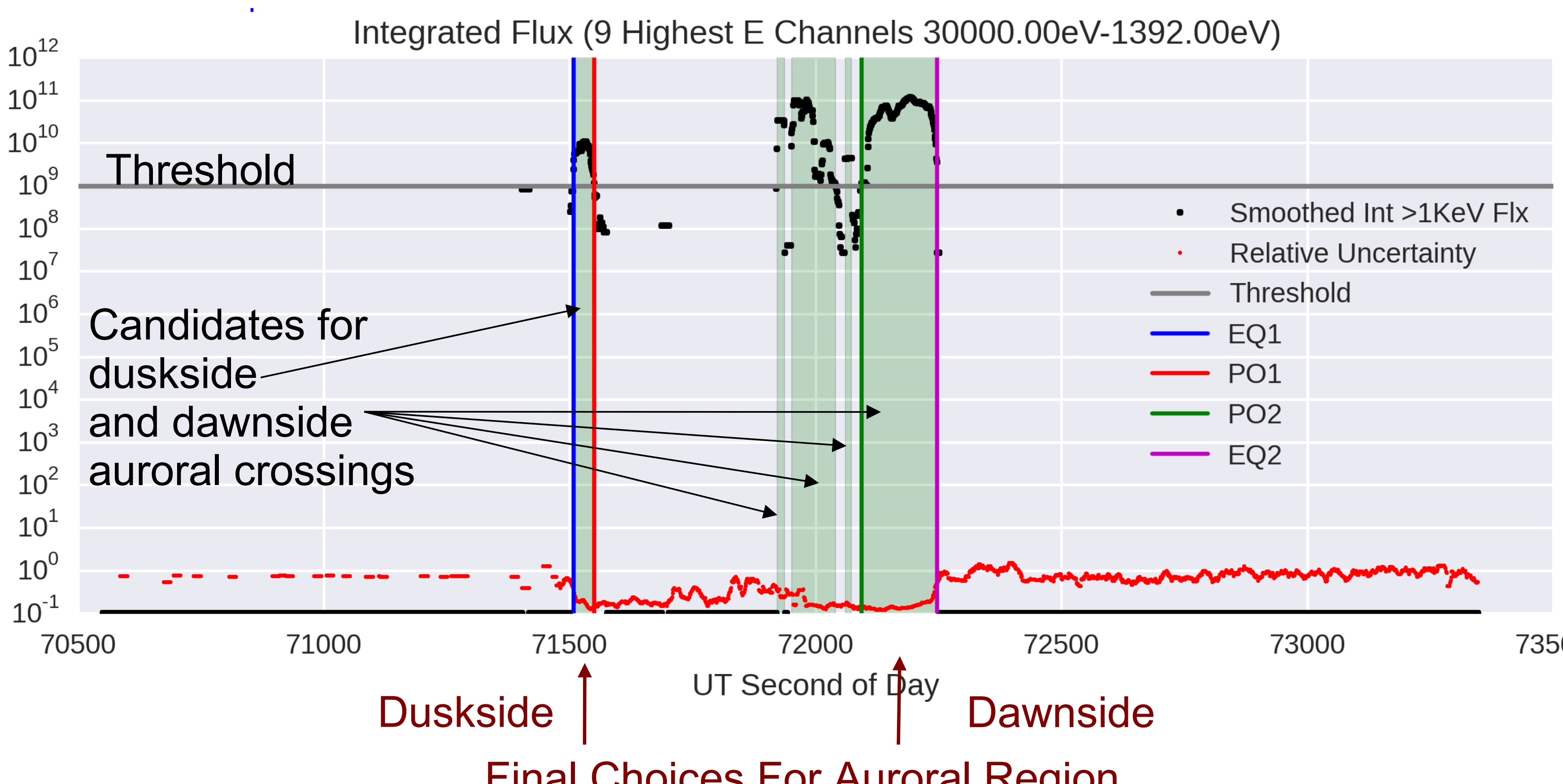
Northern Hemisphere



# SSJ Auroral Boundaries

**Boundary finding algorithm based on Redmon et. al. (2010) method, but incorporating uncertainty information**

1. Identify regions of continuously above-threshold (shaded green) integrated SSJ electron energy flux with electron energy > 1 KeV as **candidates** for the dusk/dawn auroral crossing

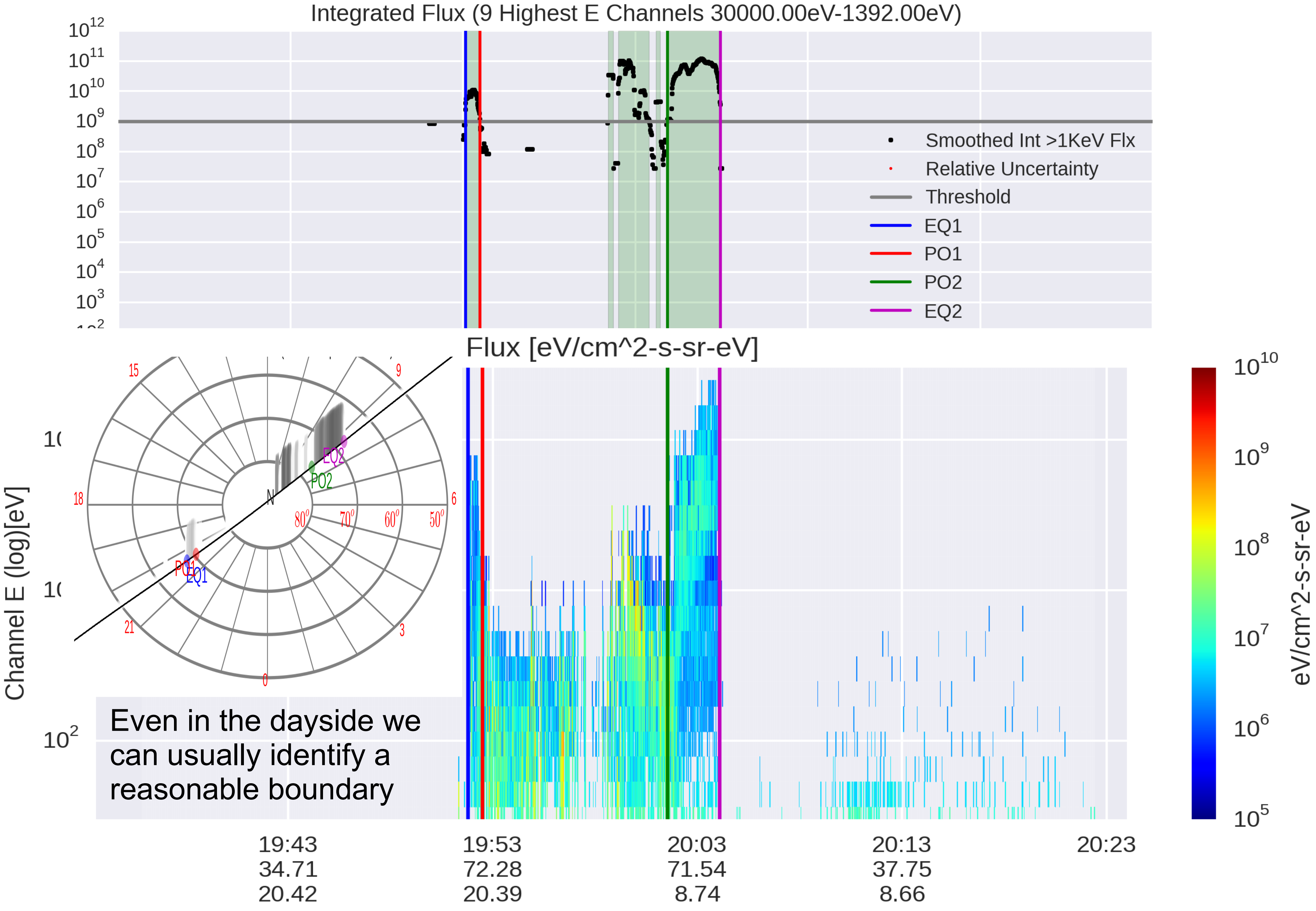



2. Choose best 2 candidate regions by maximizing a scalar, dimensionless figure of merit (FOM) computed for each possible combination.

**FOM rewards combinations with:**
**1. larger polar caps**
**2. smaller total uncertainty in above-threshold region**
**3. wider duskside and dawnside crossings**

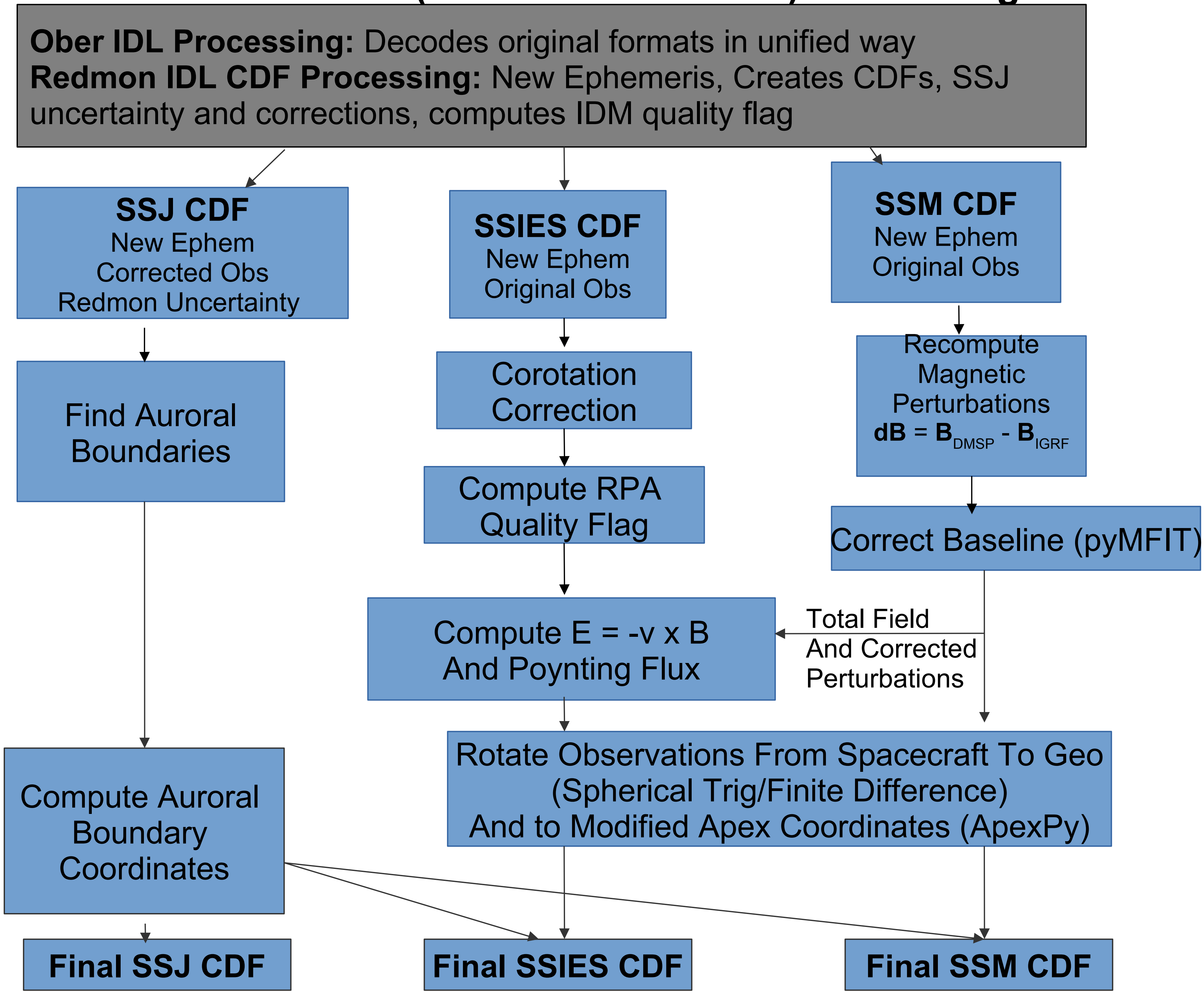
# SSJ Auroral Boundaries

**Boundary finding algorithm based on Redmon et. al. (2010) method, but incorporating uncertainty information**



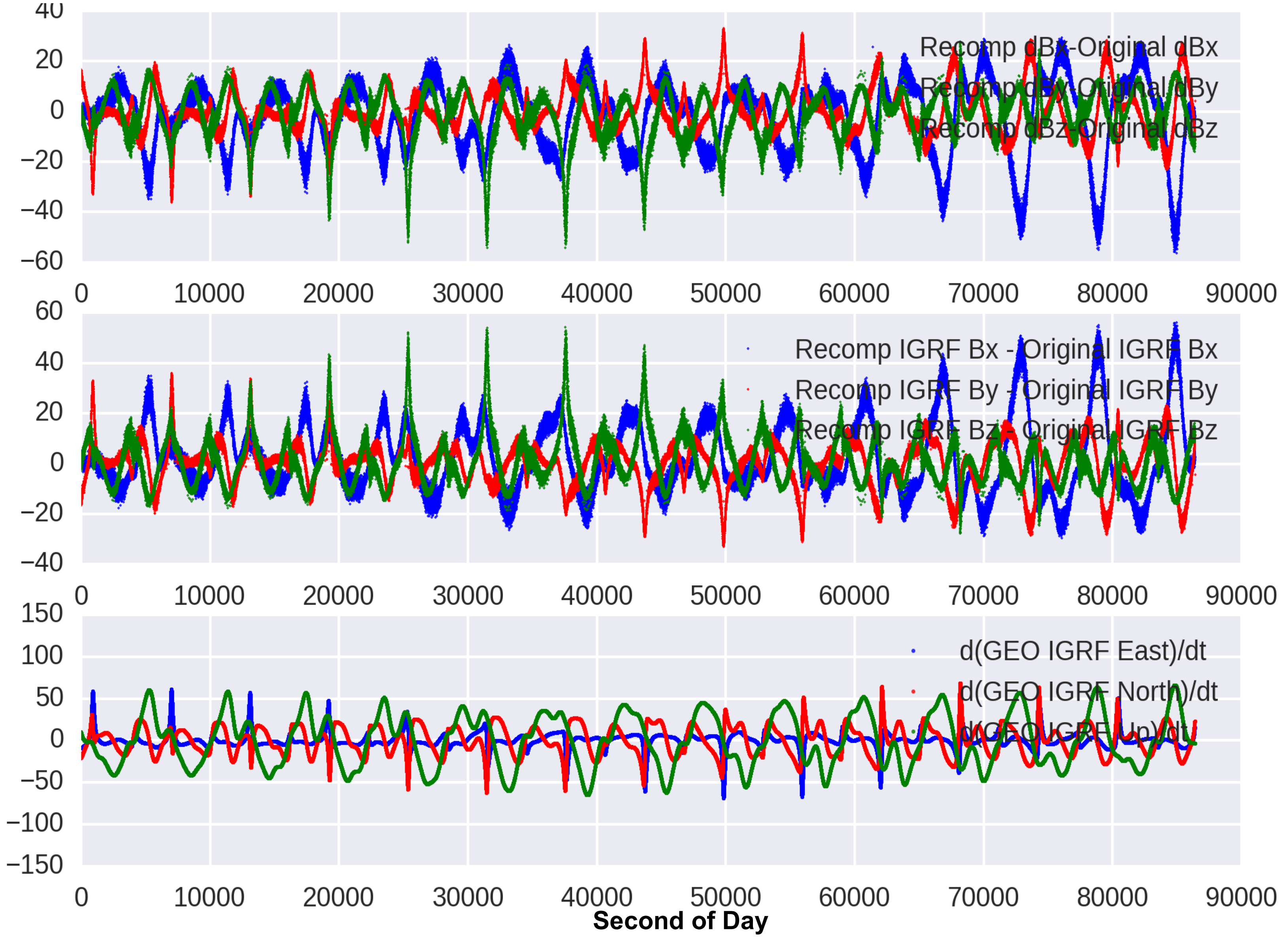

Even in the dayside we can usually identify a reasonable boundary

# Unified DMSP (SSM + SSIES + SSJ) Processing Flow



# Recomputing Magnetic Perturbations At New Locations

Blue: **X** – Down, Red: **Y** – Along Track / Ram, Green: **Z** – Across Track (To Right)




Difference Between Recomputed dB and Original dB

Difference Between New Location IGRF and Original IGRF

Change in IGRF field per second along spacecraft track at 850 km

**Effect of Recomputing Perturbations:**
**Same Size As Change in IGRF Field Over 7km At DMSP Altitude**

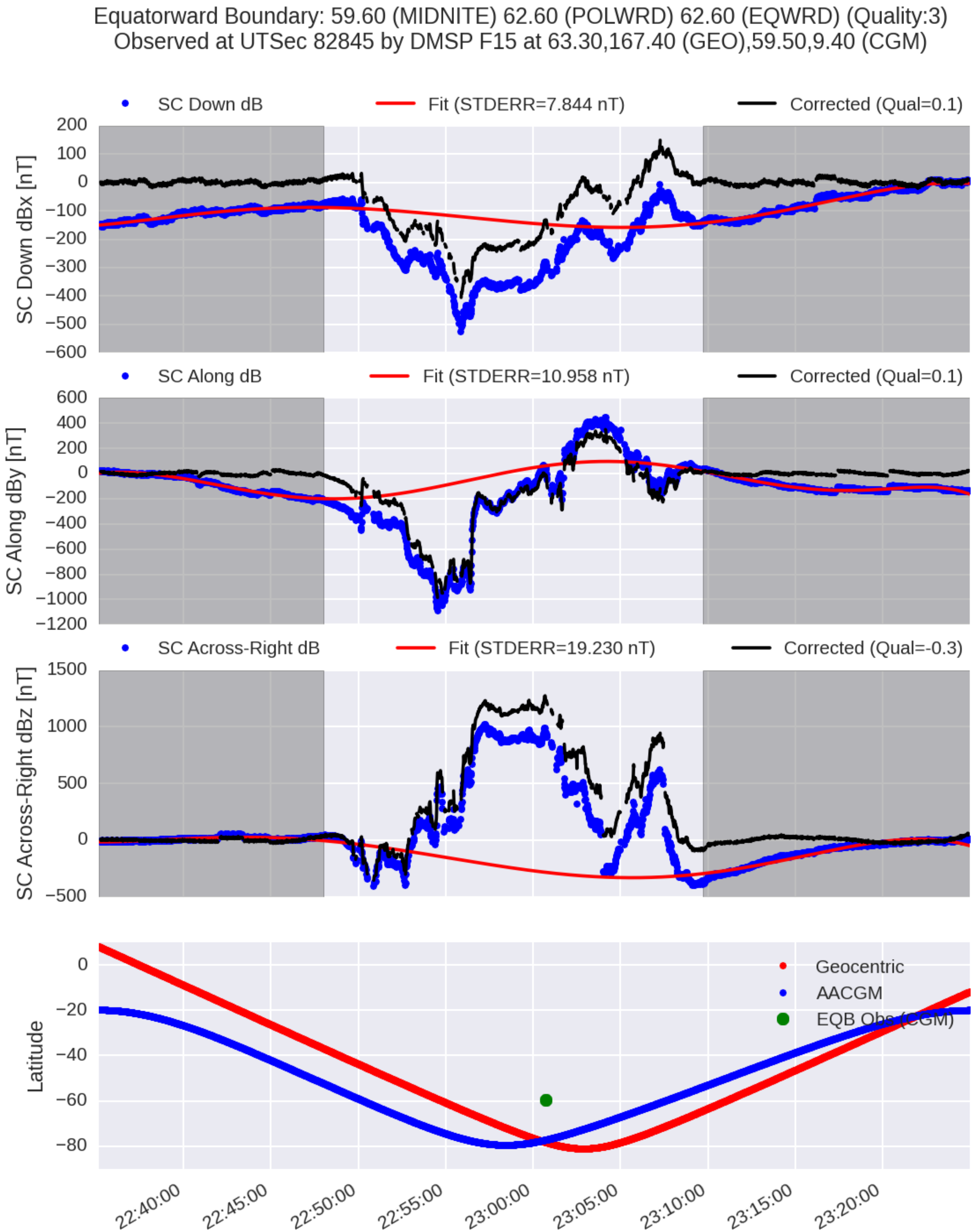
# Correcting SSM Baseline

**Odd-order polynomial (red) is fit to each component of the original magnetic field data (blue) and subtracted**

Possible source of baseline?
-Boom twist
-Crustal fields not resolved by IGRF
-Timing/Calibration errors

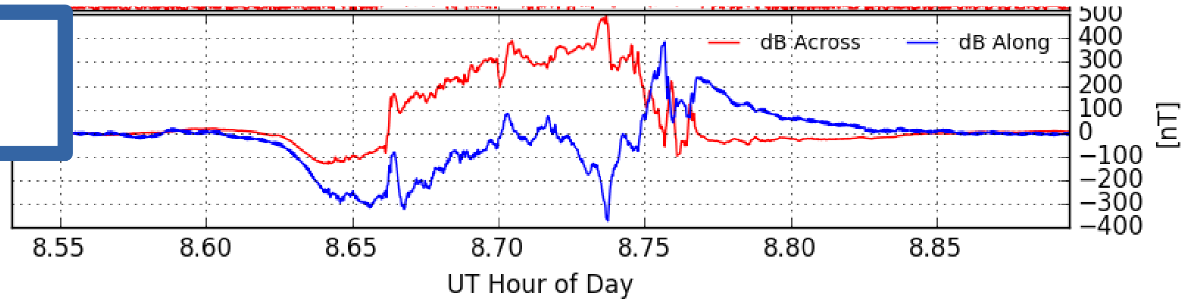
Grey - portion of the data that was judged to be outside of the auroral region and used to fit the polynomial

Black – Resulting corrected SSM magnetic perturbations

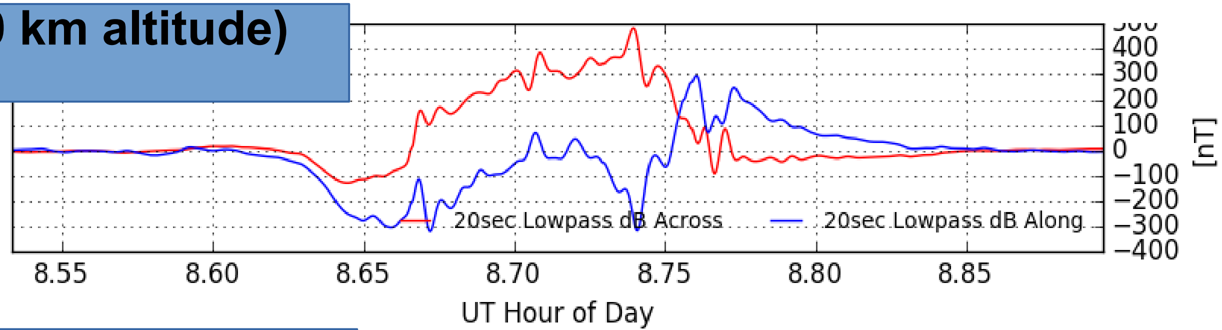


# Mesoscale FAC determination

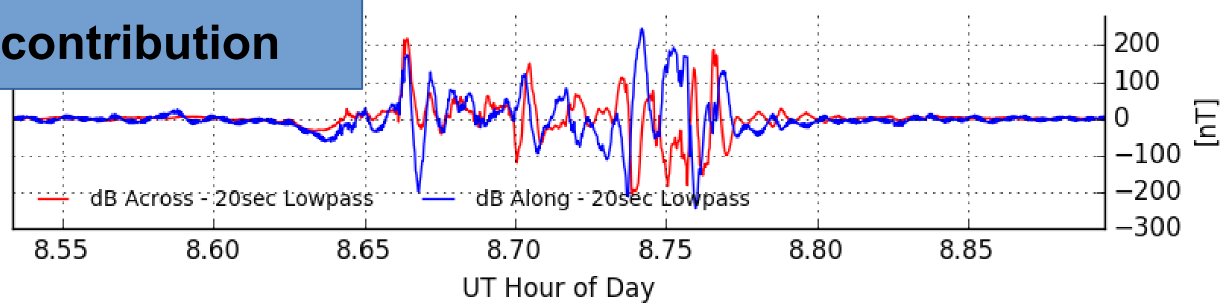
**½ orbit (equator to equator) SSM dB**
*Recomputed and Baseline Corrected*




**20 second (~120 km scale size @110 km altitude)**
**Digital Lowpass Filter**




**Subtract to get smaller scale FAC contribution**




**Use naive single spacecraft FAC expression**
**to estimate current density**