Calculating Hemispheric Power and Joule Heating using Defense Meteorological Satellite Program (DMSP) F-13 data

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Research mentors:

Dr. Barbara Emery & Dr. Astrid Maute

Outline

I. Introduction
- Preliminary knowledge
- Definition of Joule heating
- Importance of Joule heating

II. Research Strategy
- Motivation
- Framework for calculation & analysis
- Goals

III. Programming methodology & results
- Single day analysis
- Multiple day results

IV. Key Findings
- Dawn Vs. Dusk comparison
- Equatorward Vs. Poleward comparison
- Hemispheric Power Vs. Joule Heating

V. Conclusions

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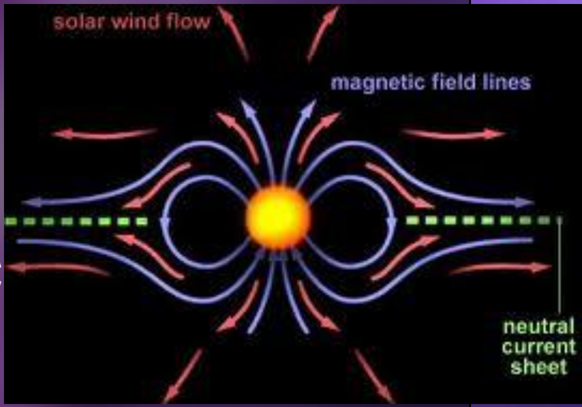
Preliminary knowledge

- ***Interplanetary Magnetic Field (IMF)*** is the Sun's magnetic field carried by solar wind in interplanetary space.
- IMF is a 3D vector : [Bx, By, Bz]
  Bx & By are parallel to the ecliptic whereas Bz is perpendicular.



- When Bz is negative, IMF points south and is anti-parallel to the geomagnetic field. This creates a door for energetic particles to enter Earth's inner magnetosphere.

Preliminary knowledge

- *The __DMSP F13 satellite__* was launched in March 1995 into a Sun synchronous, polar orbit in the 6-18 local time frame.
- We use DMSP data from two of its instruments:
  (1) Special Sensor Precipitating Electron and Ion Spectrometer (SSJ/4)
  (2) Ion Drift Meter (IDM).

Preliminary knowledge

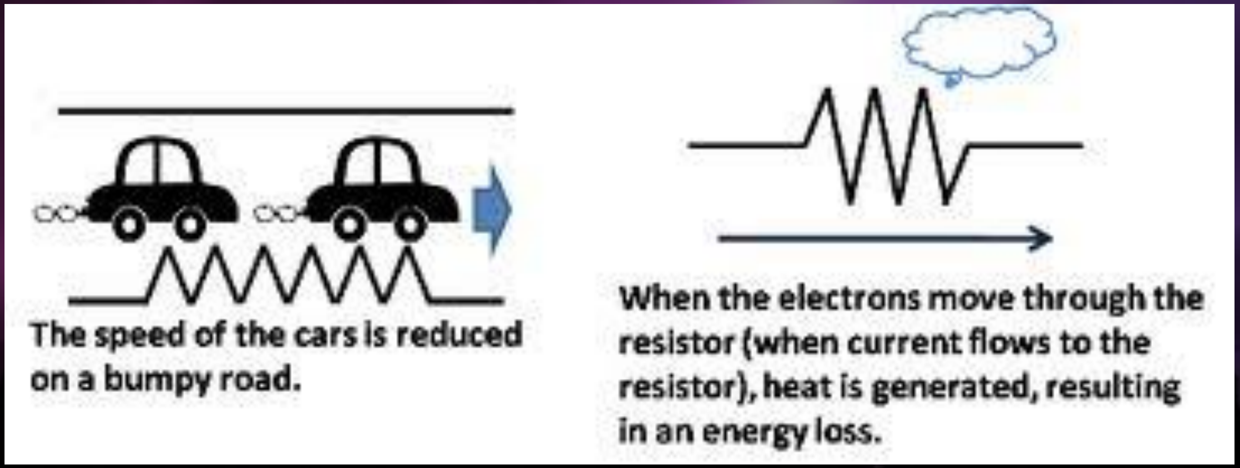
- ***Ion drift velocity (Vi)*** = (ExB)/B^2 where E is Electric Field and B is Earth's magnetic field.
- *Vy* is the horizontal cross-track ion velocity.
- *Convection Reversal Boundary (CRB)* is where Vy reverses direction.

Preliminary knowledge

- ***Weimer 2005*** is an empirical model of the high-latitude ion drift velocity. We compare Weimer 2005 Vy with IDM Vy observations.
- ***TIEGCM (Thermosphere Ionosphere Electrodynamics General Circulation Model)*** is a numeric simulation model for Earth's upper atmosphere. TIEGCM uses Weimer 2005 model.
- ***Hemispheric power (HP)*** is the spatially integrated energy flux of precipitating electrons.

Definition of Joule heating

- *Joule heating (QJ)* is the heat loss due to passage of electric current through a conductor.
- In the ionosphere, it occurs due to the friction of ions moving through neutral atoms.



Importance of Joule Heating

1. Joule heating is usually the largest heat source in high-latitude regions. During geomagnetic storms, Joule heating can also exceed the global solar heating from UV and EUV radiation [Knipp et al., Solar Physics, 2004].
2. Joule heating is the largest source of uncertainty in the energetics of the thermosphere.

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Motivation

- Figure 8 from Heelis et al. [JGR,1980] is an estimate of the relative locations of the aurora and the ion drift .
- We aim is to improve the parameterization of the aurora in the TIEGCM so that the resulting Joule heating is approximately correct.

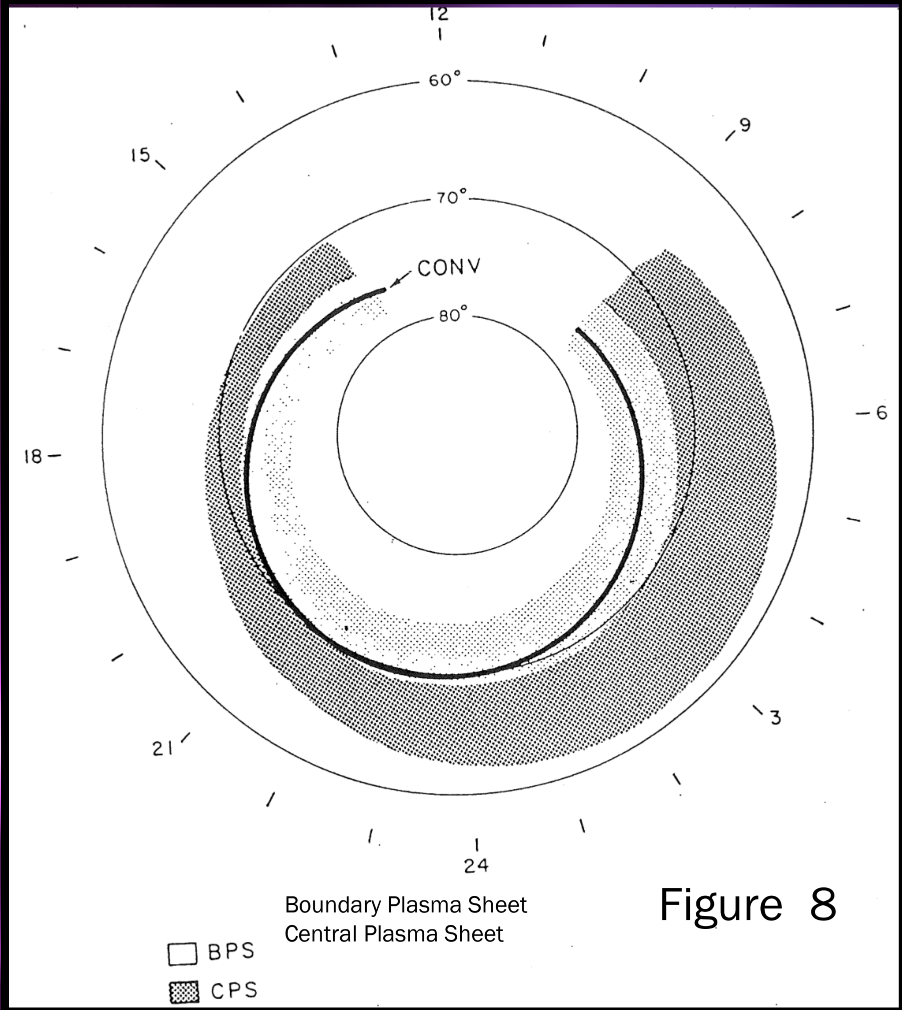

Figure 8

Framework for calculation & analysis

- $Total\ Joule\ heating$
  $\approx Pedersen\ Conductance \times Electric\ Field^2$

- $Particle\ Joule\ heating$
  $\approx Auroral\ Pedersen\ Conductance \times Electric\ Field^2$

- $Total\ Joule\ heating$
  $= \sqrt{Particle\ Joule\ heating^2 +\ EUV\ and\ UV\ Joule\ heatng\ ^2}$

II. Research Strategy

Framework for calculation & analysis

- Need to analyze the components of Joule heating.

- Joule Heating
  - Pedersen Conductance
    - Auroral Pedersen Conductance
      - Electron Energy-measured by SSJ4
      - Electron Energy Flux-measured by SSJ4
    - EUV and UV Pedersen Conductance
  - Electric Field^2
    - Vy (we can safely ignore Vx because DMSP F-13 is in a dwn dusk orbit)-measured by IDM

Goals

1. Analyze the local time variation in Joule heating, i.e. compare Joule heating during dawn, dusk, midnight and noon.
2. Study the spatial distribution of Joule heating In particular, compare Joule heating in the polar cap (anti-sunward ion flow) with equatorward Joule heating (sunward ion flow).
3. Analyze the relative location of electron energy flux with respect to Vy.
4. Quantitatively compare hemispheric power, particle Joule heating, and total Joule heating for different IMF values,.

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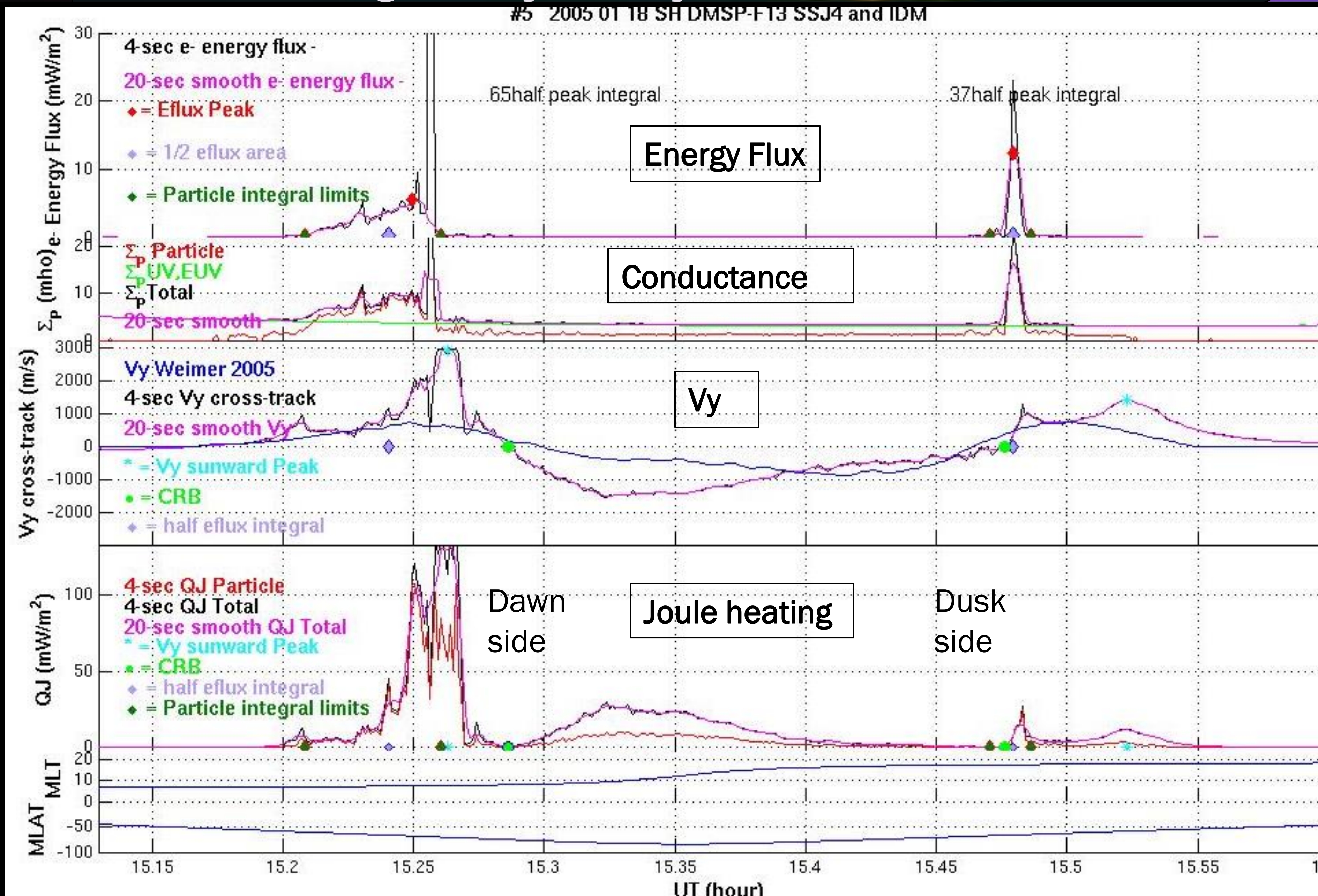
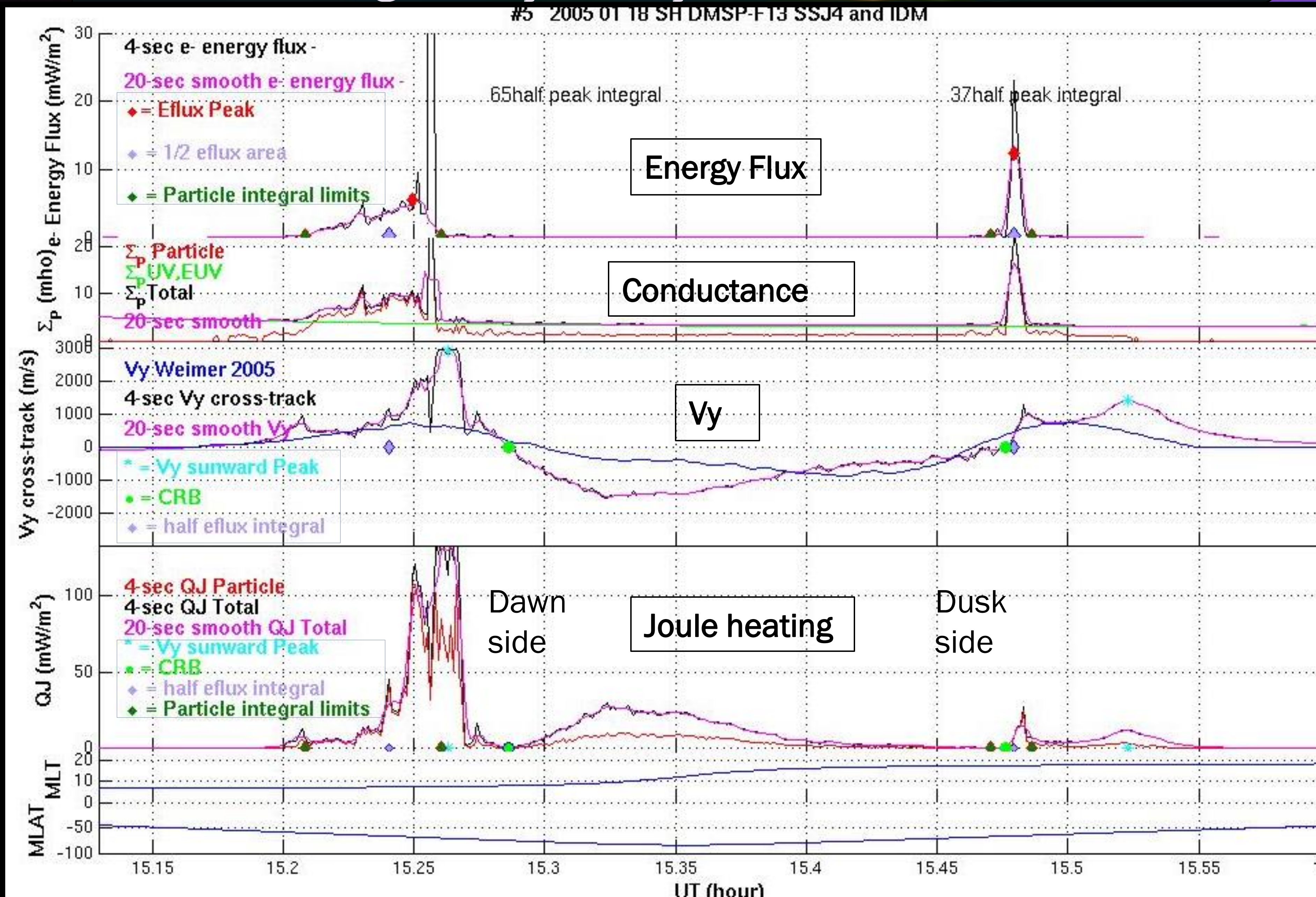
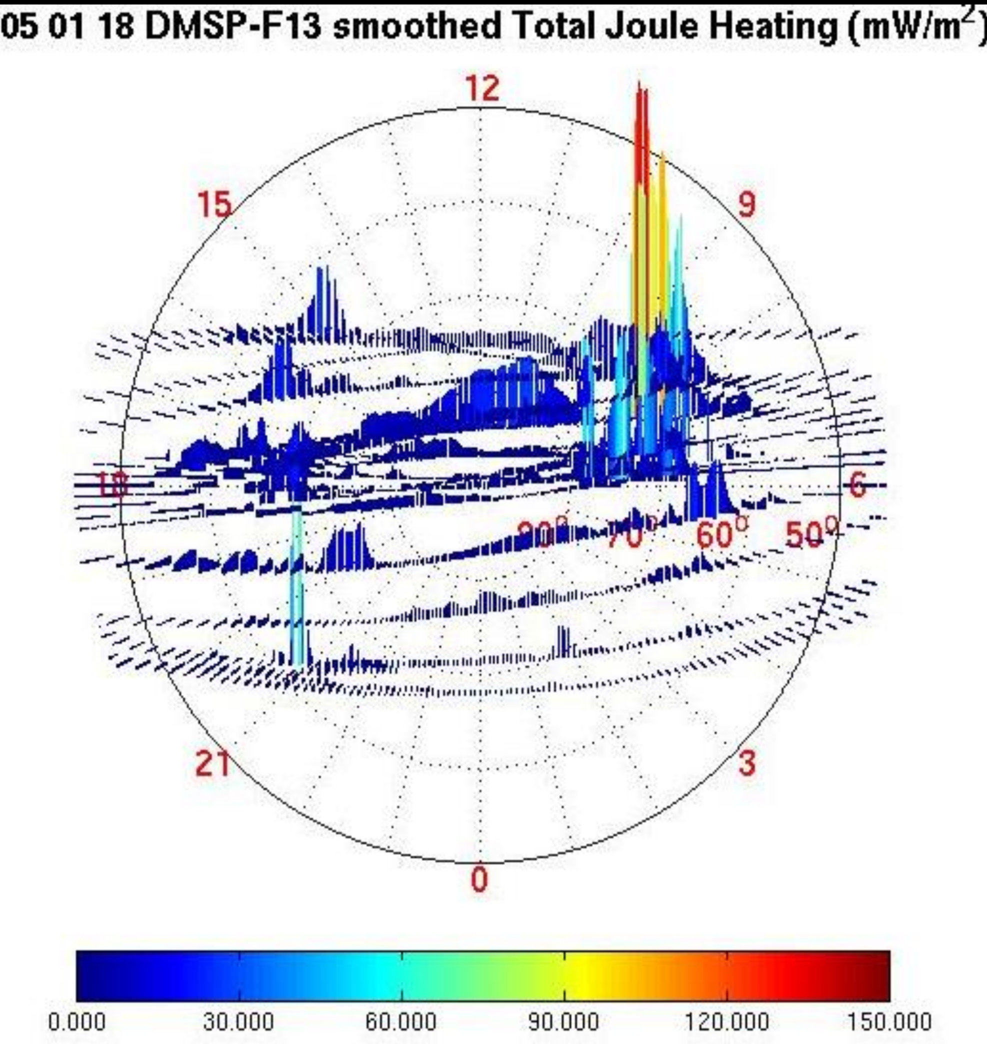
Single day analysis: One Orbit

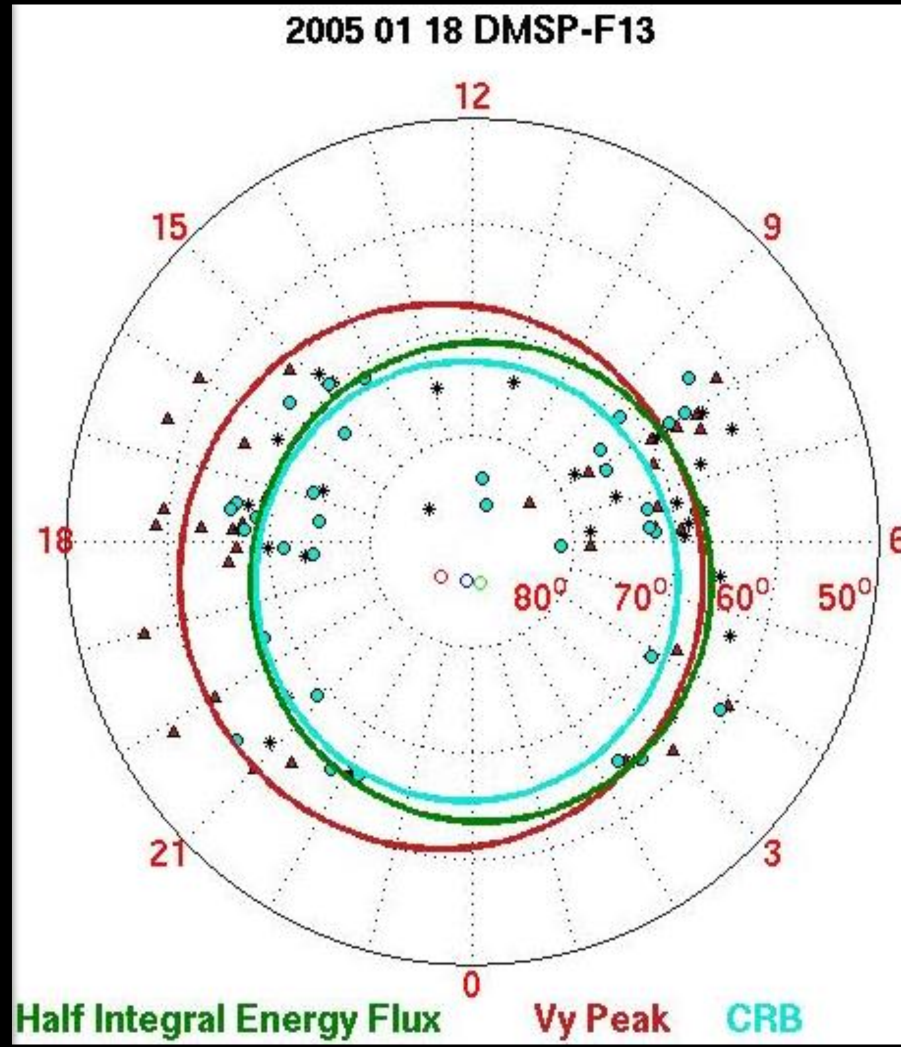


Single day analysis: One Orbit

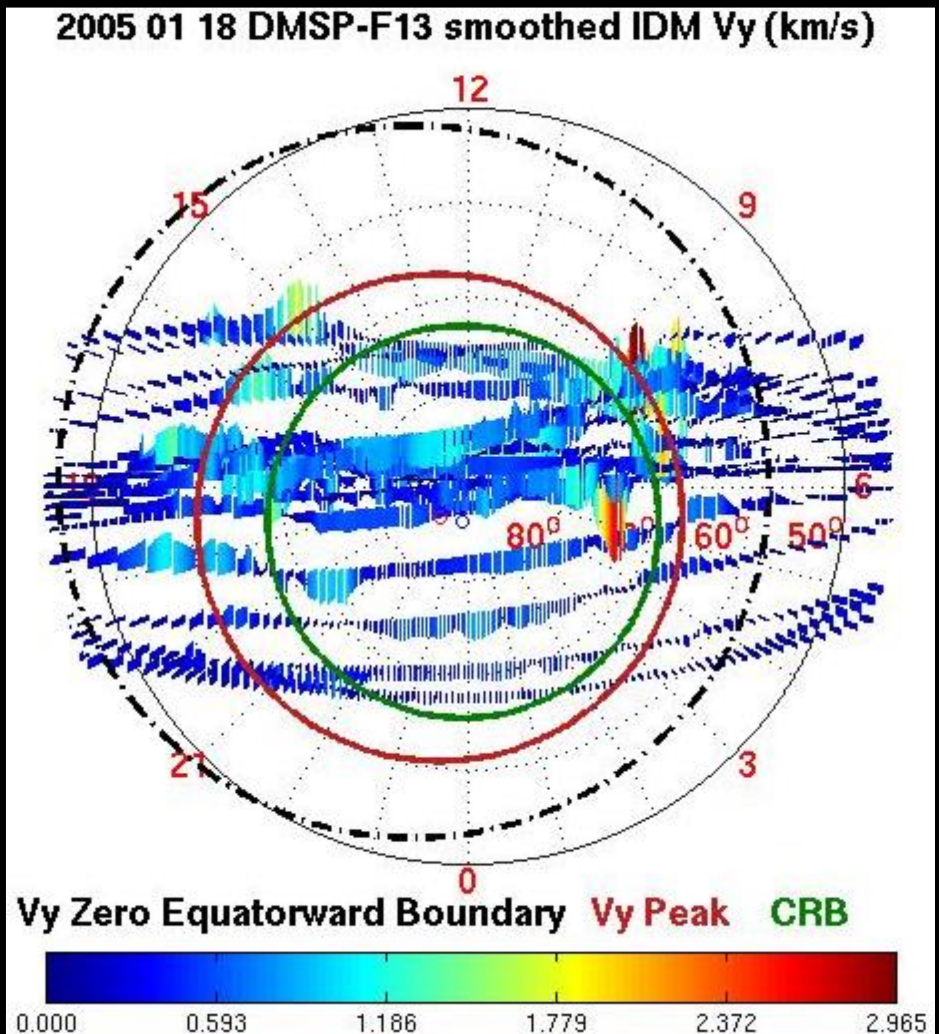


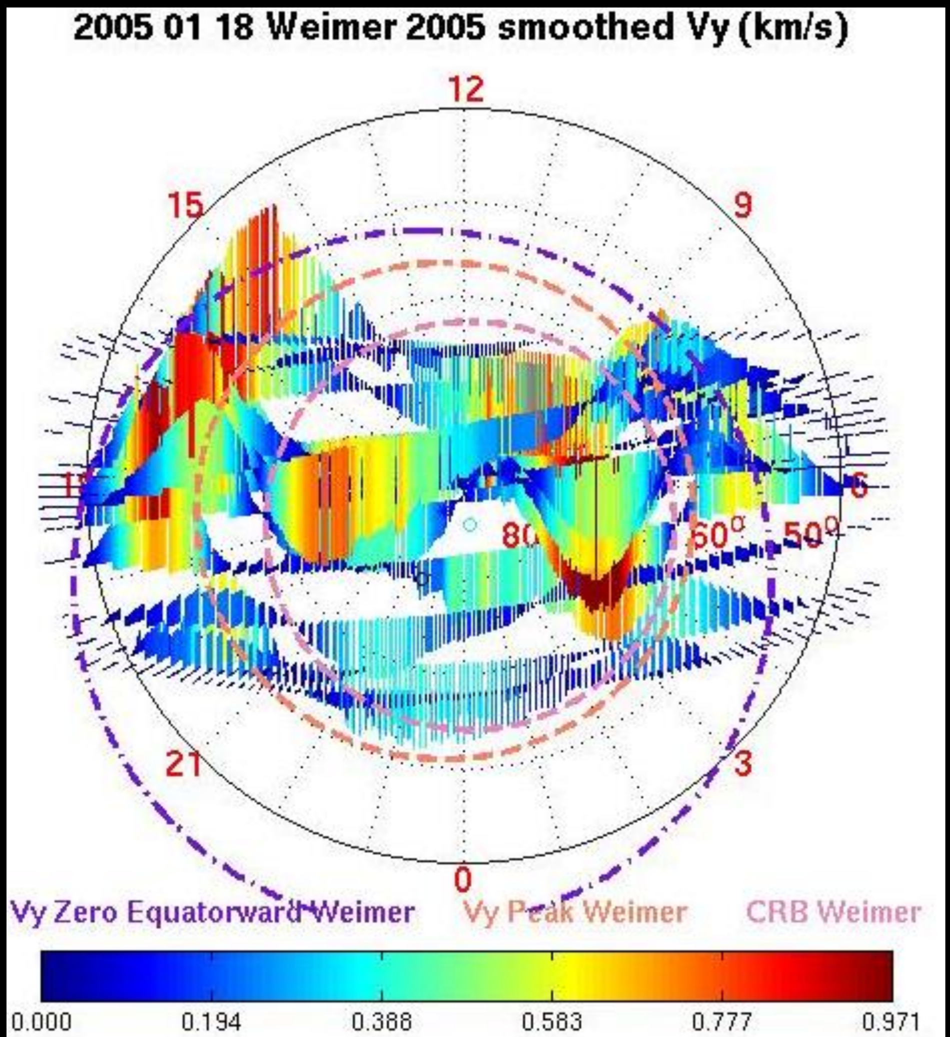
Single day analysis: Format for All Orbits





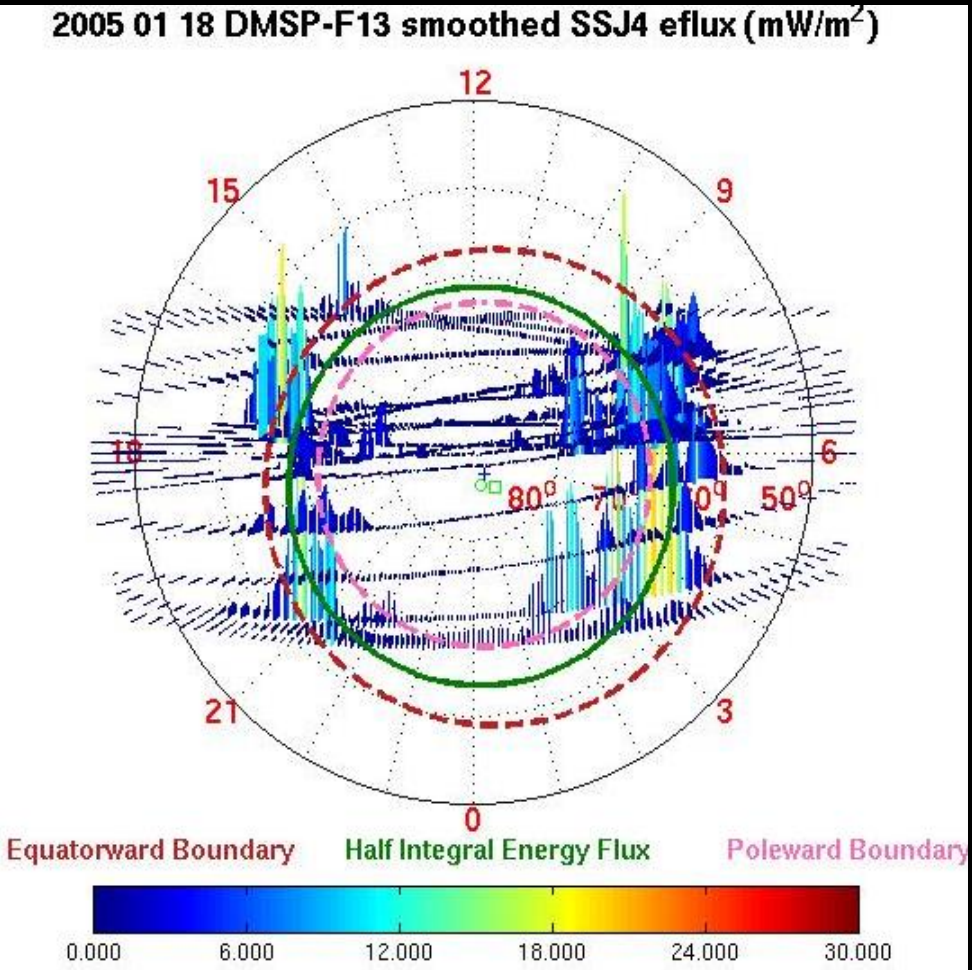
Single day analysis: All Orbits

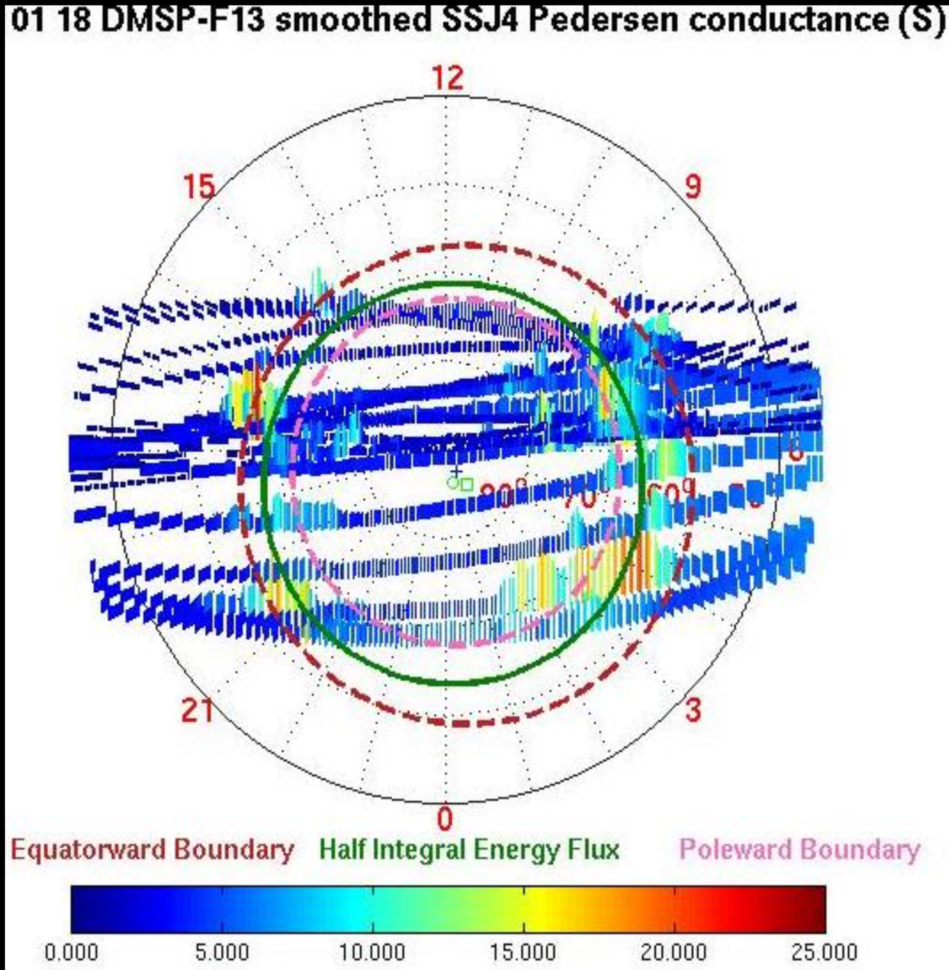




III. Programming methodology & results

Single day analysis: All Orbits

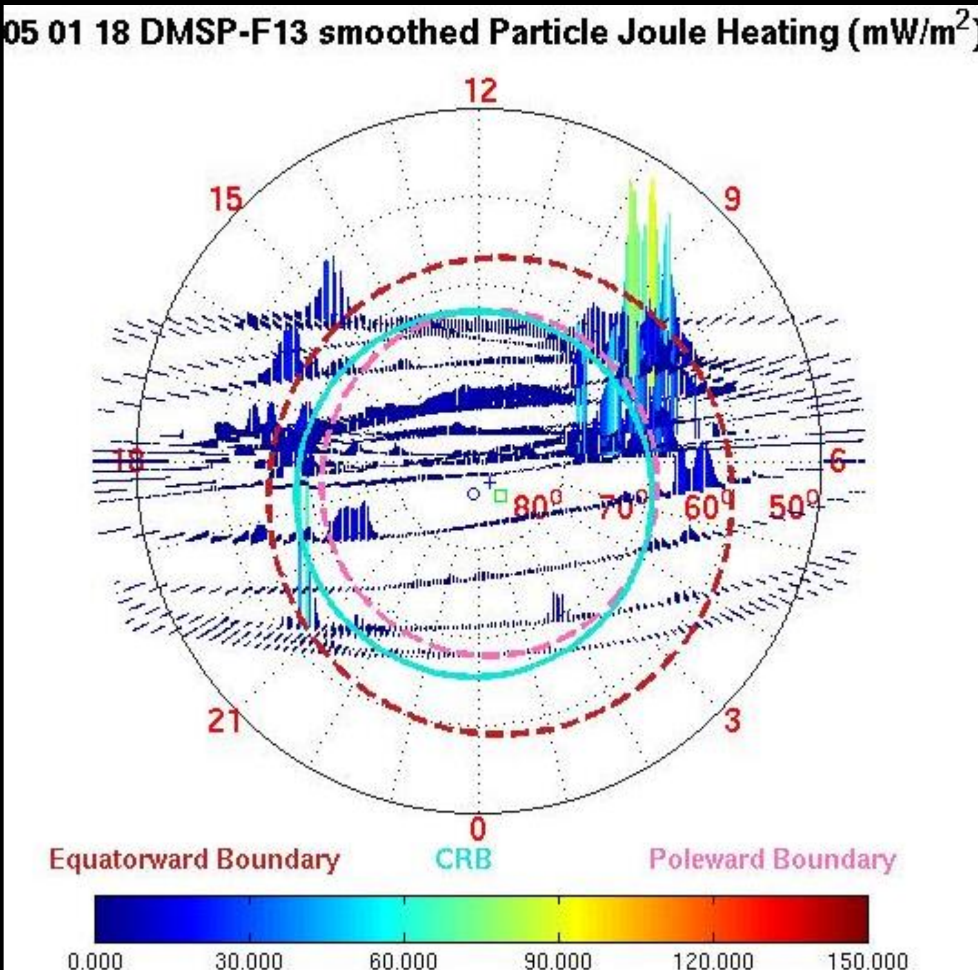


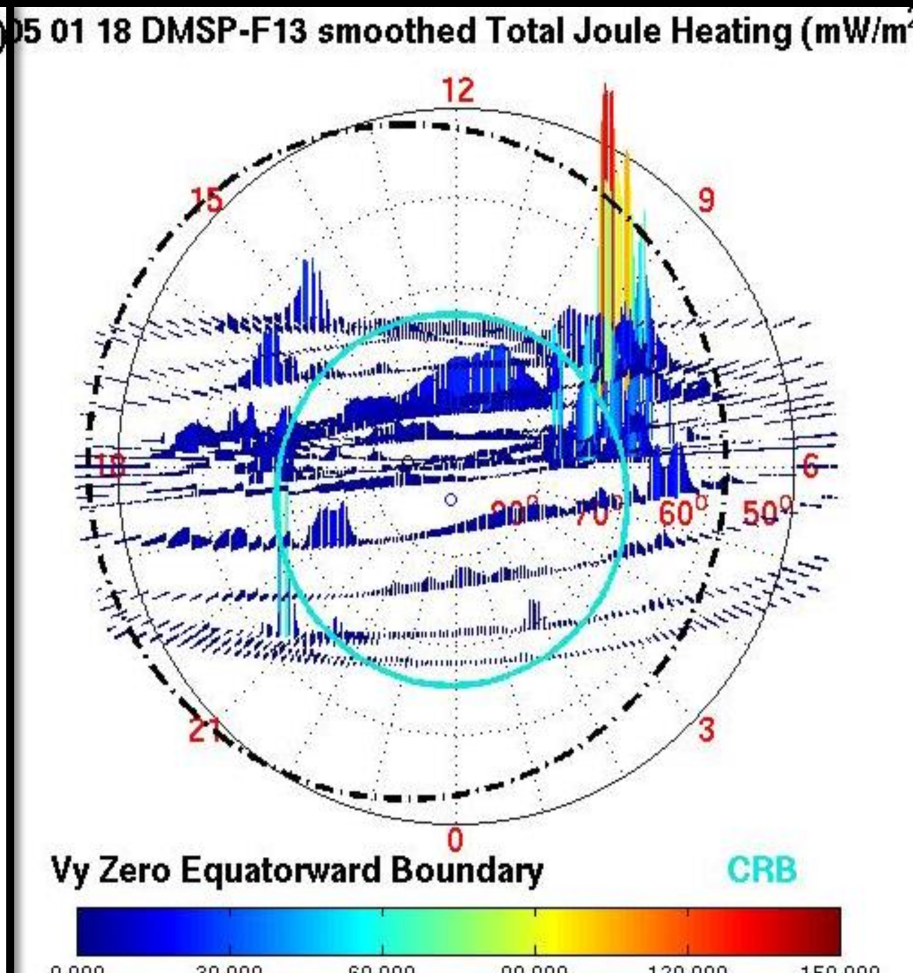


Particle Joule heating and Hemispheric Power are calculated for the region between the Poleward and Equatorward boundary.

III. Programming methodology & results

Single day analysis: All Orbits

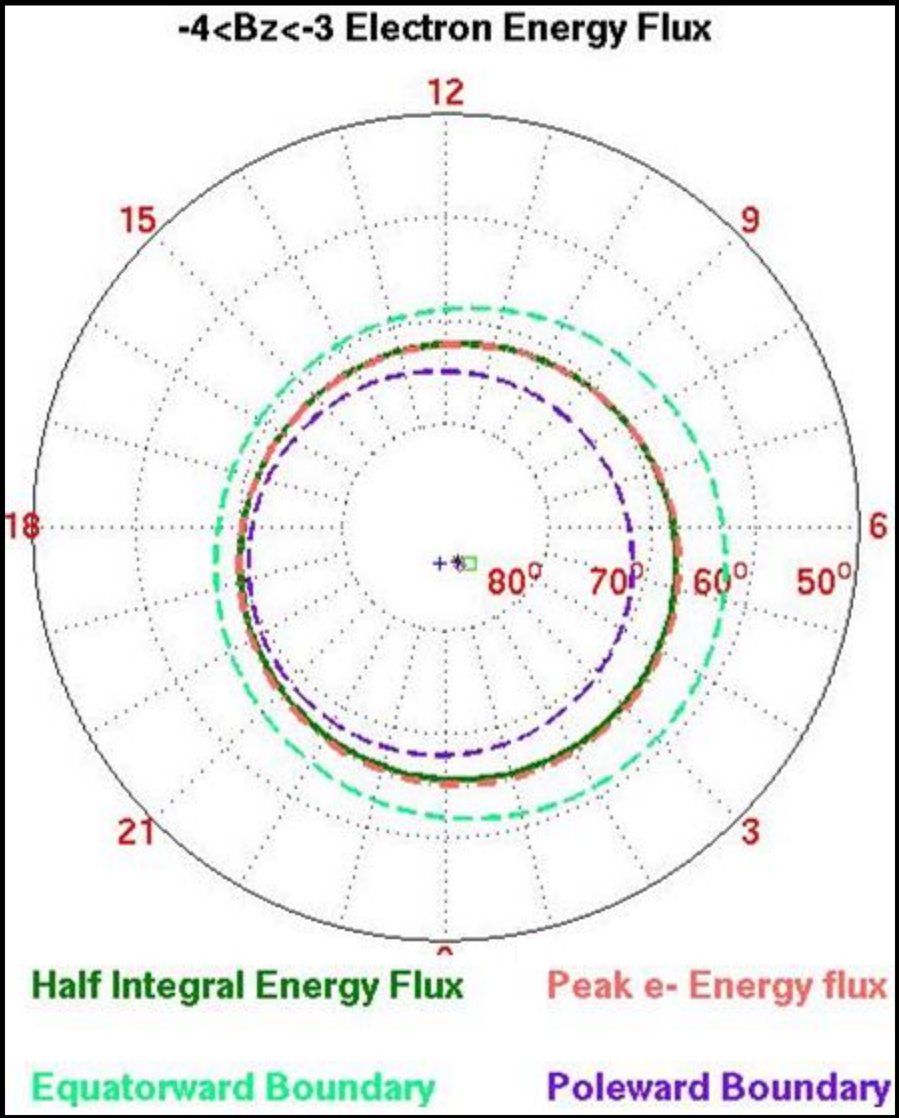


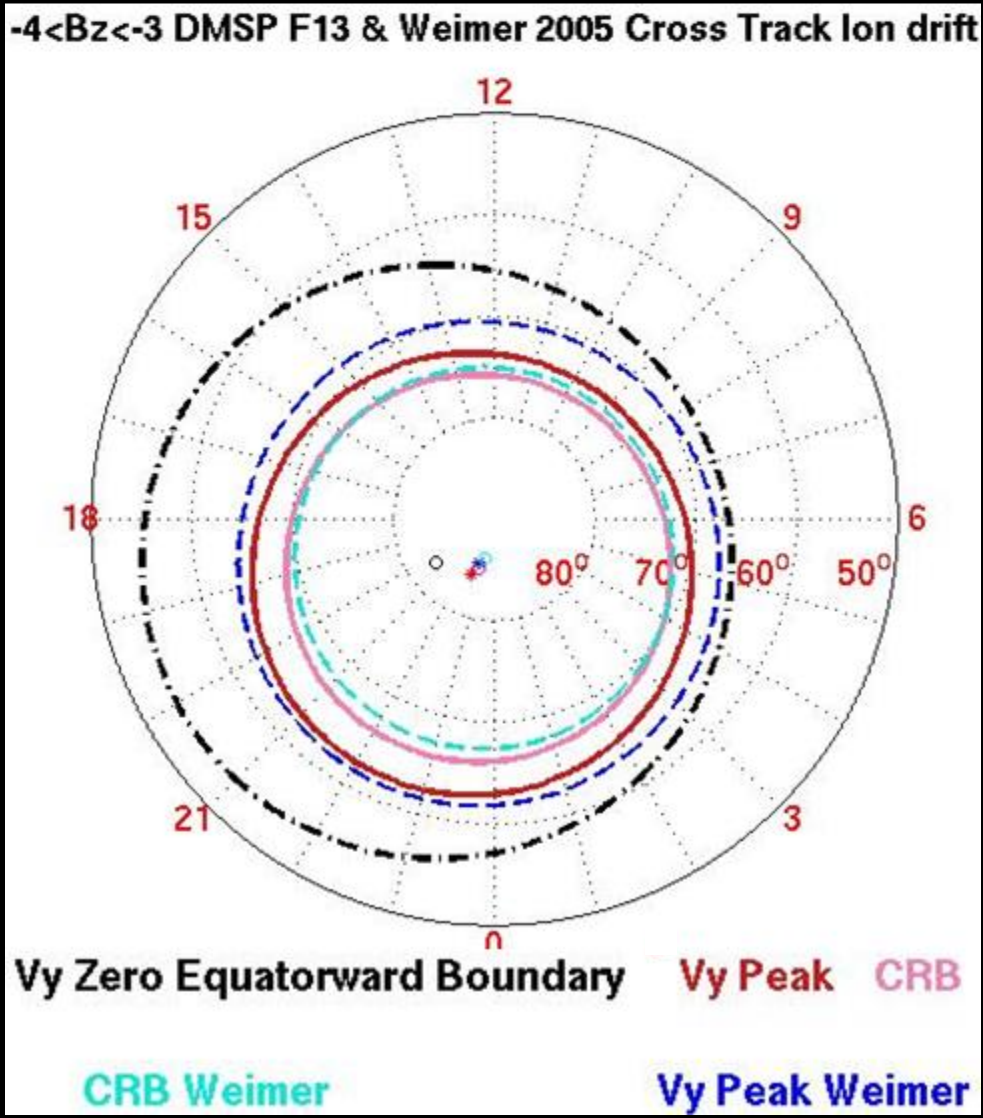


Region inside CRB circle has *poleward Joule heating* due to anti-sunward ion flow, whereas the region between Vy zero Equatorward Boundary and CRB has *equatorward Joule heating* due to sunward ion flow .

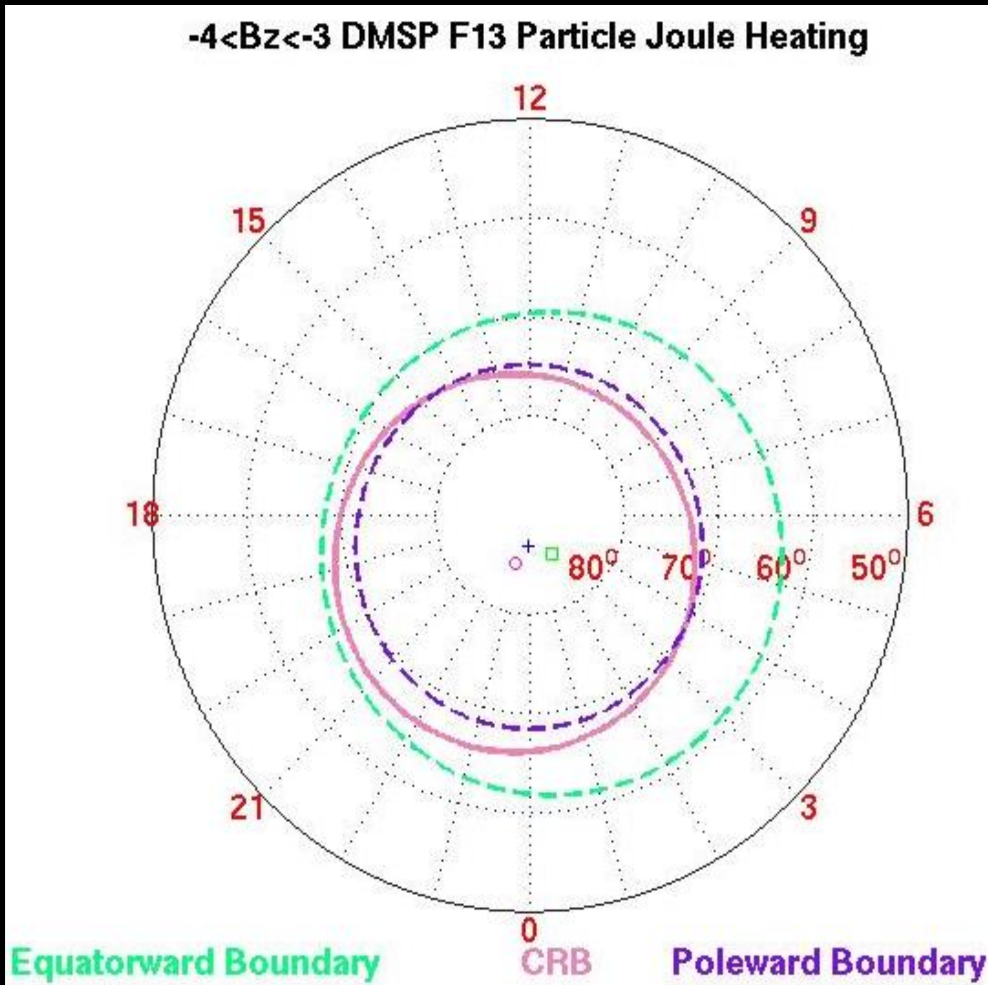
III. Programming methodology & results

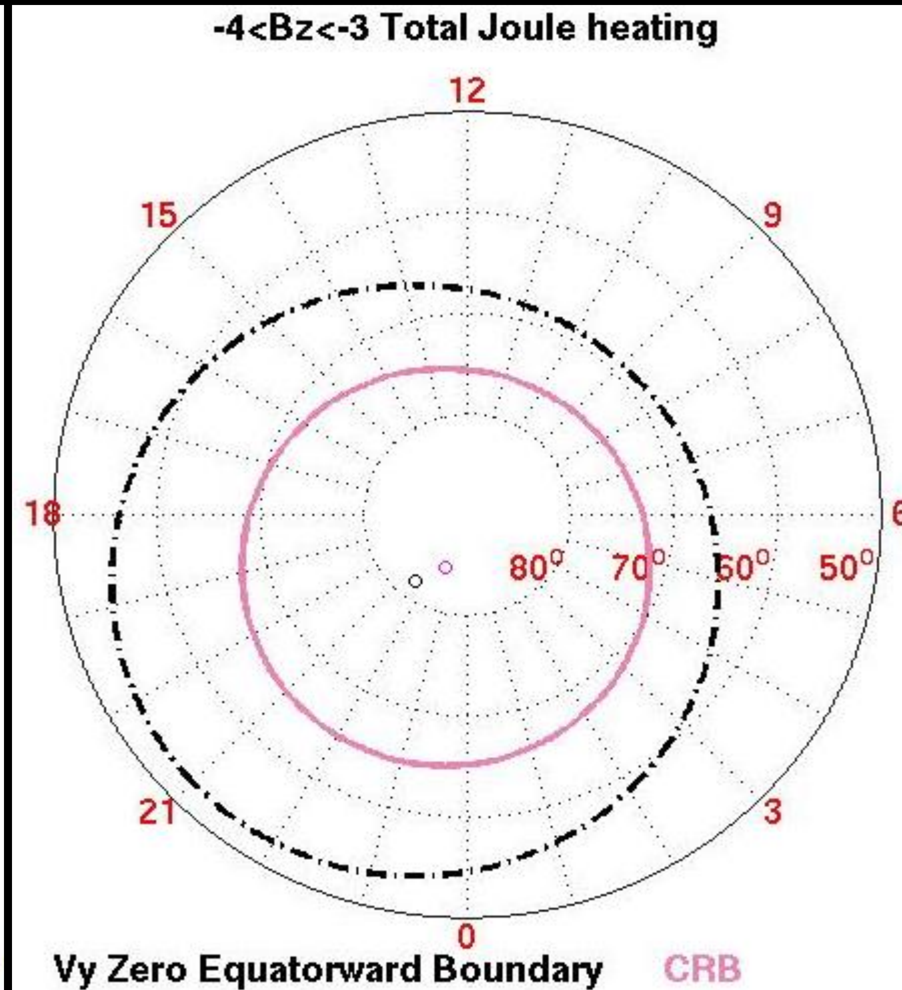
Multiple day results: Jan-June 2005





Multiple day results: Jan-June 2005

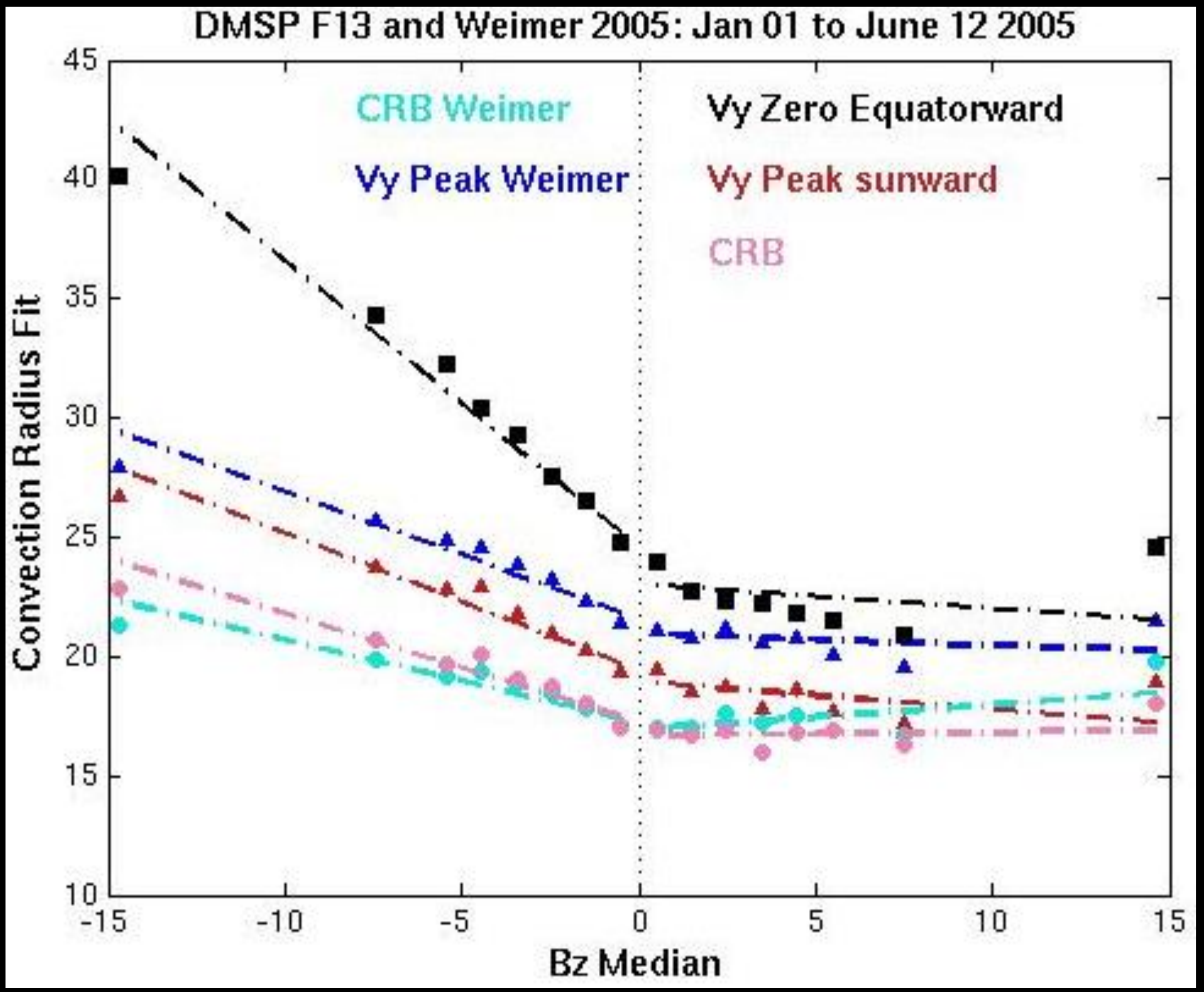




Area for particle Joule heating is bigger on the dawn side compared to the dusk side.

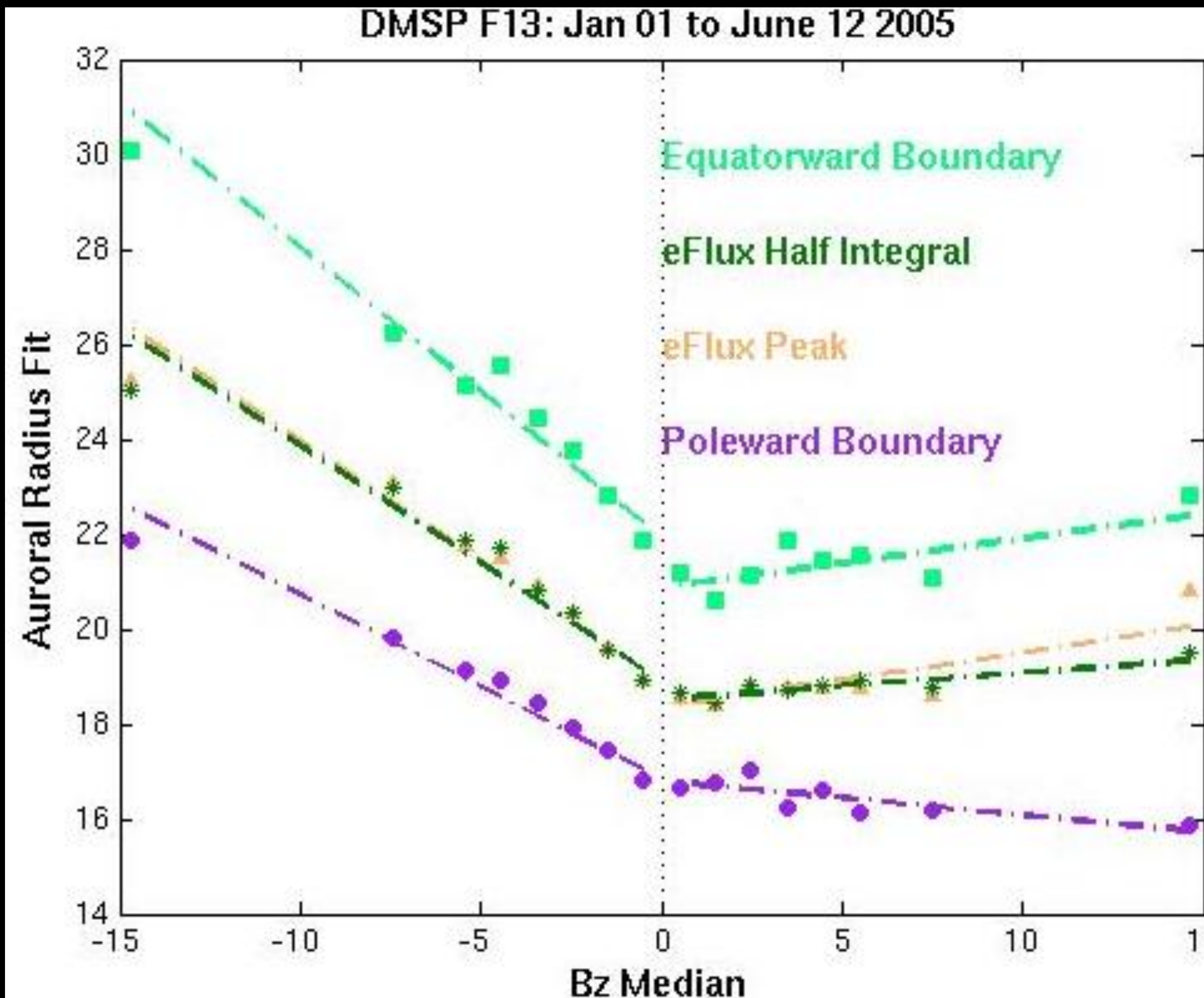
Area for Total Joule heating is bigger on the dusk side compared to the dawn side.

Multiple day results: Jan-June 2005



Difference between radii of **CRB** and **Vy Zero Equatorward Boundary** increases as Bz decreases. *This means area for equatorward Joule heating increases as Bz becomes more negative. Also, as Bz becomes more negative , CRB radius increases and so does the area for poleward Joule heating .*

Multiple day results: Jan-June 2005



Difference between the radii of **Equatorward** and **Poleward** Boundaries increases with the absolute value of Bz.

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Aha, finally ☺

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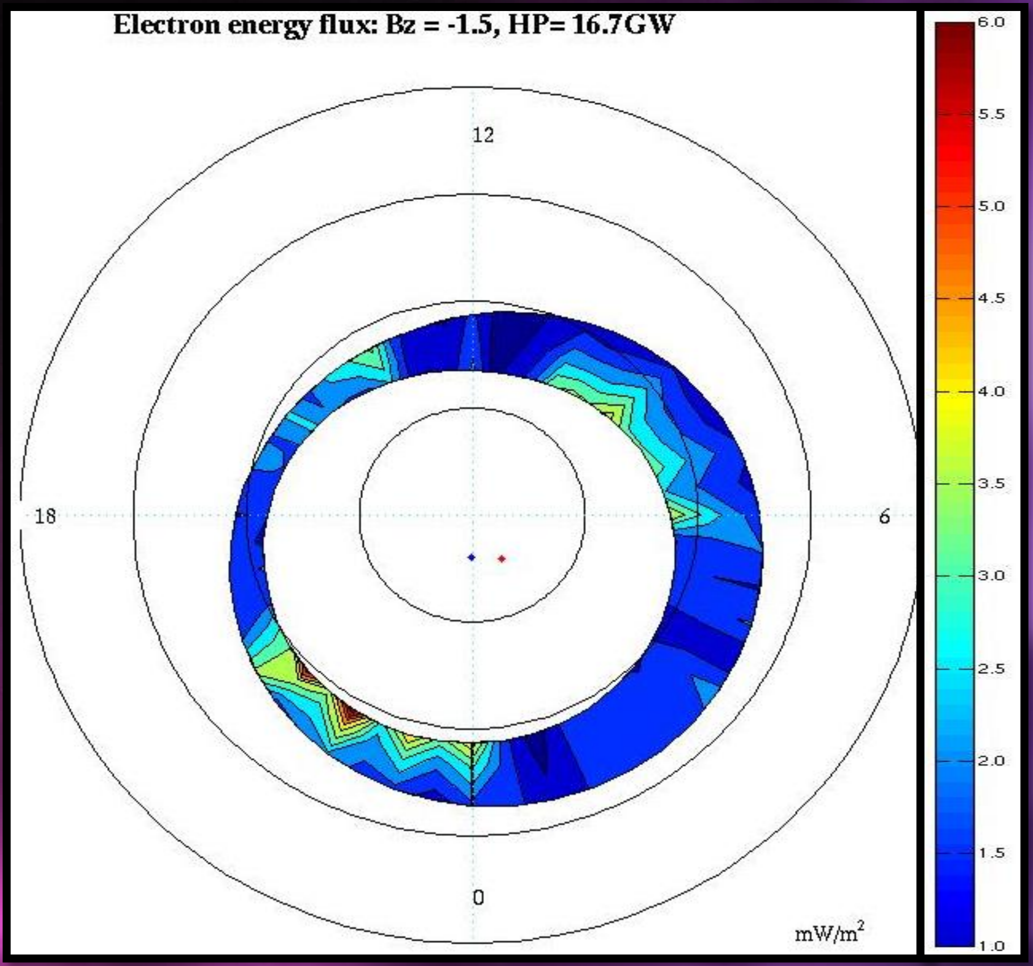
V. Conclusions

IV. Key Findings: Dawn Vs. Dusk

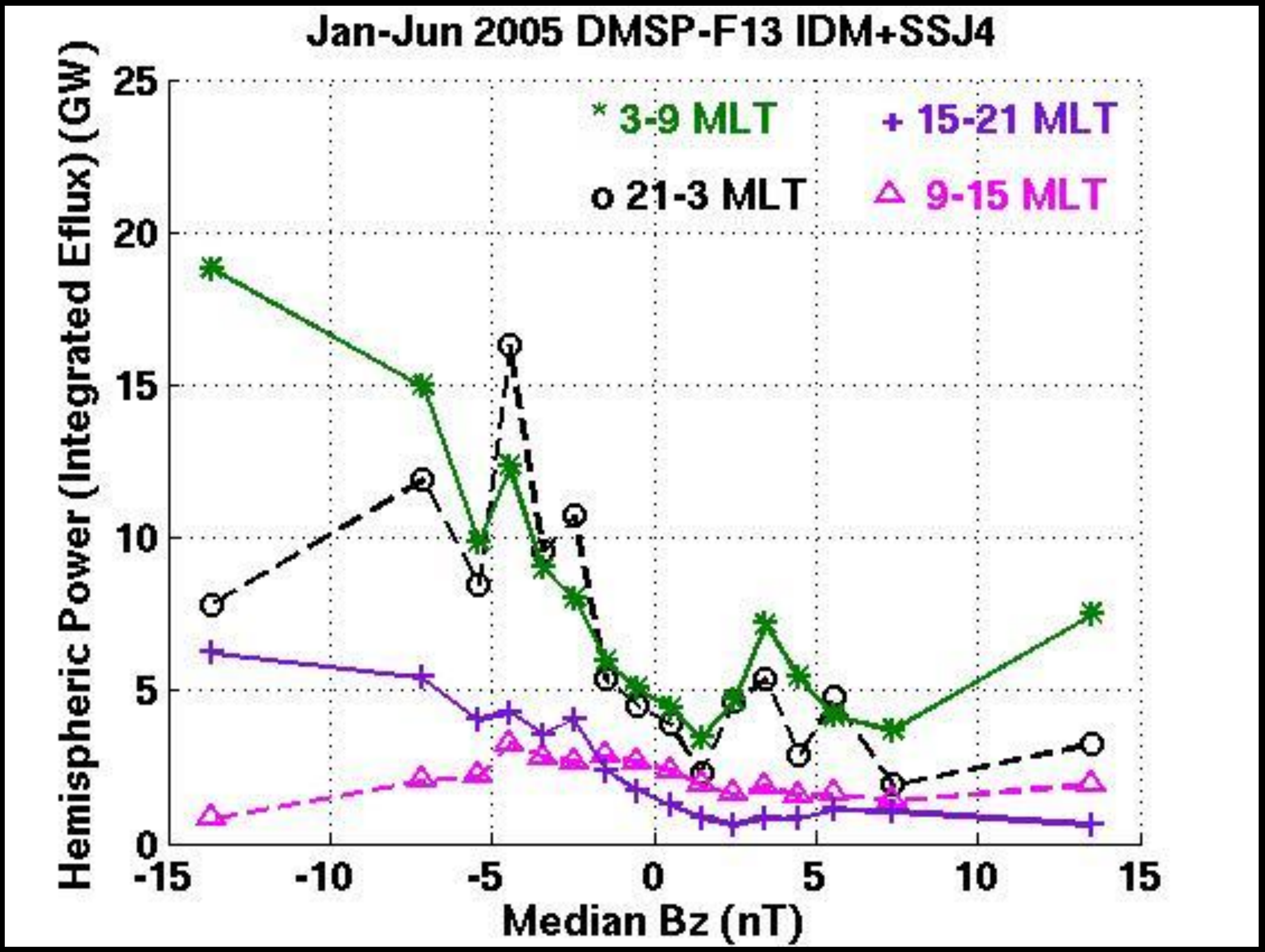
Electron Energy Flux and Hemispheric Power



Area for Hemispheric Power is mostly bigger on the dawn side compared to the dusk side.

IV. Key Findings: Dawn Vs. Dusk

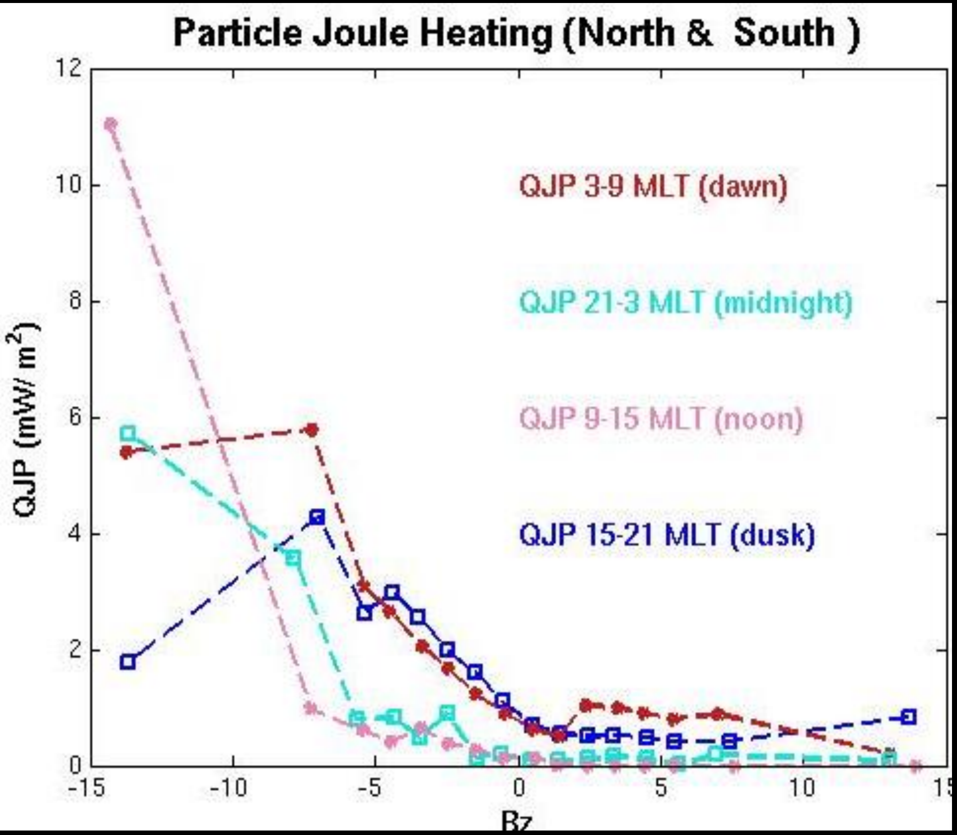
Hemispheric power

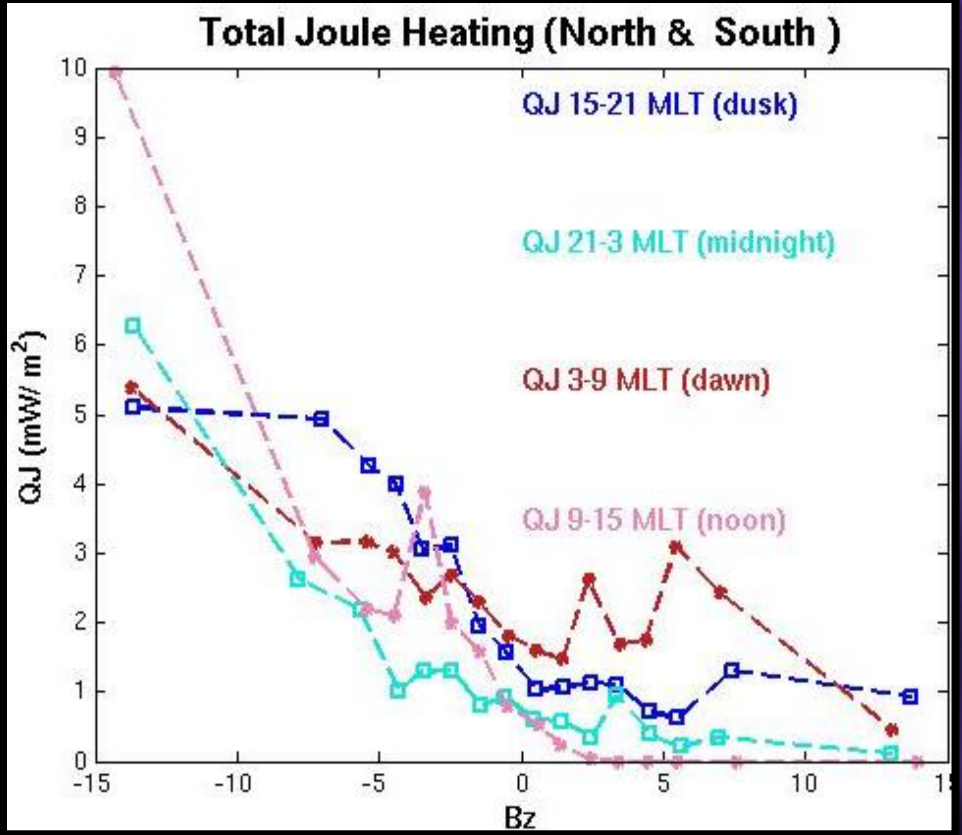


HP is highest on the **dawn side**, and HP for the **dusk side** is relatively small.

IV. Key Findings: Dawn Vs. Dusk

Average Particle & Total Joule heating



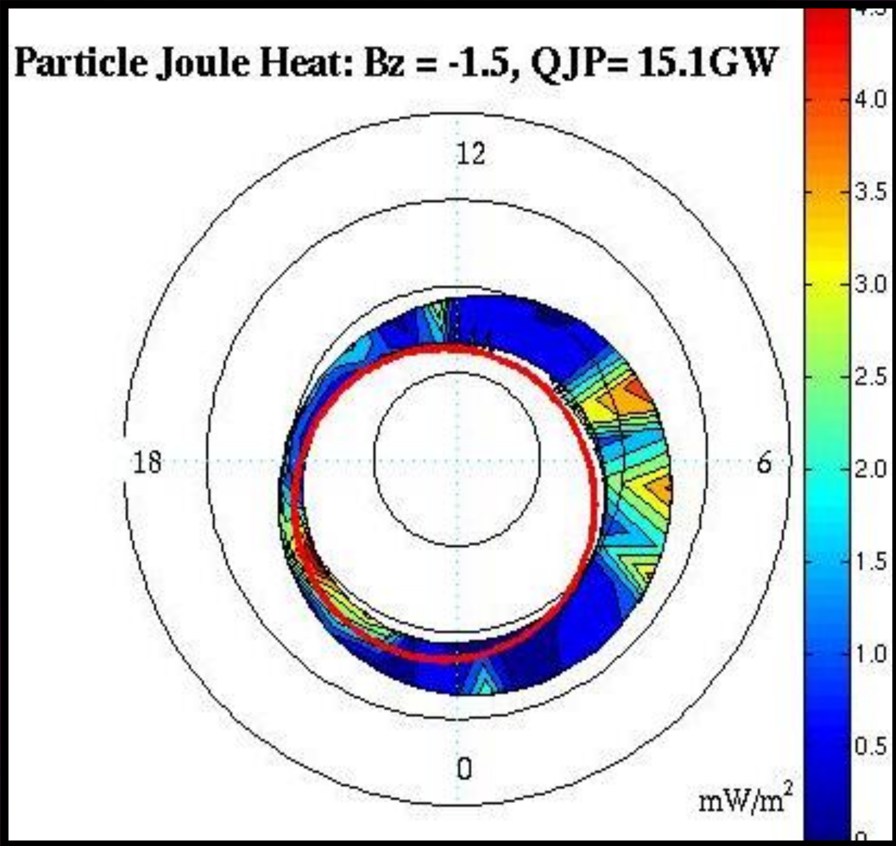


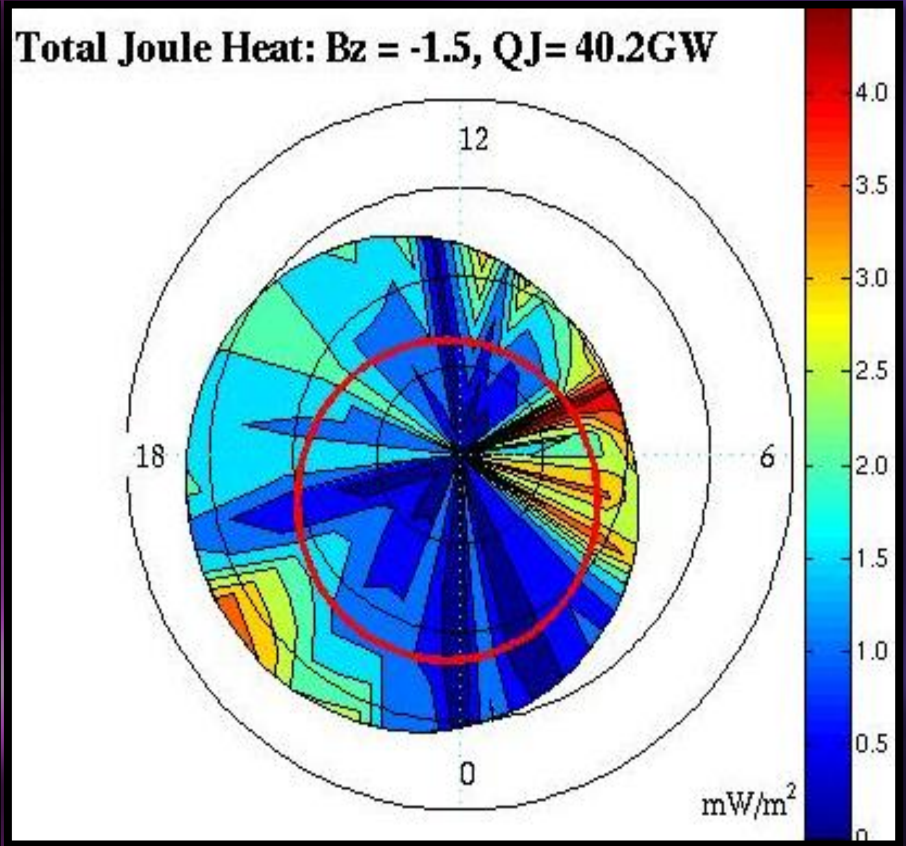
Average particle Joule heating on dawn side is almost equal to average particle Joule heating on dusk side.

Average Joule heating for dawn side is greater than that for dusk side when Bz>o, and vice versa for Bz<o.

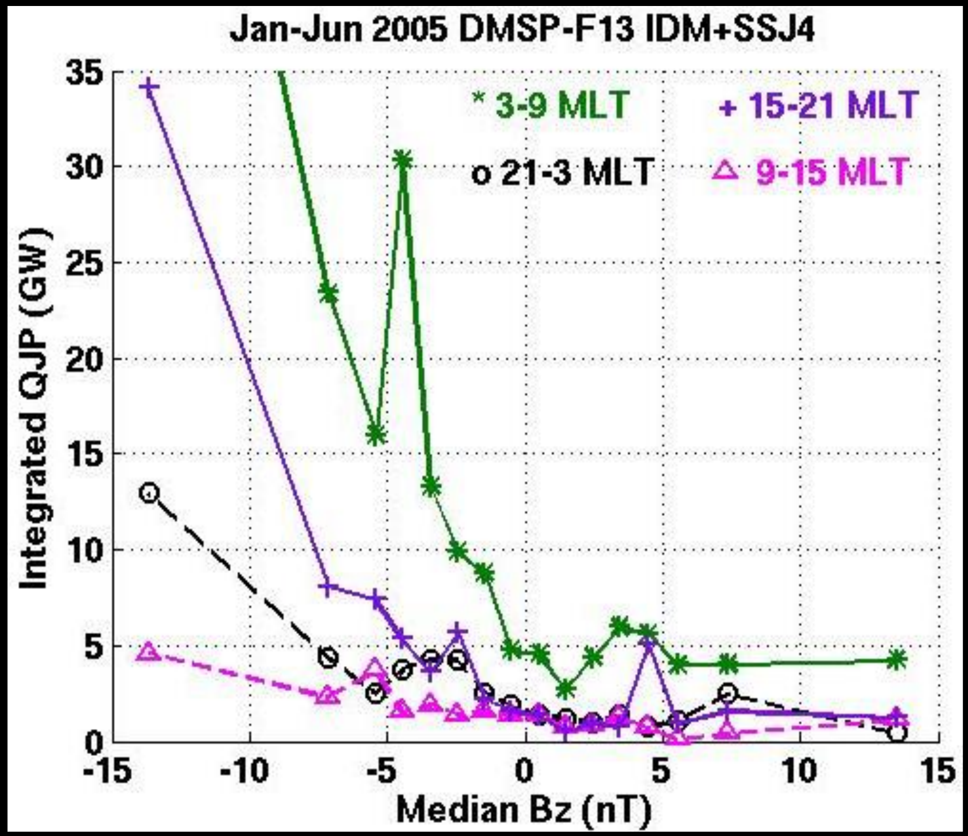
IV. Key Findings: Dawn Vs. Dusk

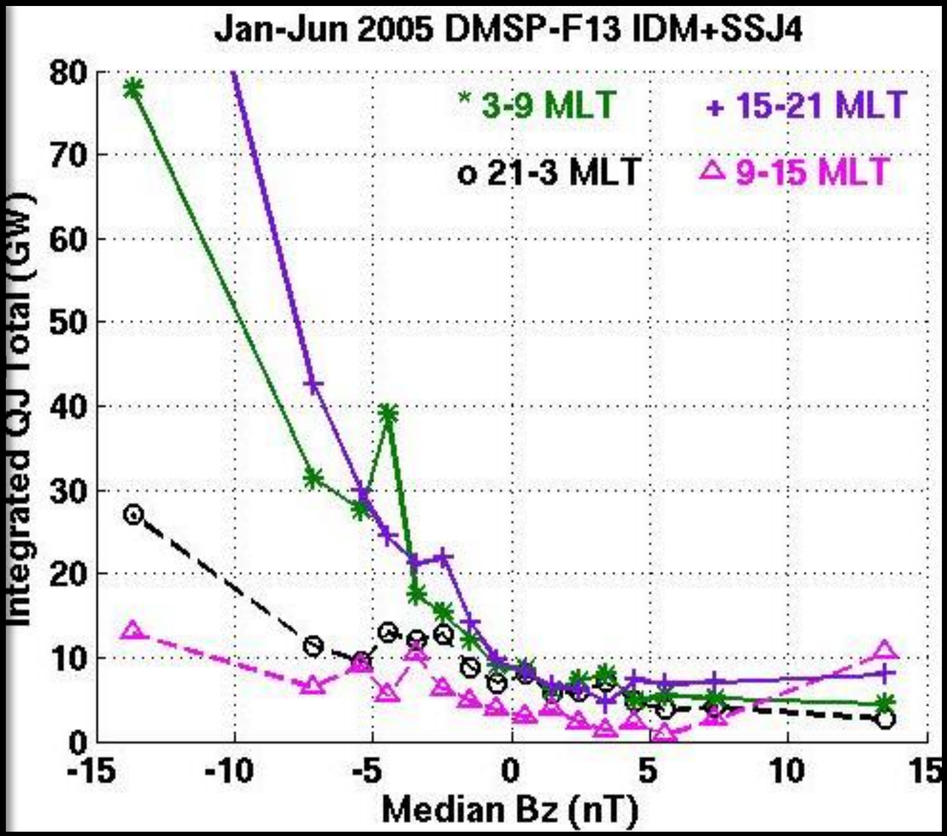
Area for Particle & Total Joule heating





Area Integrated Particle & Total Joule heating

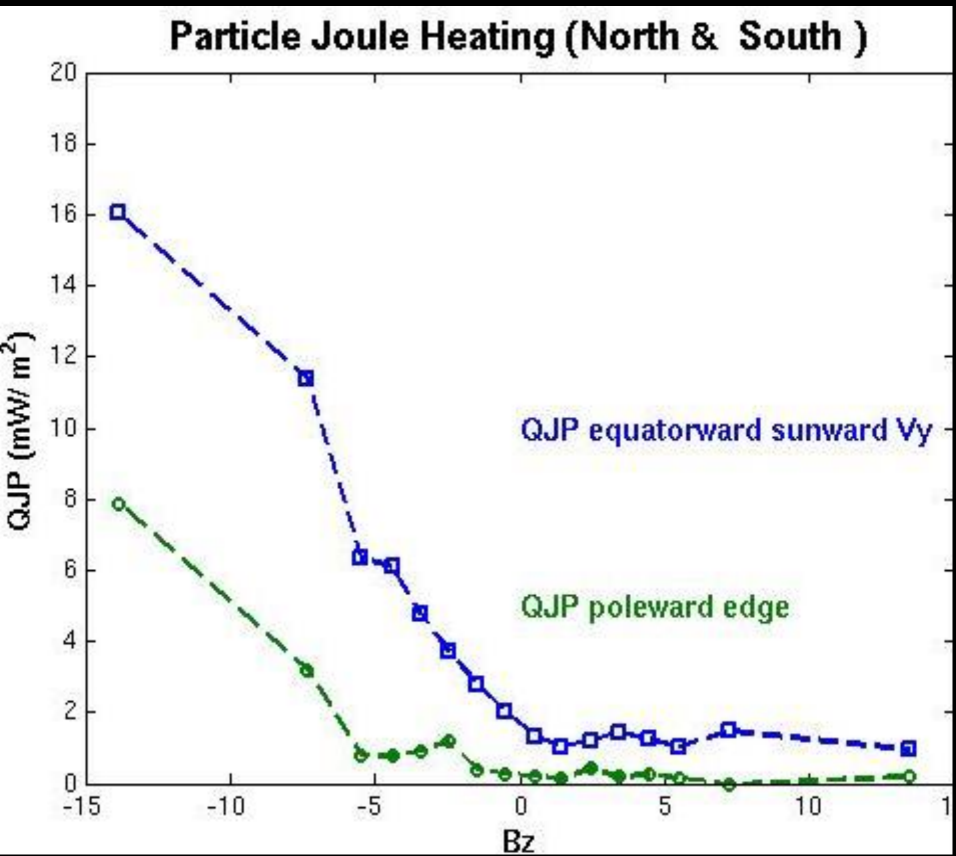


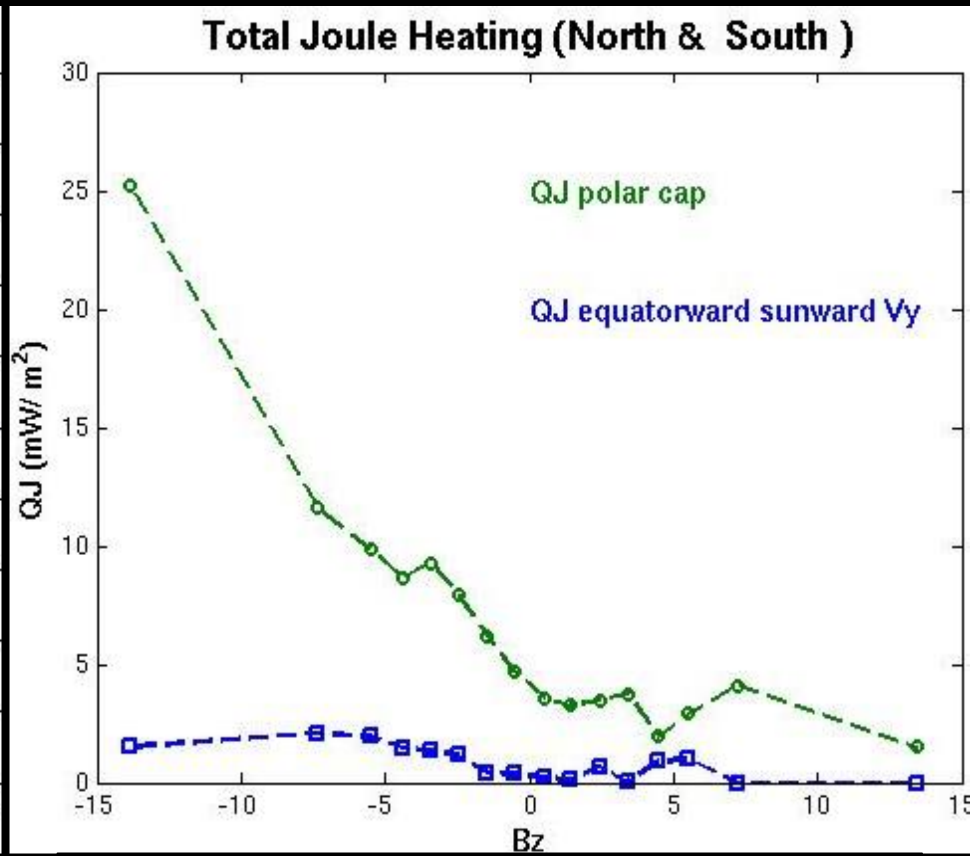


Integrated particle Joule heating is higher on the dawn side than on the dusk.

Integrated QJ on the dawn side is almost equal to QJ on the dusk side.

Average Particle & Total Joule heating



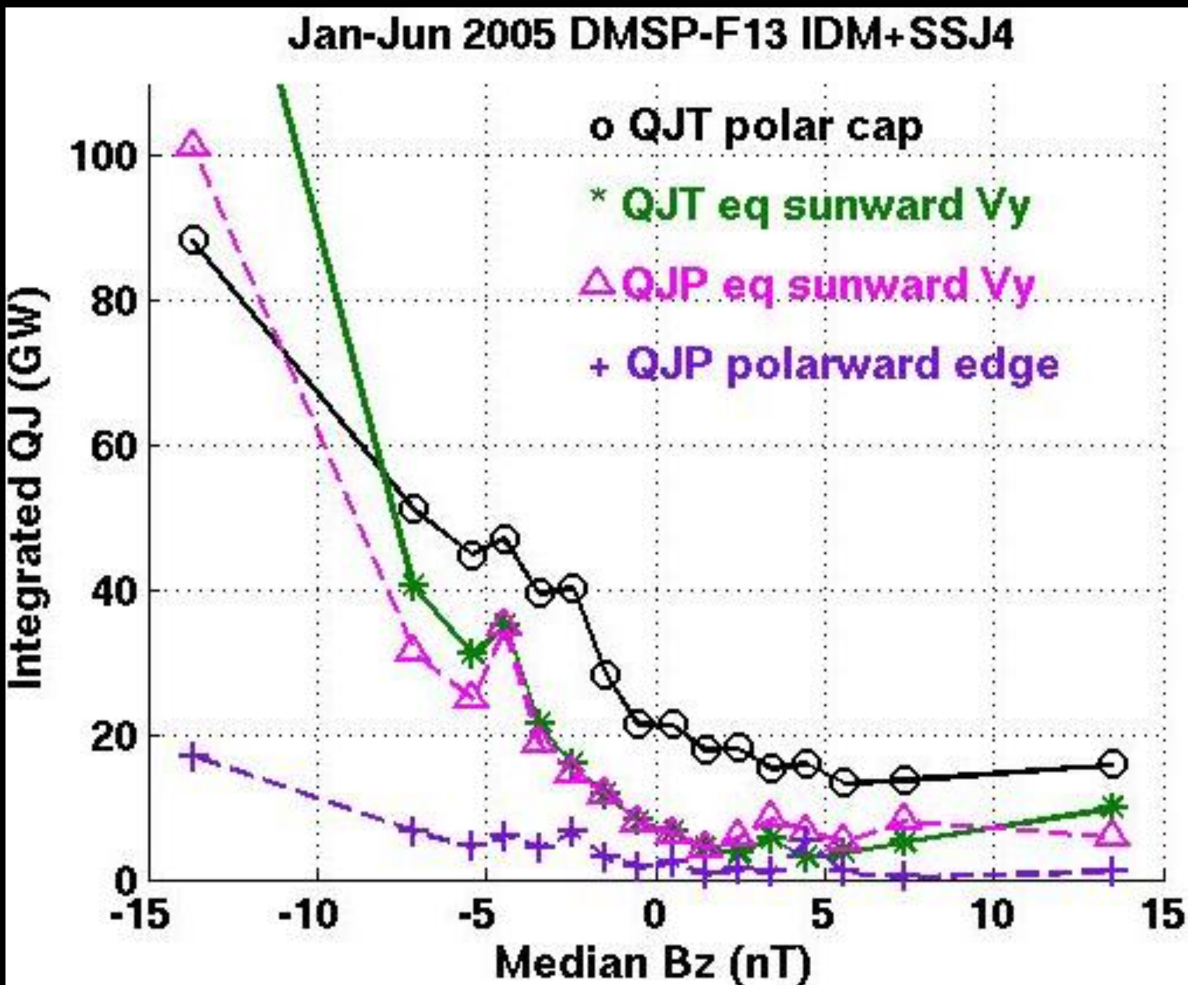


Average equatorward particle Joule heating for sunward Vy is greater than average poleward particle Joule heating.

Average Joule heating in the polar cap for anti-sunward Vy is greater than the average equatorward Joule heating .

IV. Key Findings: Equatorward Vs. Poleward

Area Integrated Particle & Total Joule heating



- Integrated QJ in the polar cap is more than integrated equatorward QJ for sunward Vy.
- Integrated equatorward QJP for sunward Vy is more than integrated poleward QJP.
- On the equatorward side, QJP is mostly equal to QJ, indicating the importance of the auroral Pedersen conductance.

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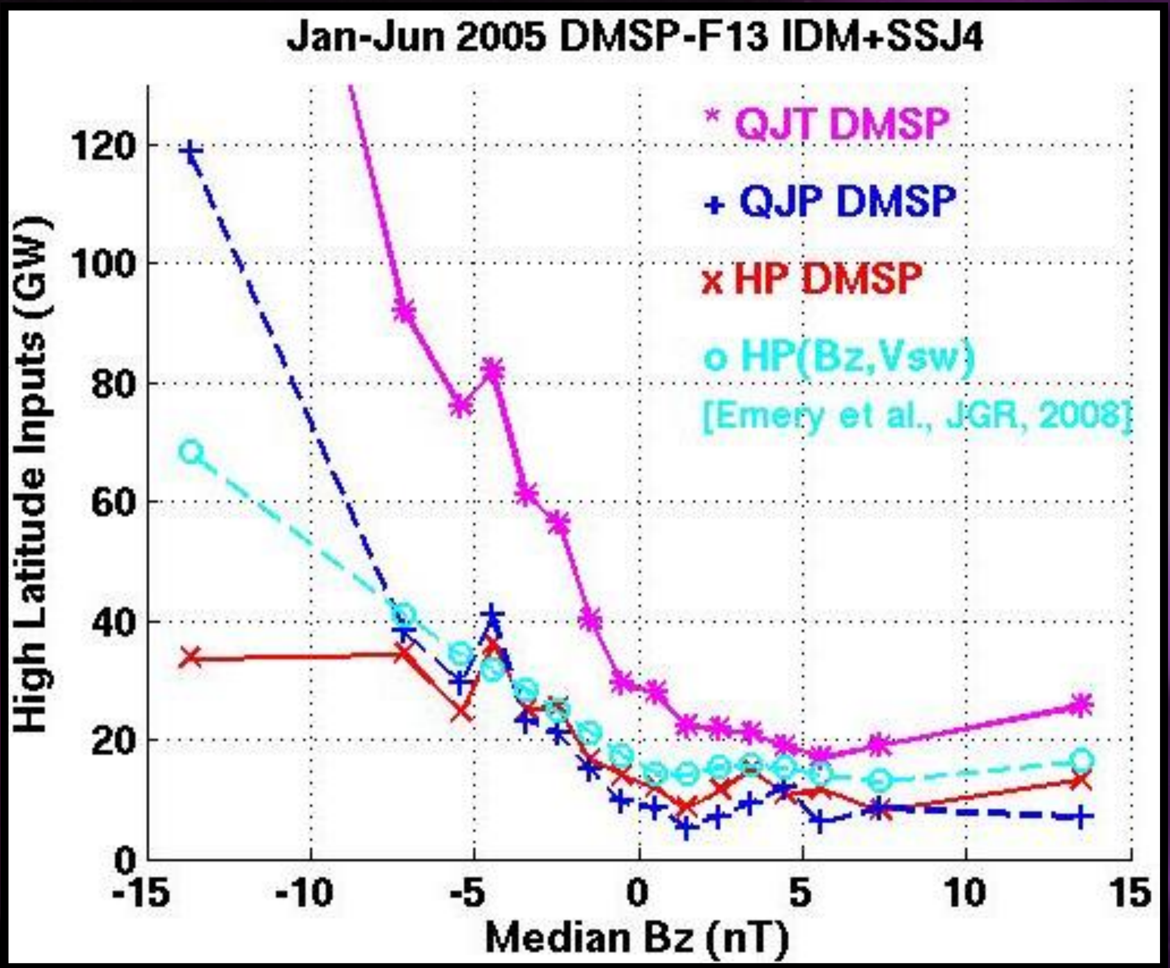
Integrated Joule heating Vs. Hemispheric Power



- Integrated total Joule heating is much higher than Hemispheric Power.
- Integrated Particle Joule heating has almost the same magnitude as Hemispheric Power .

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Conclusions

Particle Joule Heating (QJP)	Total Joule Heating (QJ)
Average QJP: **Mostly, Dawn side≈ Dusk side.** **Integrated QJP:** **Dawn side>Dusk side since dawn area is larger than dusk area**	**Average QJ:** when Bz>0, Dawn side>Dusk side when Bz<0, Dawn side<Dusk side **Integrated QJ:** Dawn side ≈ Dusk side although dusk area is mostly greater than dawn area
Average QJP: **Equatorward>Poleward.** **Integrated QJP:** **Equatorward>Poleward.** **QJP≈HP**	**Average QJ:** Poleward (anti-sunward Vy)>Equatorward (sunward Vy) **Integrated QJ: QJ>>HP** Poleward>Equatorward. On the equatorward side, QJP≈ QJ.
Area for QJP and **HP** increases as the absolute value of Bz increases.	**Area for QJ** ,especially equatorward QJ , increases as Bz becomes more negative

Acknowledgements

- Thank you to Dr. Barbara Emery for her time, support & guidance.
- Thank you to Dr. Astrid Maute for her help and encouragement.
- Thank you to LASP and HAO for giving me this amazing research opportunity.
- Thank you to Marty, Erin and all REU students. It was wonderful meeting you all!

Thank you for your attention!

Questions?