Ionospheric Poynting Flux Binned in Auroral Boundary Coordinates

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Motivations

- Energy deposition in ionosphere driven by EUV solar radiation and incoming plasma winds
- Negative Poynting flux implies absorption and interaction of EM waves, heating of ionosphere
- Measurements of magnetic field and electric field in low earth orbit via DMSP satellite constellation can be used to calculate the Poynting flux
- Mapping Poynting flux values to auroral boundaries demonstrates where energy is deposited

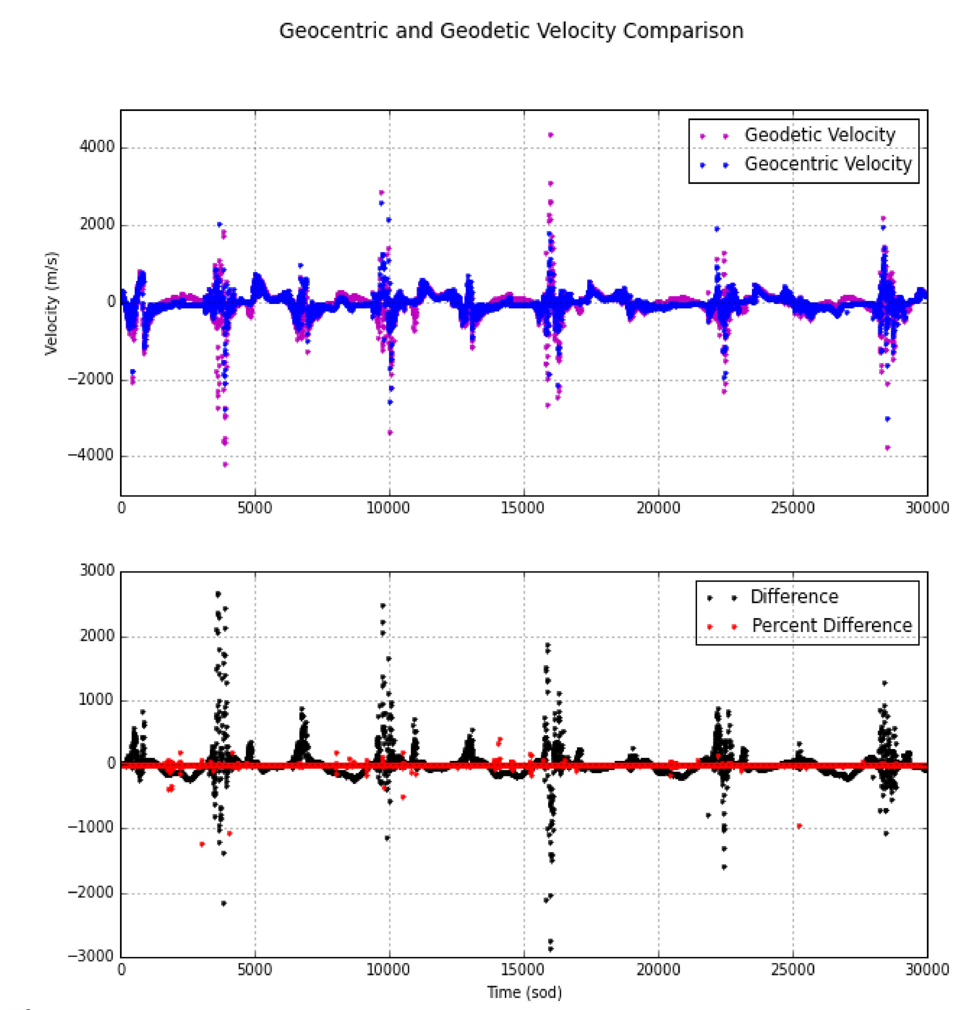

Figure 1 – *(Top)* Spacecraft velocity calculations utilizing geodetic and geocentric latitudes. *(Bottom)* Differences observed between the two methods

Geocentric versus Geodetic

- Velocity calculated using satellite position in geocentric latitude and longitude over time

Result: The largest difference between geocentric and geodetic velocity occurs near the poles which can be seen by the periodic spikes in the magnitude of difference (Figure 1, bottom). The percent difference between the two methods remains small (Figure 1, bottom) and near-zero throughout the day observed.

- **Conclusion:** Due to the relatively small degree of difference the latitude correction makes when compared to the much larger uncertainties inherent in this data set, it was determined that the correction would be omitted from further calculations.

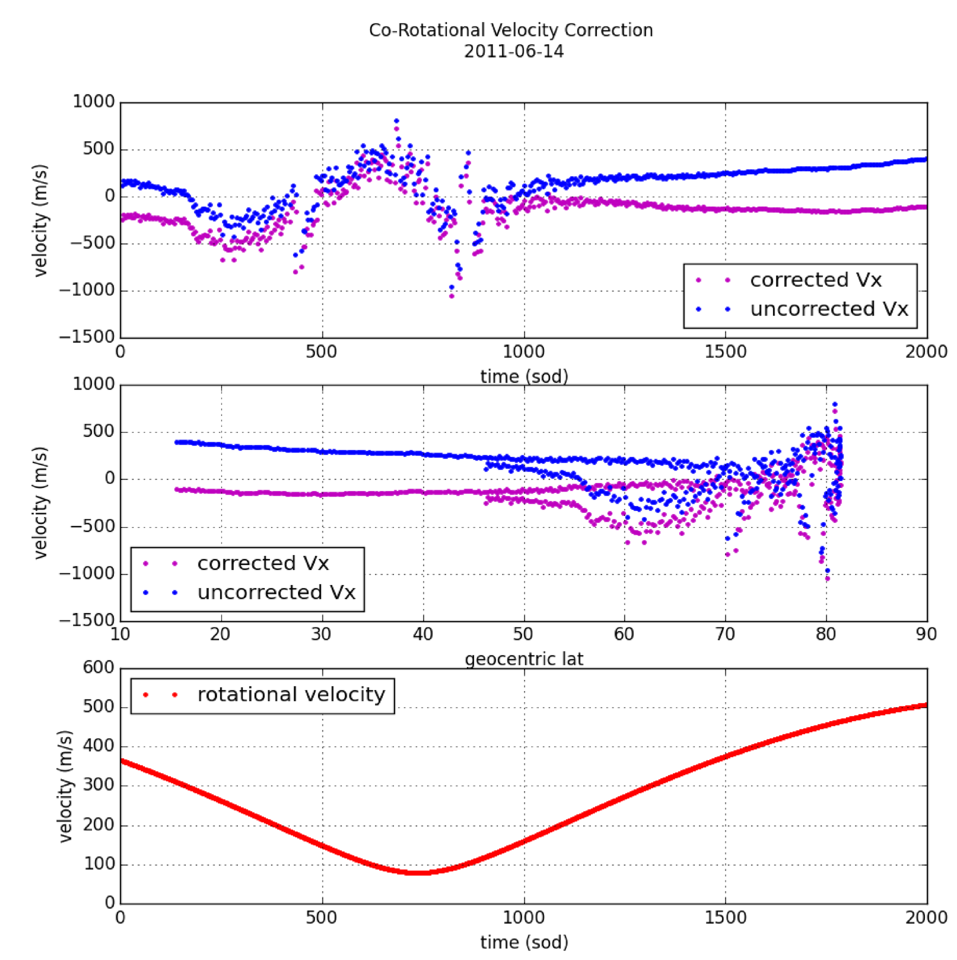

Figure 2 – *(Top)* Velocity calculated over one spacecraft day. Velocity behavior becomes less linear during passage over polar cap (~250 s), indicating energy deposition. *(Middle)* Velocity plotted against latitude also demonstrates presence of increasing Poynting flux. *(Bottom)* Trend of rotational velocity over spacecraft path shows expected smooth expected geometric variance.

Plasma Co-Rotational Velocity

Co-rotational velocity of plasma fixed to Earth's magnetic field lines must be subtracted from total measured ion velocity to determine electric field

$$\vec{E} = q\vec{v} \times \vec{B}$$

Electric field is then used to calculate the Poynting flux

$$\vec{S} = \frac{1}{\mu_0}\vec{E} \times \overrightarrow{dB}$$

Geometrically, co-rotational velocity decreases as latitude increases (Figure 2, bottom).

- Magnetic perturbations *not* associated with normal rotation of field lines indicate energy deposition
- Perturbations are evident in higher latitudes (Figure 2, middle) where ion velocity increases in magnitude

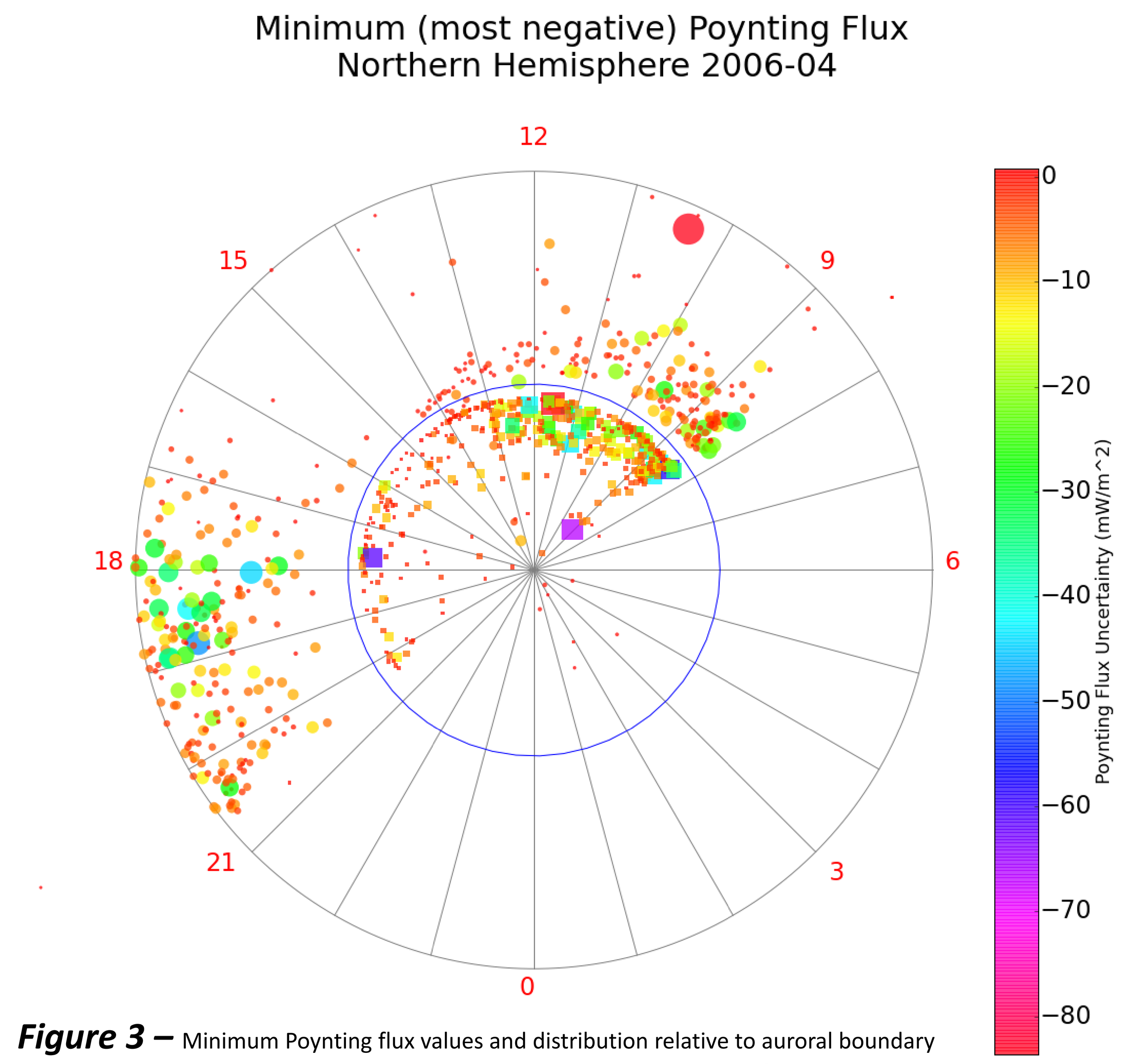

Figure 3 – Minimum Poynting flux values and distribution relative to auroral boundary location using a pseudo-latitude. Minima are shown both within polar cap (within blue circle at magnetic latitude 76º) and in the auroral zone (outside blue circle) per pass at true magnetic local time

Results

Using previously developed dynamic auroral boundary coordinates[1], a method was created to calculate and map the Poynting flux in the high latitude region based on measurements drawn from the DMSP satellite constellation. This study produced not only a useful tool for further statistical investigation of Poynting flux in this region but also offered several interesting observations based on preliminary analysis of approximately 890 successfully identified boundary passes for April 2006.

- **Development of new tool to consolidate all DMSP space environment observations and corresponding uncertainties into a scientifically useful database**

Uncertainties for DMSP measurements are a new feature of this database that has not been previously calculated

- **Concentration of Earthward flux on the poleward edge of the boundary (Figure 3, between 12 and 9)**

The expectation was that there would be significantly more energy deposition in the auroral zone, but according to this study's results, the difference is not as great as previously thought (more in Figure 6).

- **Polar cap flux tends to be located dawn-ward of noon**

Flux concentration was expected near-noon with tendencies to dawn or dusk dependent on the By IMF component. This study shows an unexplained trend dawn-ward of noon independent of IMF By.

- **Polar cap flux is consistently present throughout observed month**

The frequency of observed polar flux implies that there may be sources of energy deposition from all IMF orientations.

Pseudo-Latitude

To more accurately map the location of the pass minima to the dynamic auroral boundary coordinates, a scaling factor is determined that describes relative distance to the boundary in the method below[1]:

$$L_{AZ} = (|Mlat(t)| - |MLat_{AZ}|)/(|MLat_{PC}| - |MLat_{AZ}|)$$

$$L_{PC} = (|MLat(t)| - |MLat_{PC}|)/(90 - |MLat_{PC}|)$$

Where the magnetic latitudes of the minima and the boundaries found for that pass and used to determine the L-values. The factor is then applied to the arbitrary polar cap/auroral zone boundary at 76º for mapping purposes.

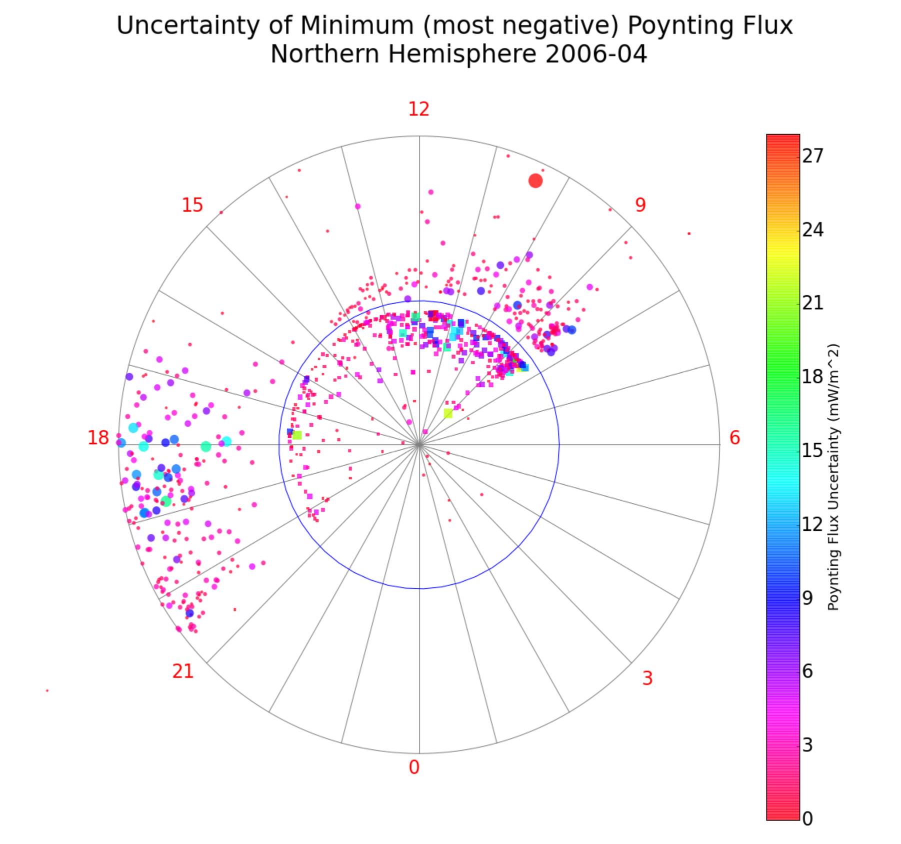

Figure 4 – Uncertainties associated with the minimum flux values in each region shown in Figure 3, also shown at true magnetic local time and a pseudo latitude based on the distance of the minimum the pass boundary.

Quality of Data

- DMSP data is flagged for quality on a 1-3 scale, three indicating data that should not be used. *3-flagged data was zeroed for this study*
- Uncertainties for the Poynting flux were calculated based on B- and E-field uncertainties
- The magnitude of the uncertainty is proportional to the magnitude of the Poynting flux (Figure 4), as both are heavily dependent on B-values
- **This study has produced approximate uncertainties for DMSP measurements**

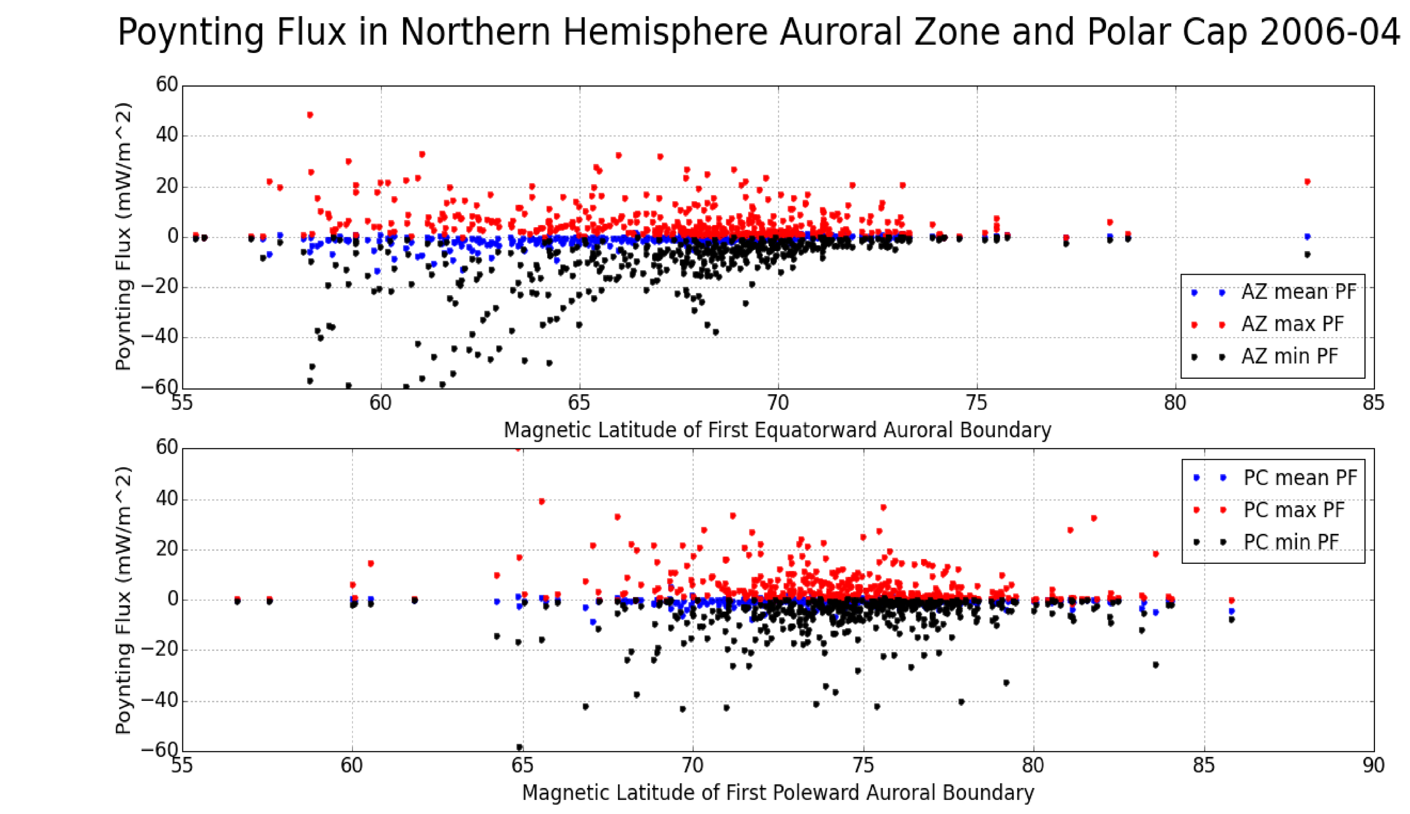

Figure 5 – Mean, Maximum (most positive), and Minimum (most negative) Poynting flux observed per identified pass in auroral zone *(Top)* and polar region *(Bottom)* plotted as a function of the magnetic latitude at which the corresponding boundary was located for that pass.

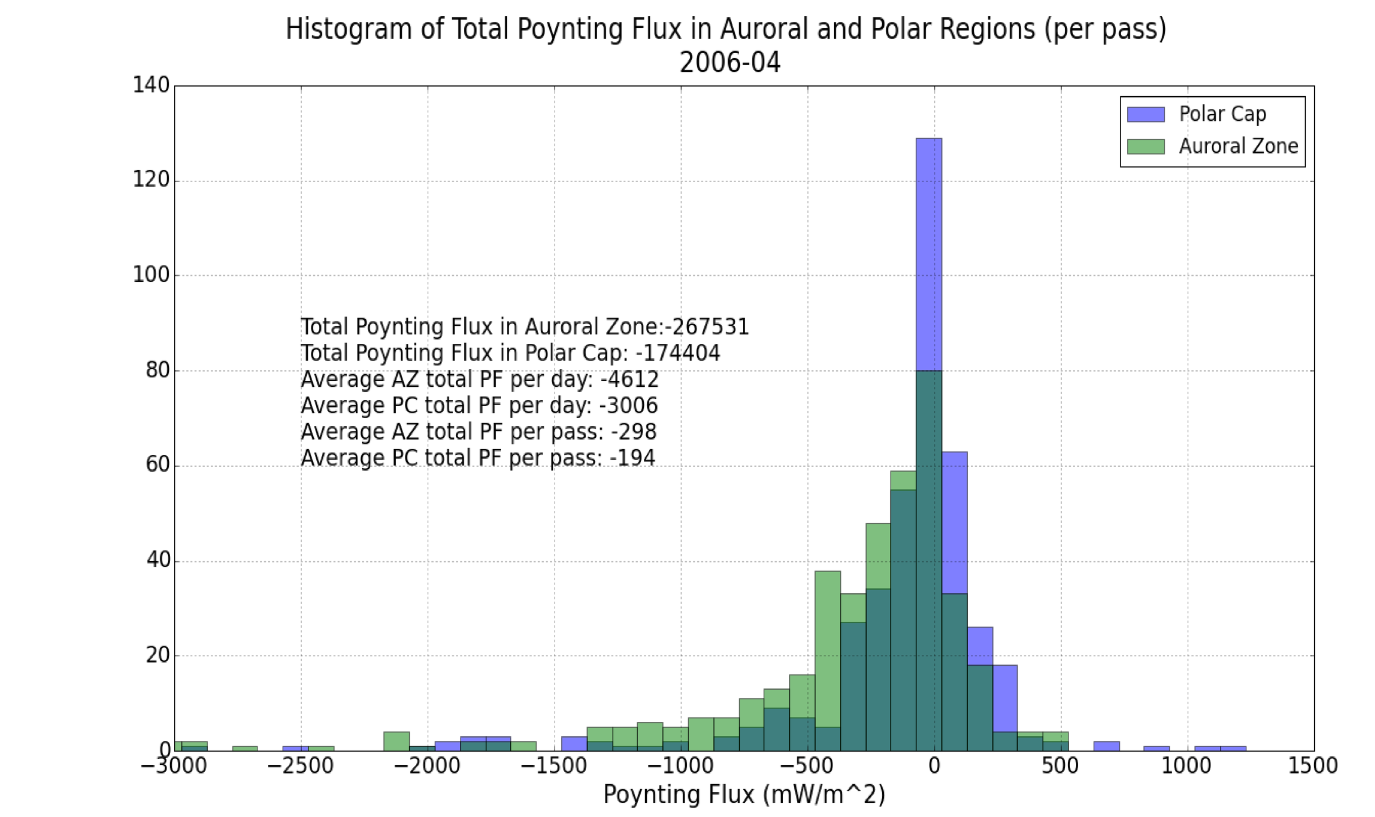

Figure 6 – Histogram of total integrated amount of Poynting flux in auroral zone and polar region, respectively. Statistical averages and sums over the month observed are located in text on graphic.

Poynting Flux Trends in High Latitude Region

Figure 5: The spatial distribution of Poynting flux maxima, minima, and mean values with respect to the magnetic latitude of the boundary located at that pass.

Figure 6: A histogram of Poynting flux totals in the distinctive high latitude regions demonstrating the magnitude and distribution of Poynting flux for the month of April 2006

Acknowledgments

Special thanks to Delores for encouraging me to dig into the project and make graphs of anything I could think of. To Liam for appreciating my emails. To Marty and Erin for being my space parents. And to the rest of the REU students who always reminded me to just do it.

Much gratitude to the National Science Foundation for funding the LASP REU program and providing myself and my peers with this opportunity.

References

[1] Redmon, R. J., W. K. Peterson, L. Andersson, E. A. Kihn, W. F. Denig, M. Hairston, and R. Coley (2010), Vertical thermal O+ flows at 50 km in dynamic auroral boundary coordinates, *J. Geophys. Res., 115*, A00J08, doi:10.1029/2010JA015589