# A Statistical Analysis of Pedersen Conductivity In SAPS Regions

Farzan Beroz
Duke University
MIT Haystack Observatory REU 2009 Program
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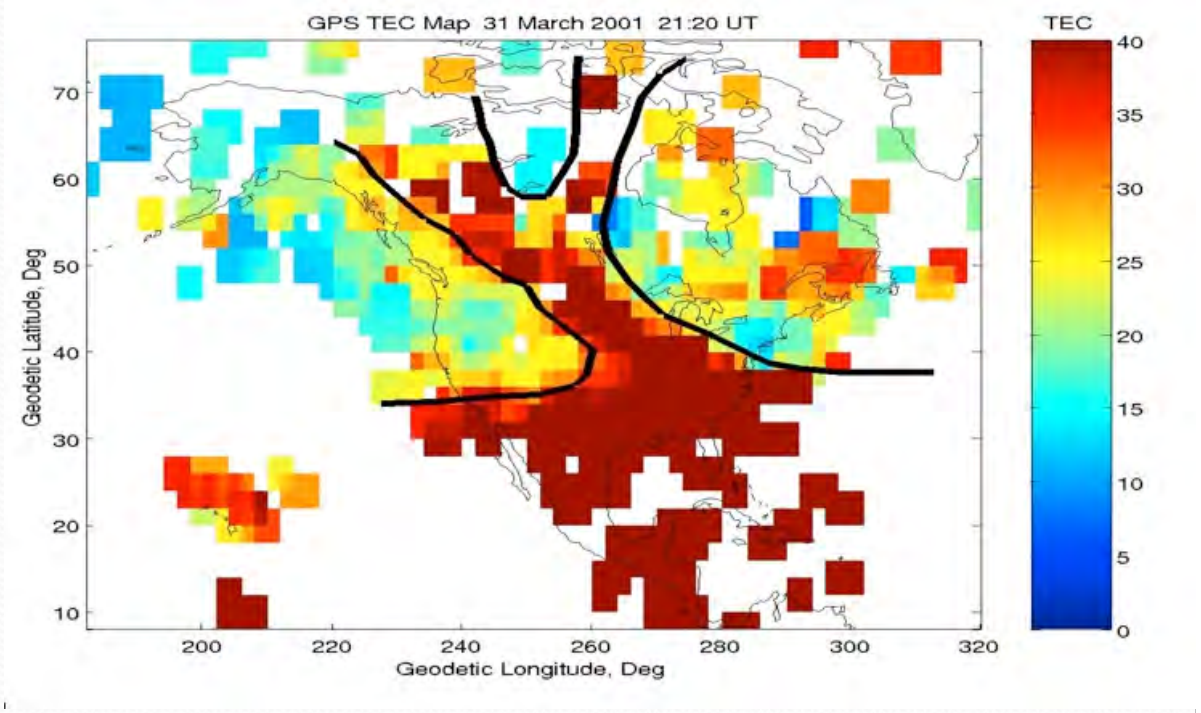
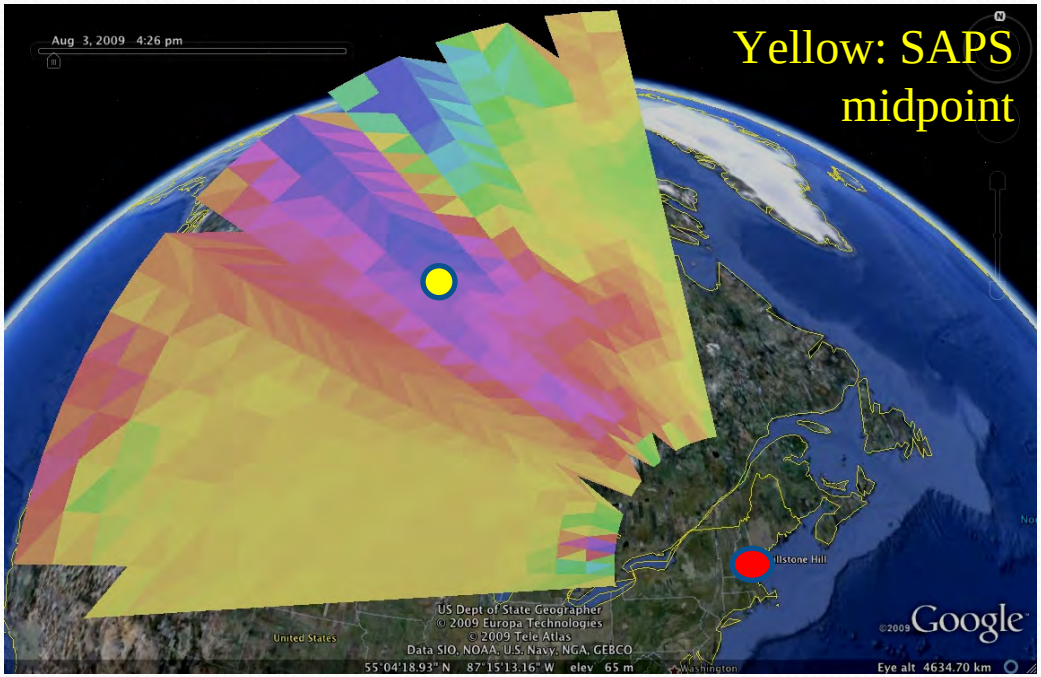
# Sub-Auroral Polarization Streams

- Areas of dense, moving plasma
- Motion from lower latitudes to higher latitudes
- Caused by coupling of ionosphere and magnetosphere
- Edges cause space weather effects



# Survey Methodology

- Millstone Hill radar scans used
- Existing database of ~1200 identified SAPS events from 1979-2001
- Improved, class-based organization



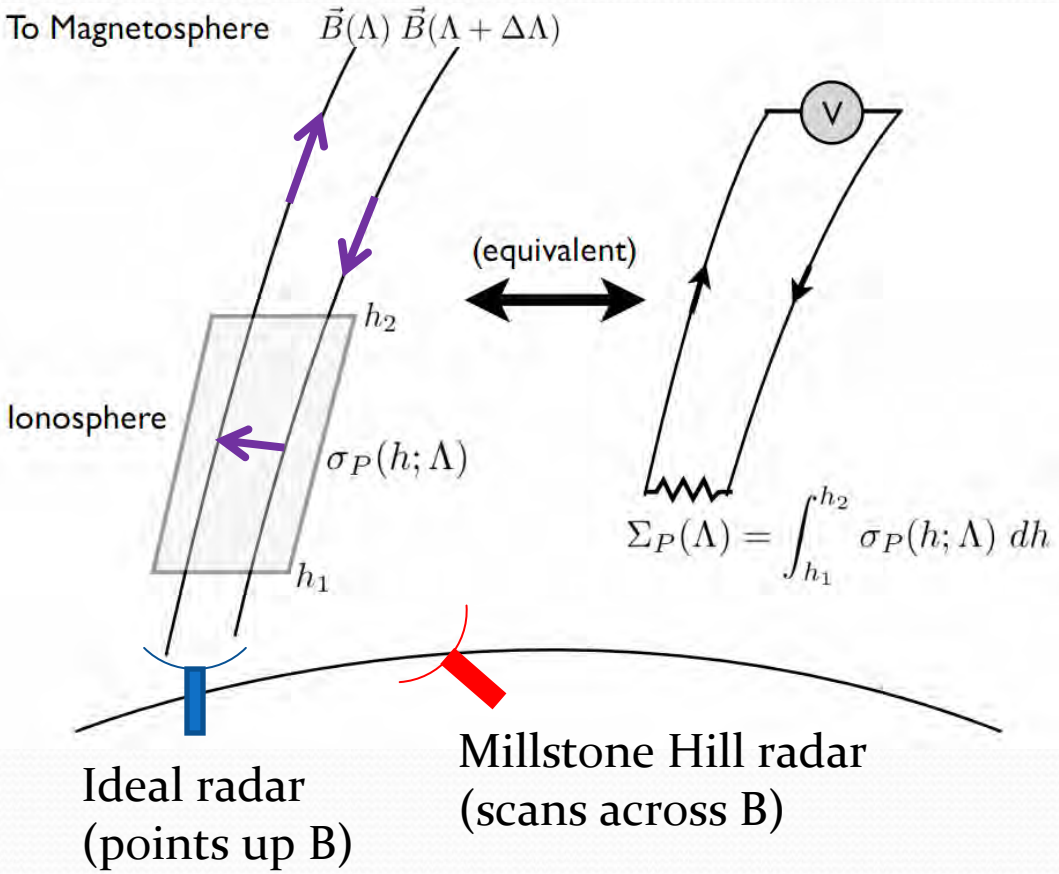

Line-of-sight ion velocity
Yellow = 0 m/s  Blue = 1000 m/s away

# Pedersen Conductivity

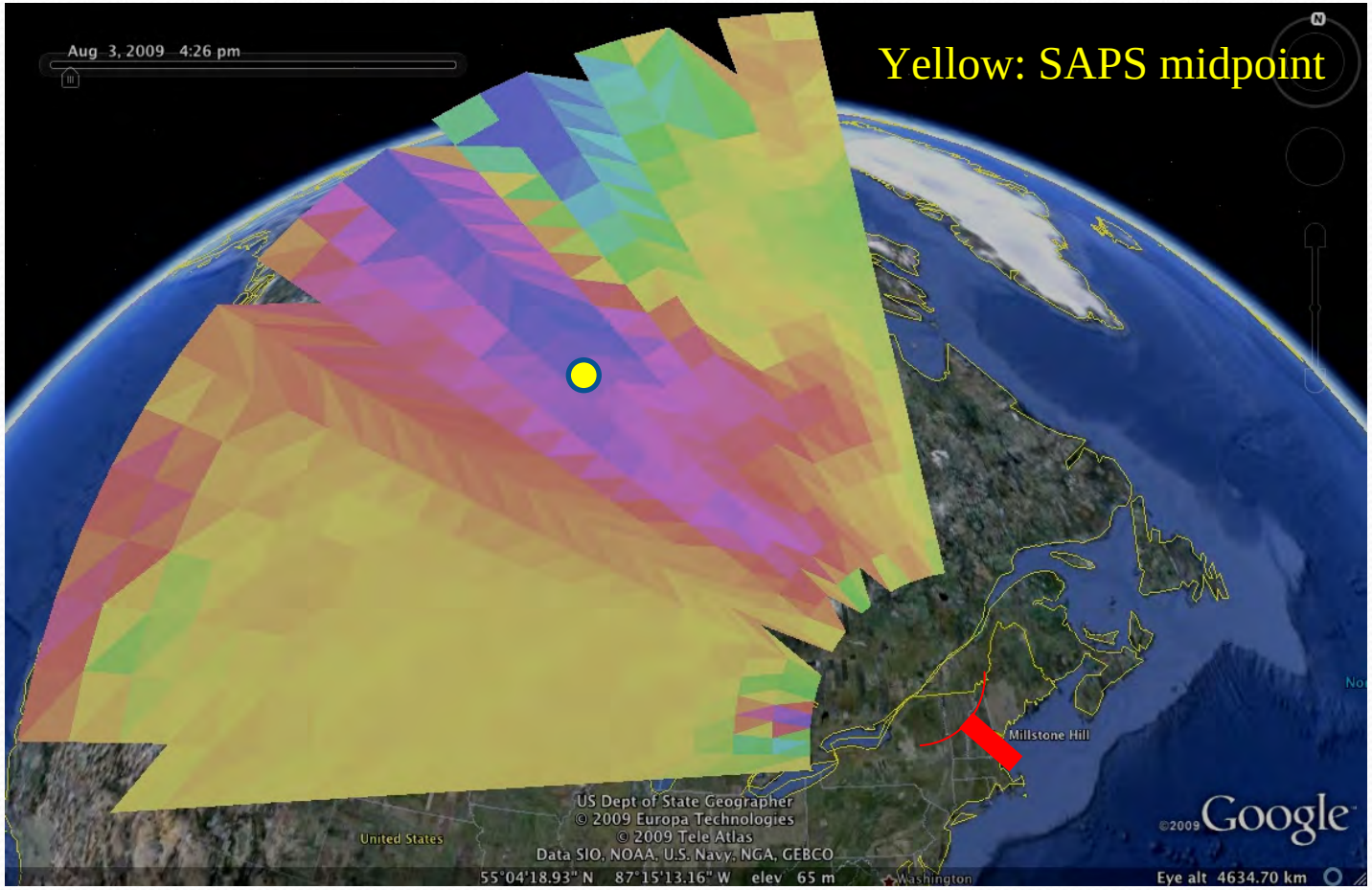
$$\sigma_P = \frac{n_e q}{B}\left[\frac{\omega_{ci}\,\nu}{(\nu^2+\omega_{ci}^2)} - \frac{\omega_{ce}\,\nu}{(\nu^2+\omega_{ce}^2)}\right]$$

Depends on:
- ionospheric electron density
- neutral density
- ion-neutral collision frequency
- magnetic field strength

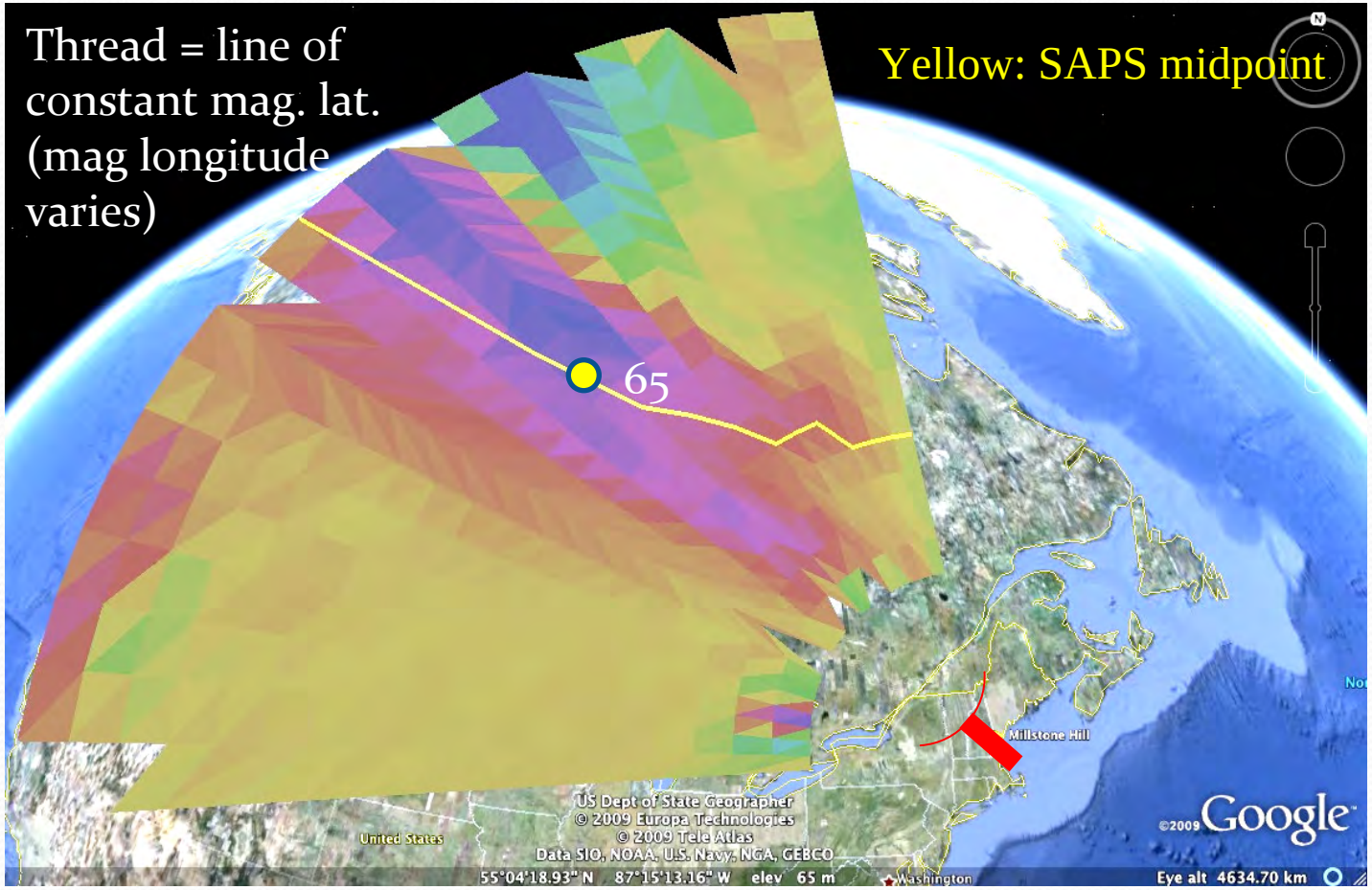
Red: measured by ISR
Green: modeled



# Altitude threads

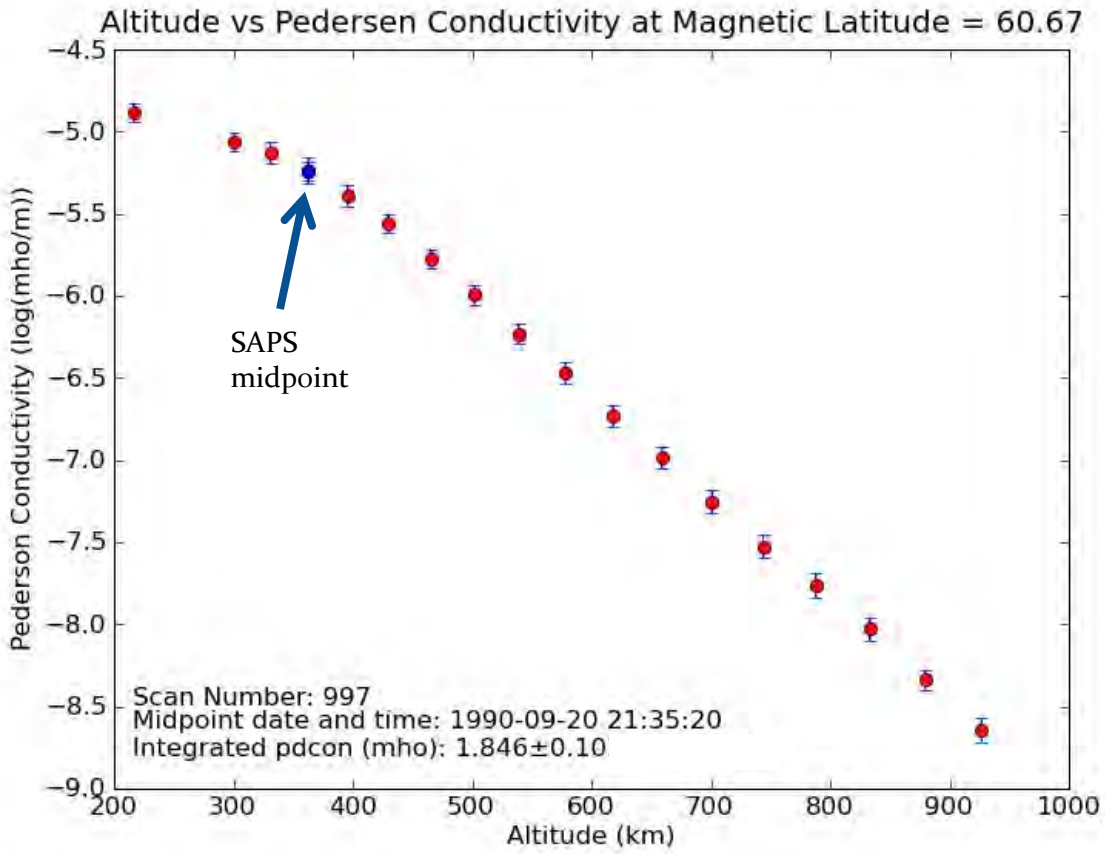


# Altitude threads

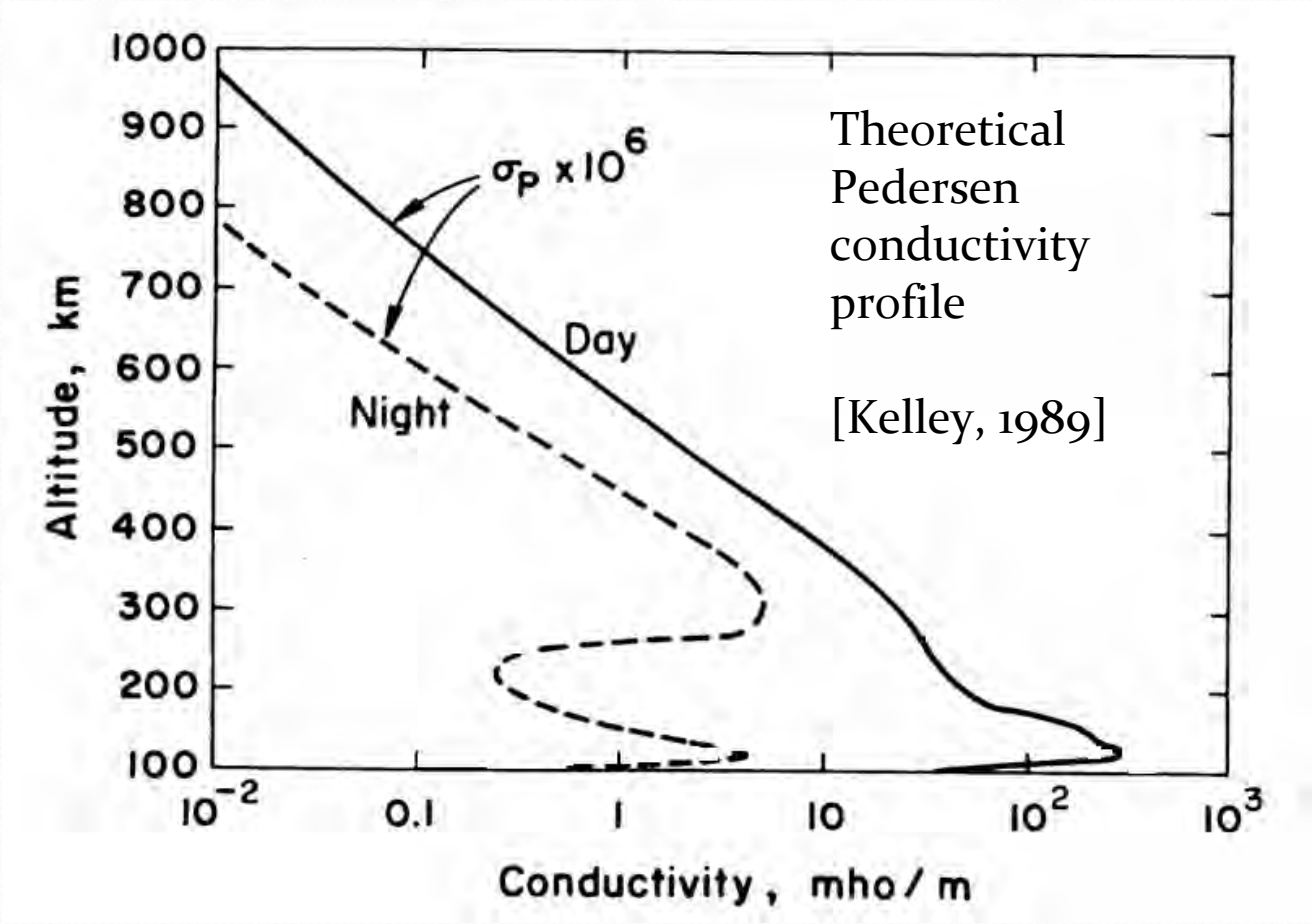


# Altitude and Pedersen Conductivity

- Graph is made from one “thread”
- Blue point is SAPS midpoint
- Integrated value calculated using trapezoidal integration



# Altitude and Pedersen Conductivity




Theoretical Pedersen conductivity profile

[Kelley, 1989]

# Altitude and Pedersen Conductivity

- Graph is made from one “thread”
- Blue point is SAPS midpoint
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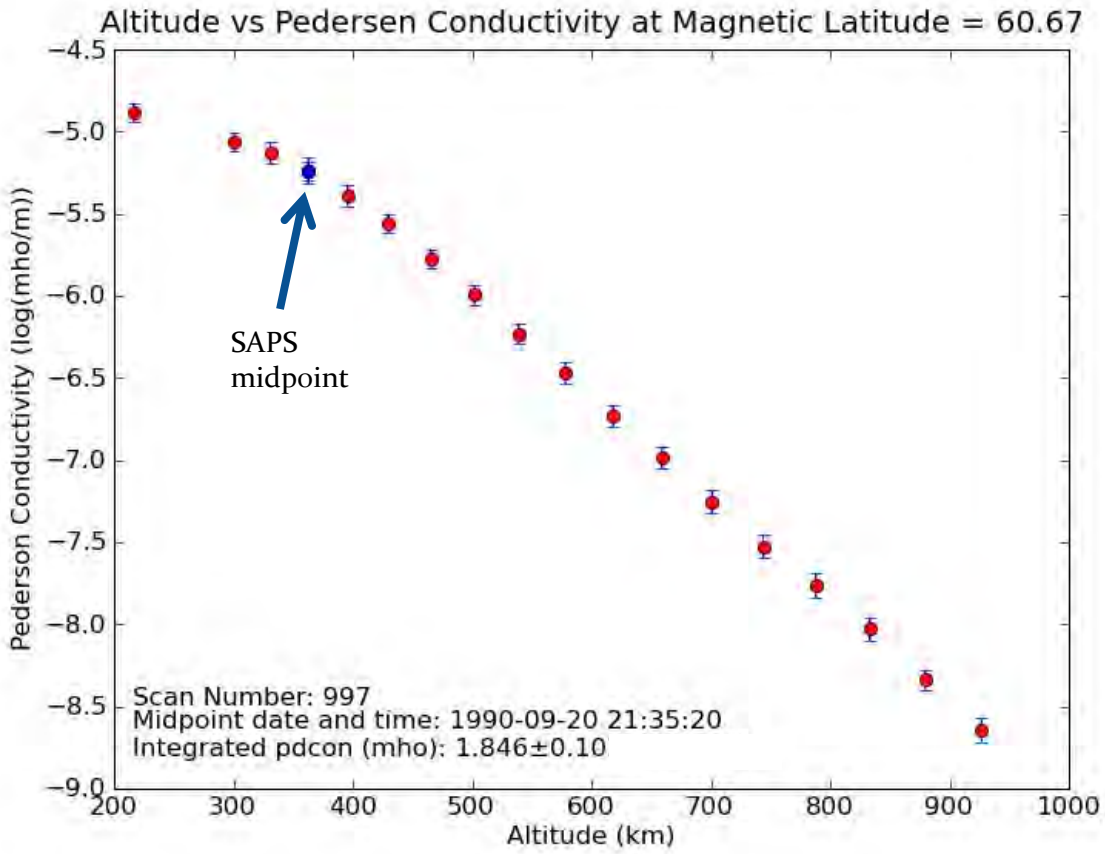
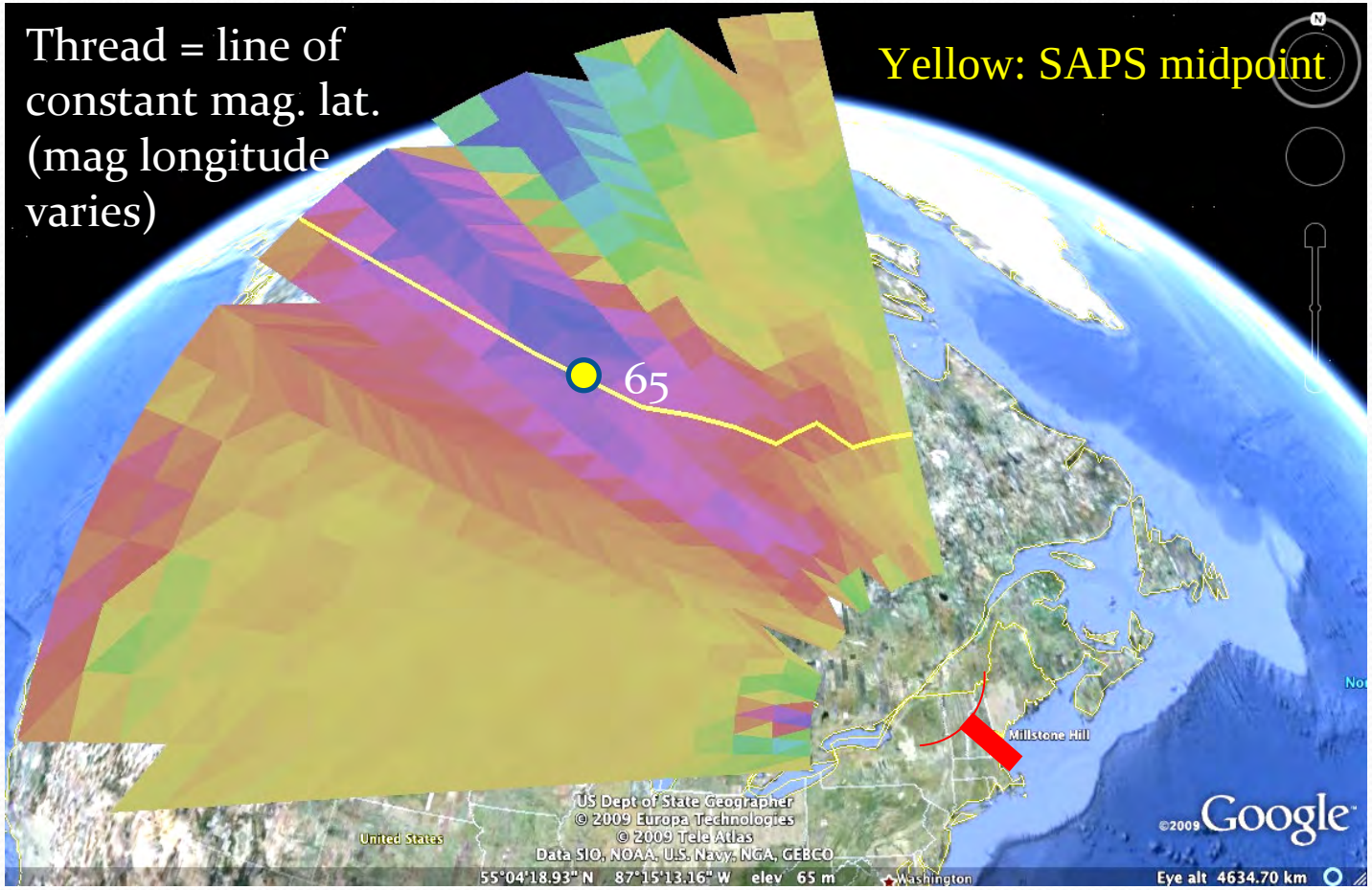
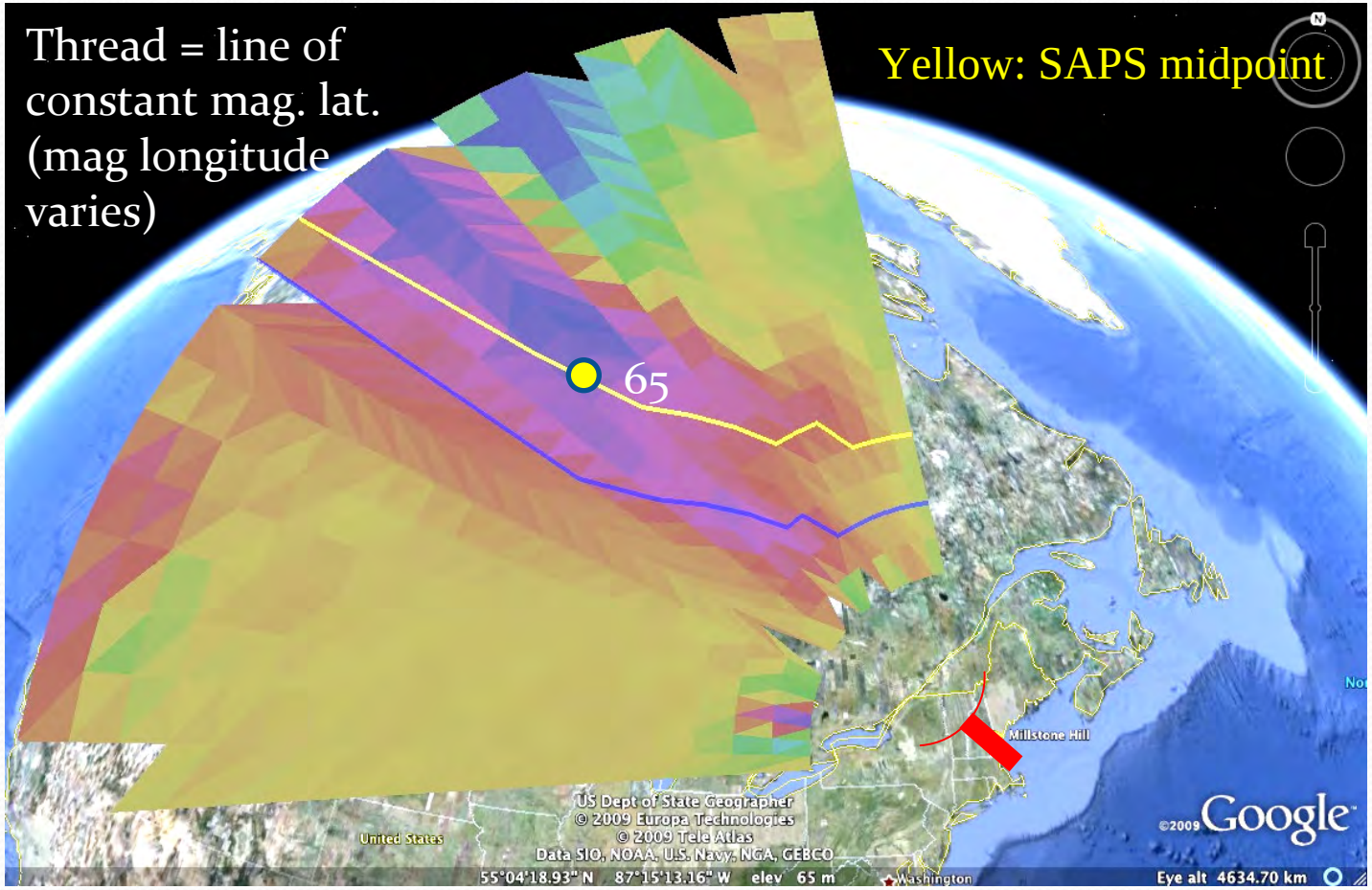


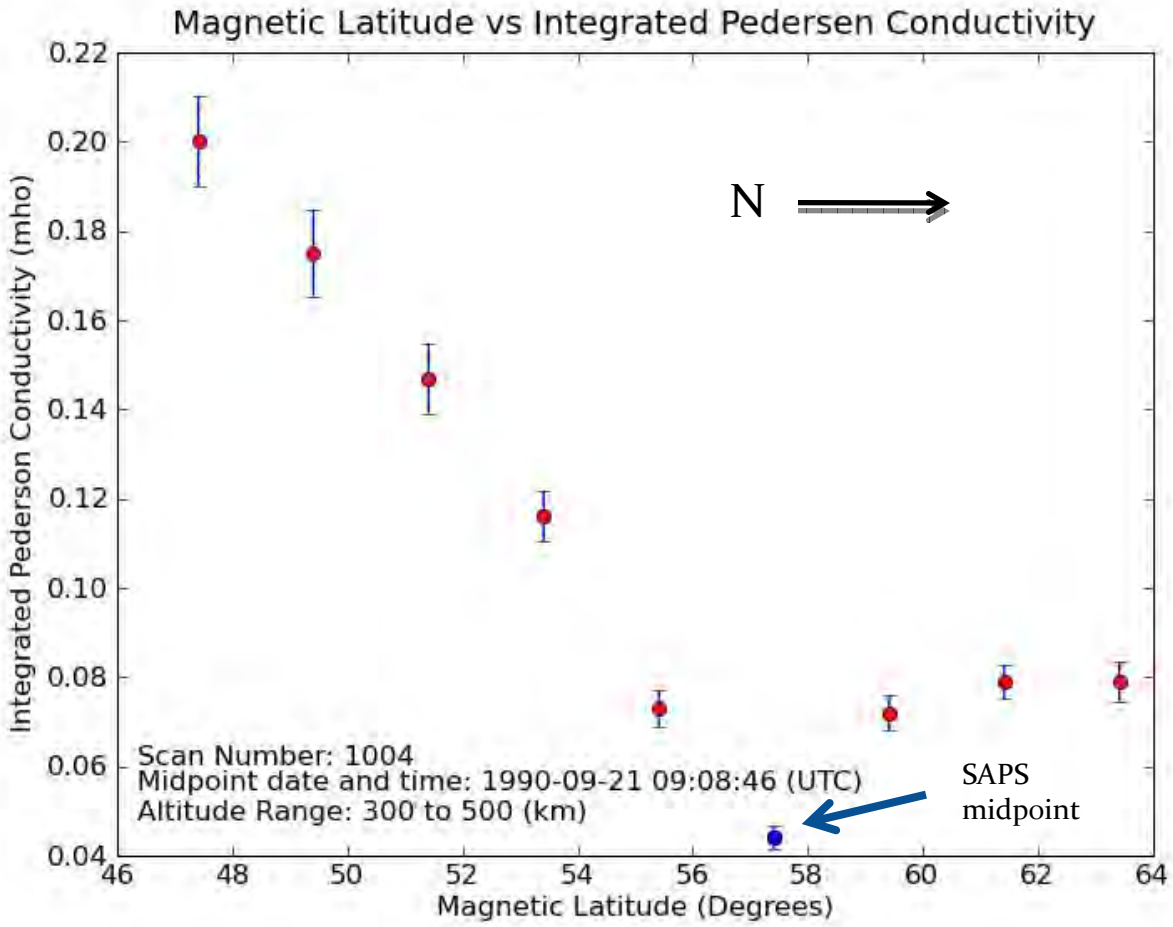
# Altitude threads



# Altitude threads

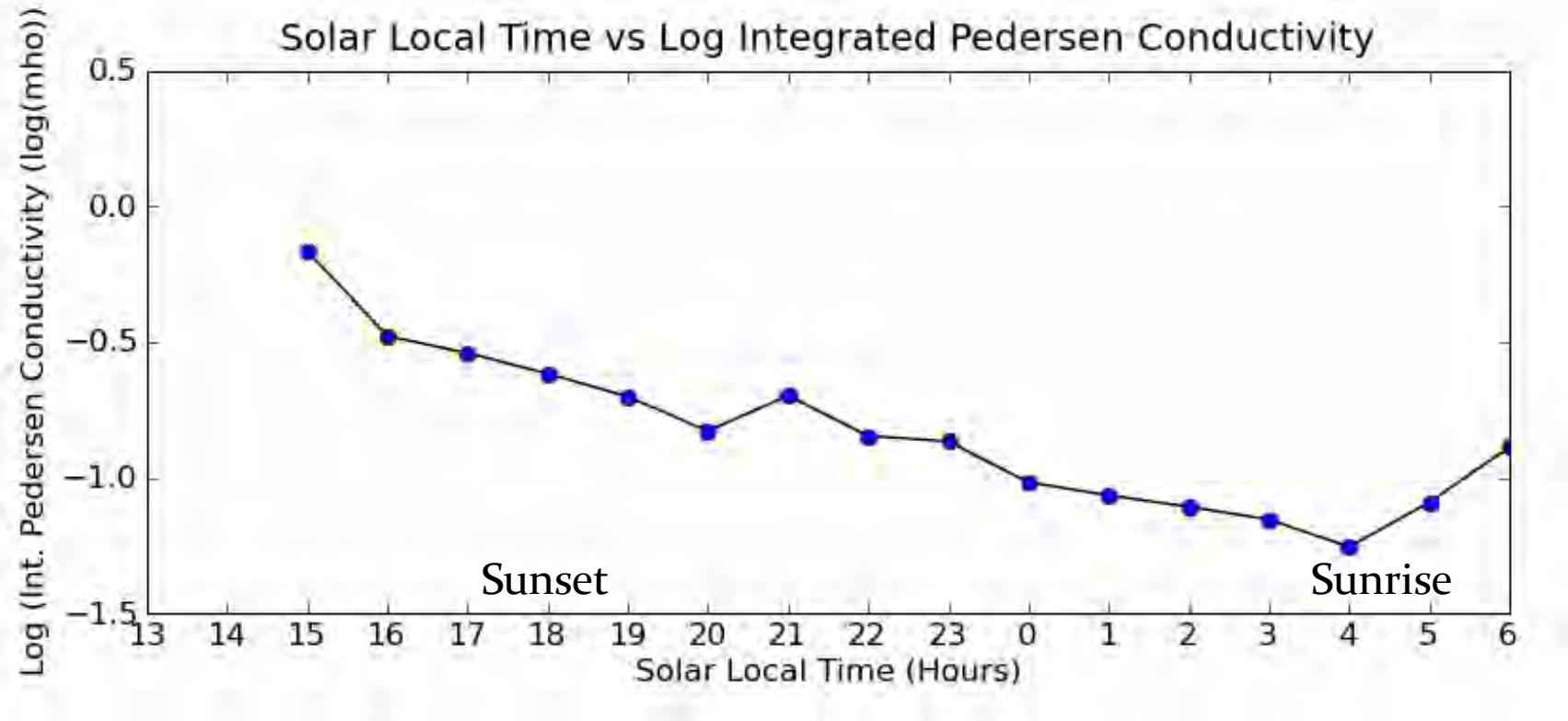


# Magnetic Latitude and Integrated Pedersen Conductivity



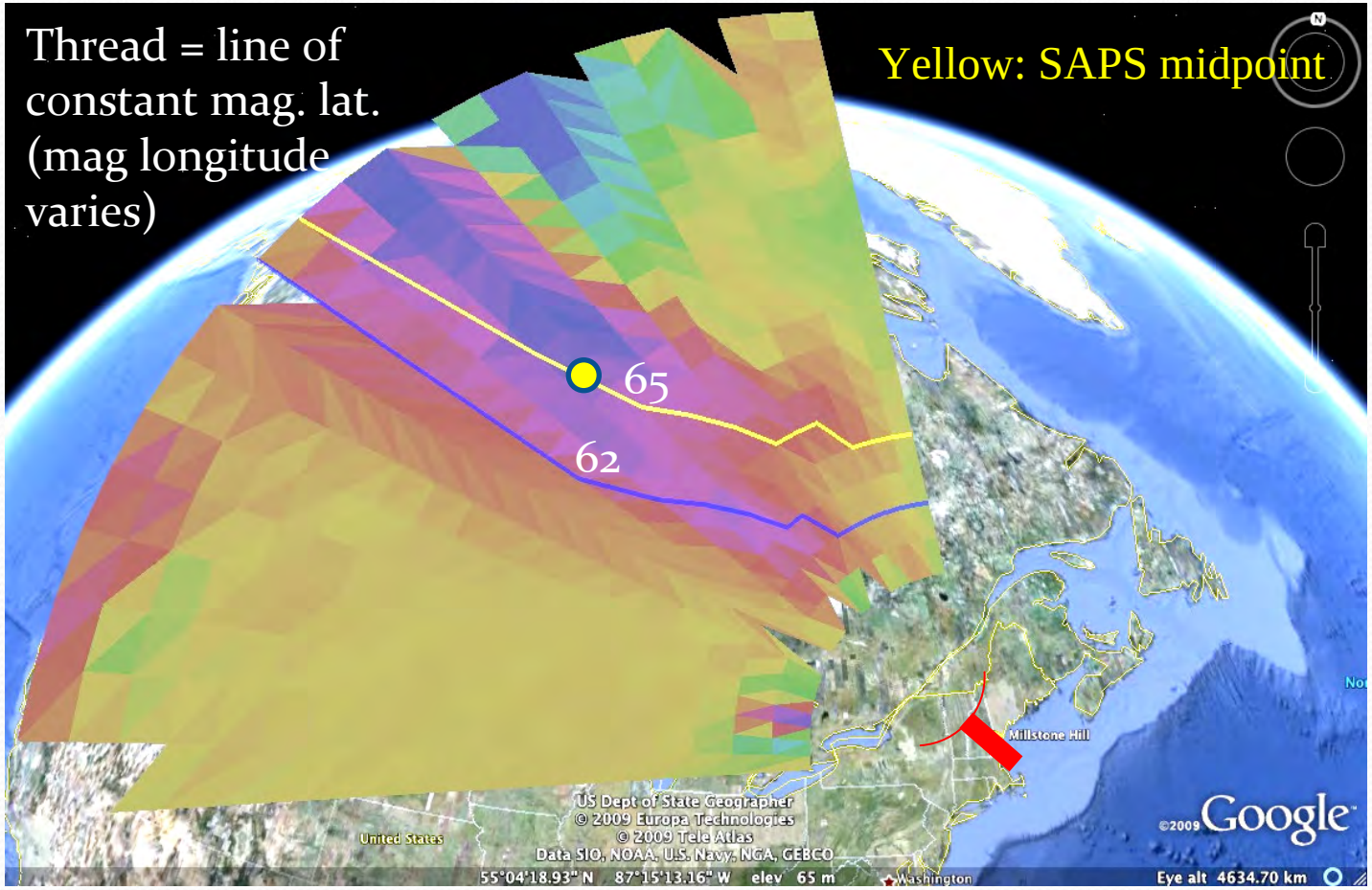

- Graph is made from multiple “threads” from one scan
- Each point is the integral of the thread’s Pedersen conductivity from 300 to 500 km
- Blue point is integrated value of the thread that runs through the midpoint

# Solar Local Time and Integrated Pedersen Conductivity



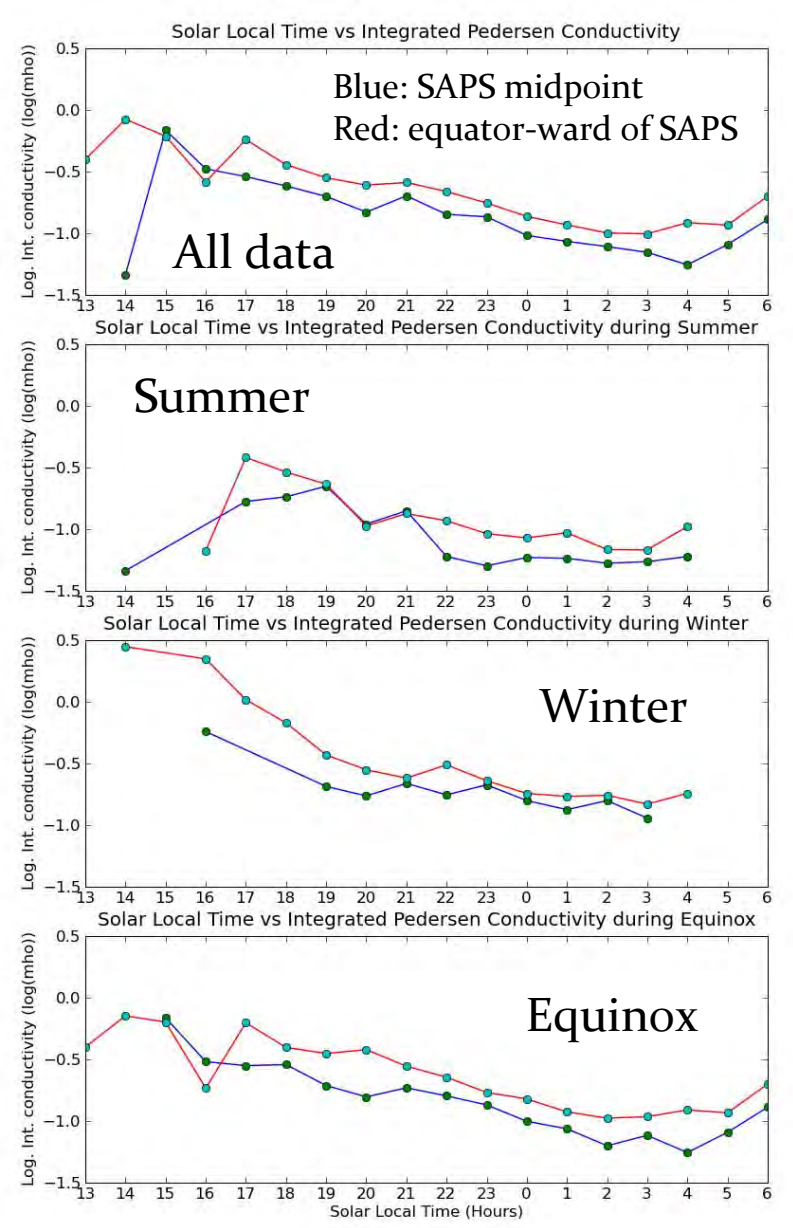

- Data from 350~ scans binned by time
- SAPS integrated conductivity decreases from day to night

# Altitude threads



# Integrated Pedersen Conductivity Inside and Outside SAPS

- Each graph shows the integrated Pedersen conductivity curves at the midpoint and three degrees equator-ward
- Integrated Pedersen conductivity at SAPS midpoint is 2x lower
- SAPS electron density peaks at higher altitudes: collisions with neutrals decrease, causing lower conductivity



# Summary

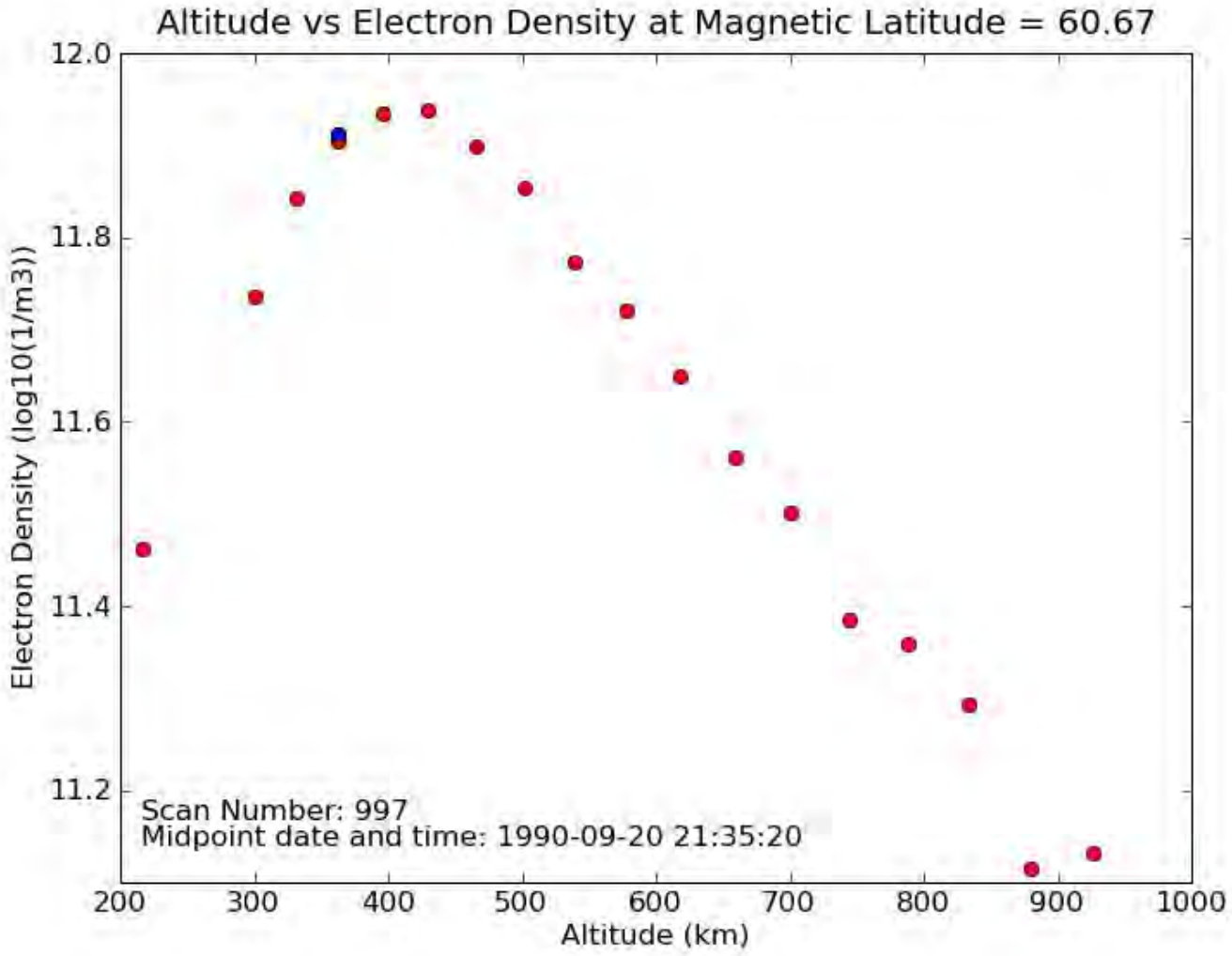
- Millstone Hill radar was used to create a unique database for SAPS studies
- Flexible software toolkit constructed
- Measured Pedersen conductivity values behave similar to predictions made using theoretical models
- Integrated Pedersen conductivity depends on location, time of day and proximity to Sub-Auroral Polarization Streams
- Lower integrated Pedersen conductivity is observed near SAPS channel midpoints

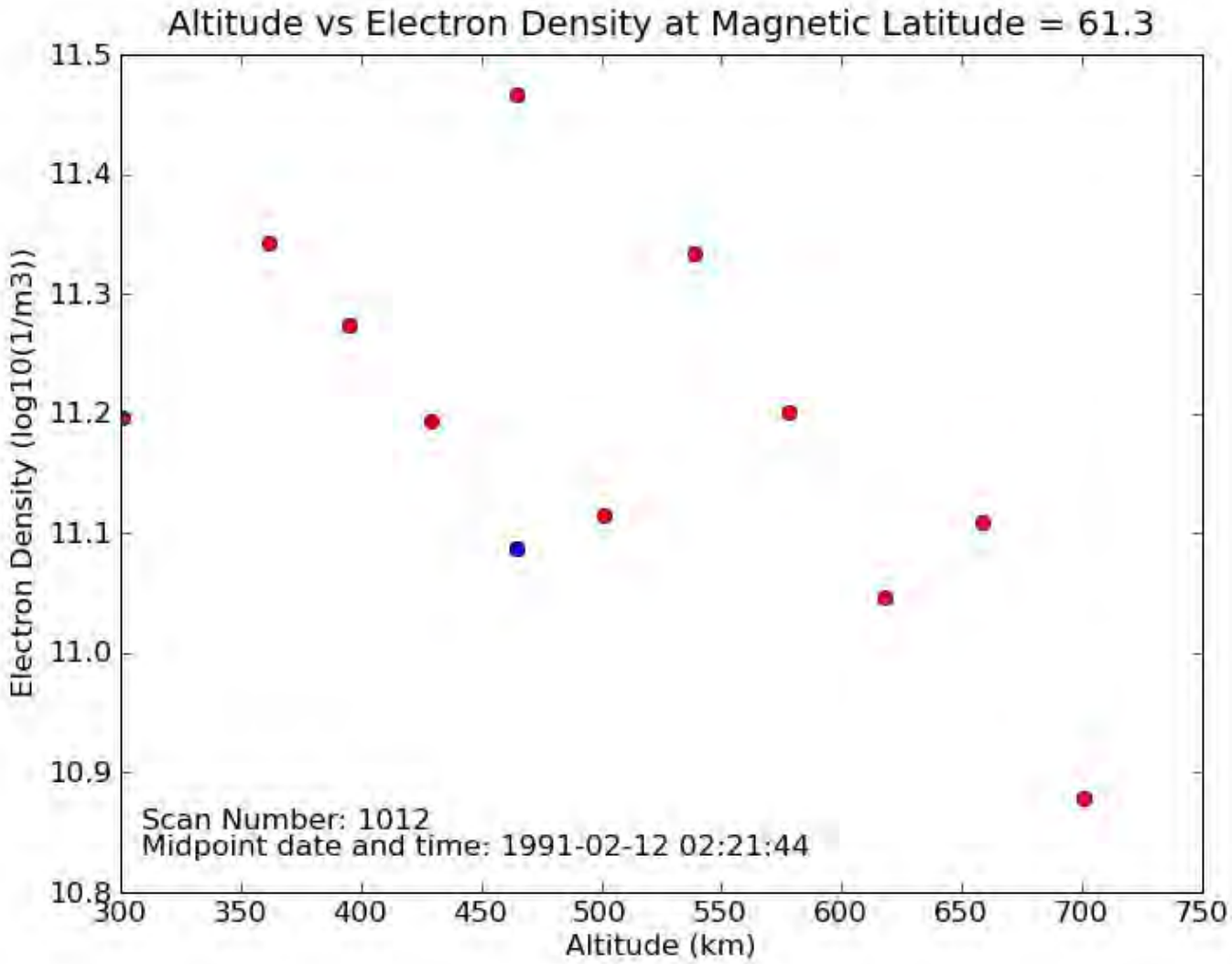
# Future Work

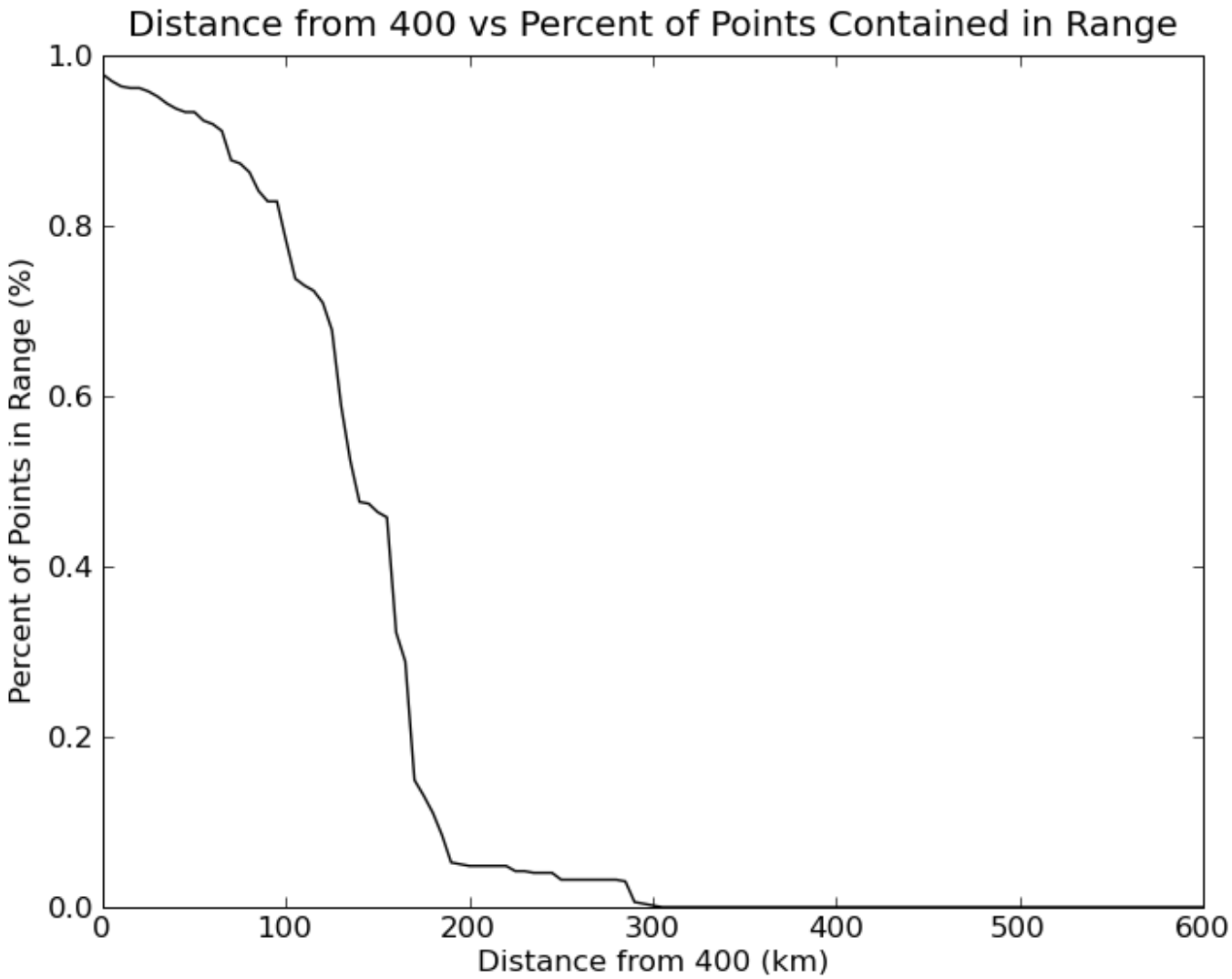
- Finish error propagation once available from Madrigal
- Improved thread interpolation and integration
- Enhanced statistical study after September NASA conference
- Correlate variations in Pedersen conductance with SAPS velocity

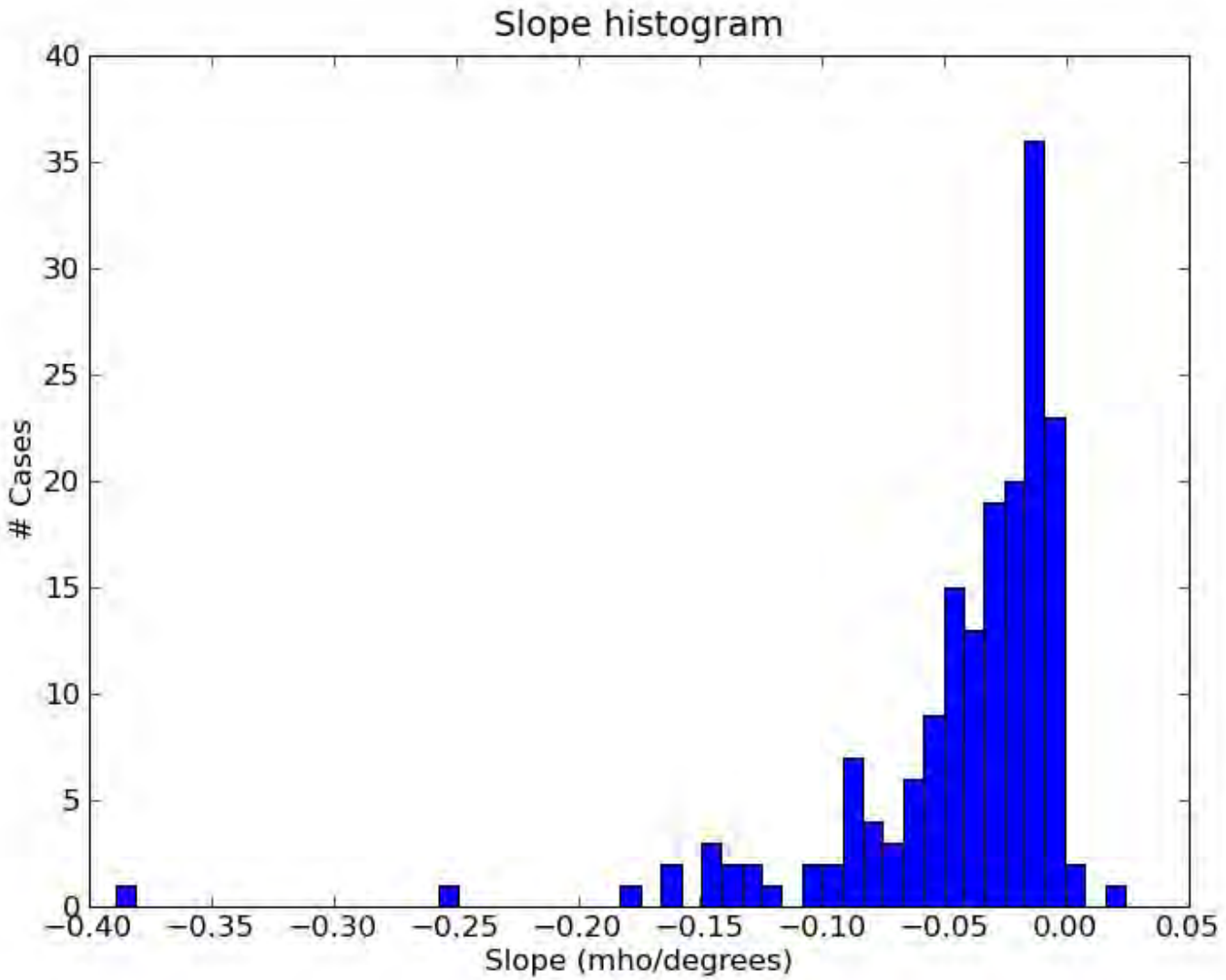
# Acknowledgements

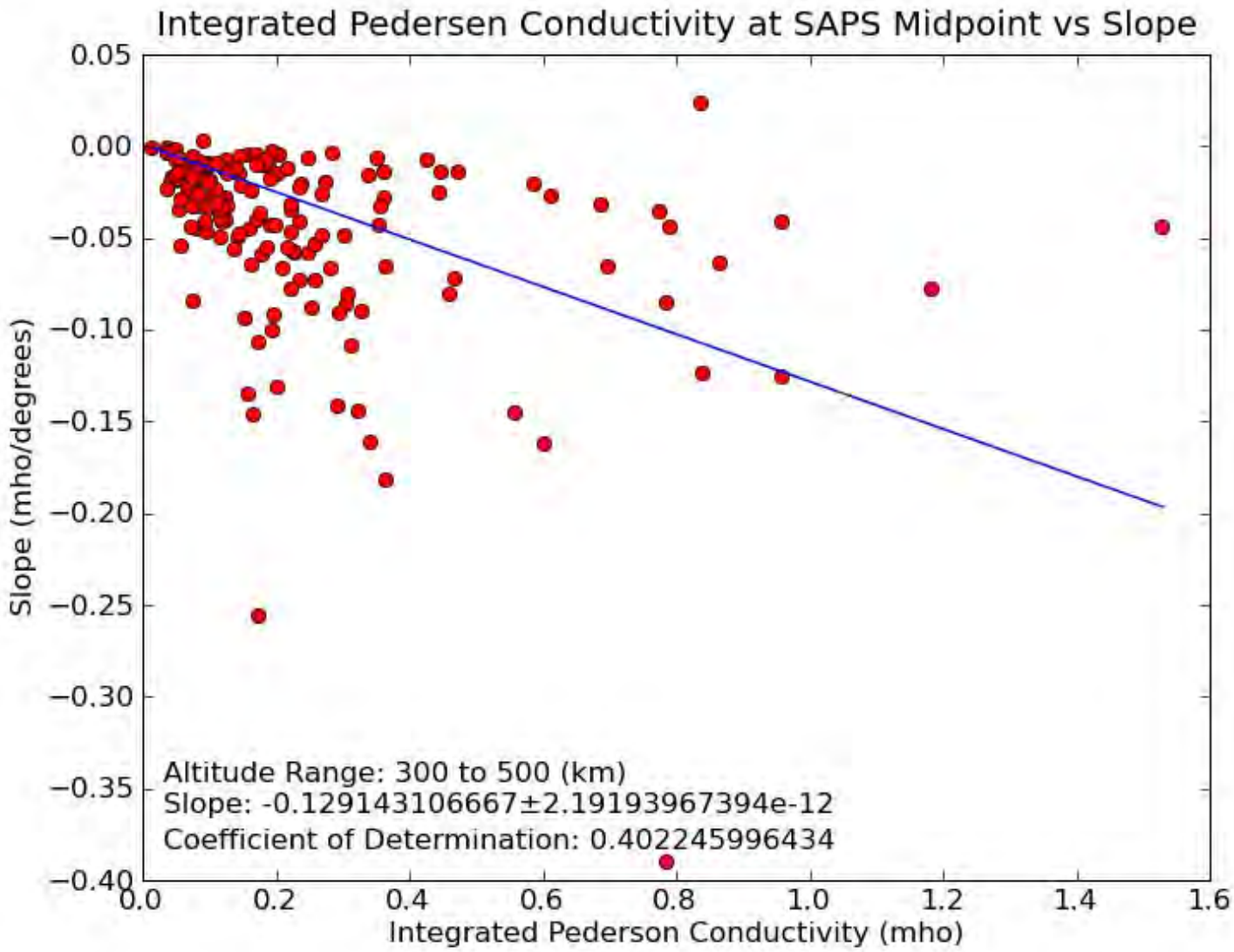

- Mentors: Bill Rideout and Phil Erickson
- REU program coordination: Vincent Fish, KT Paul
- All work was based on Marc Miskin's project from last summer
- John Foster provided useful suggestions
- Thanks to NSF for funding me

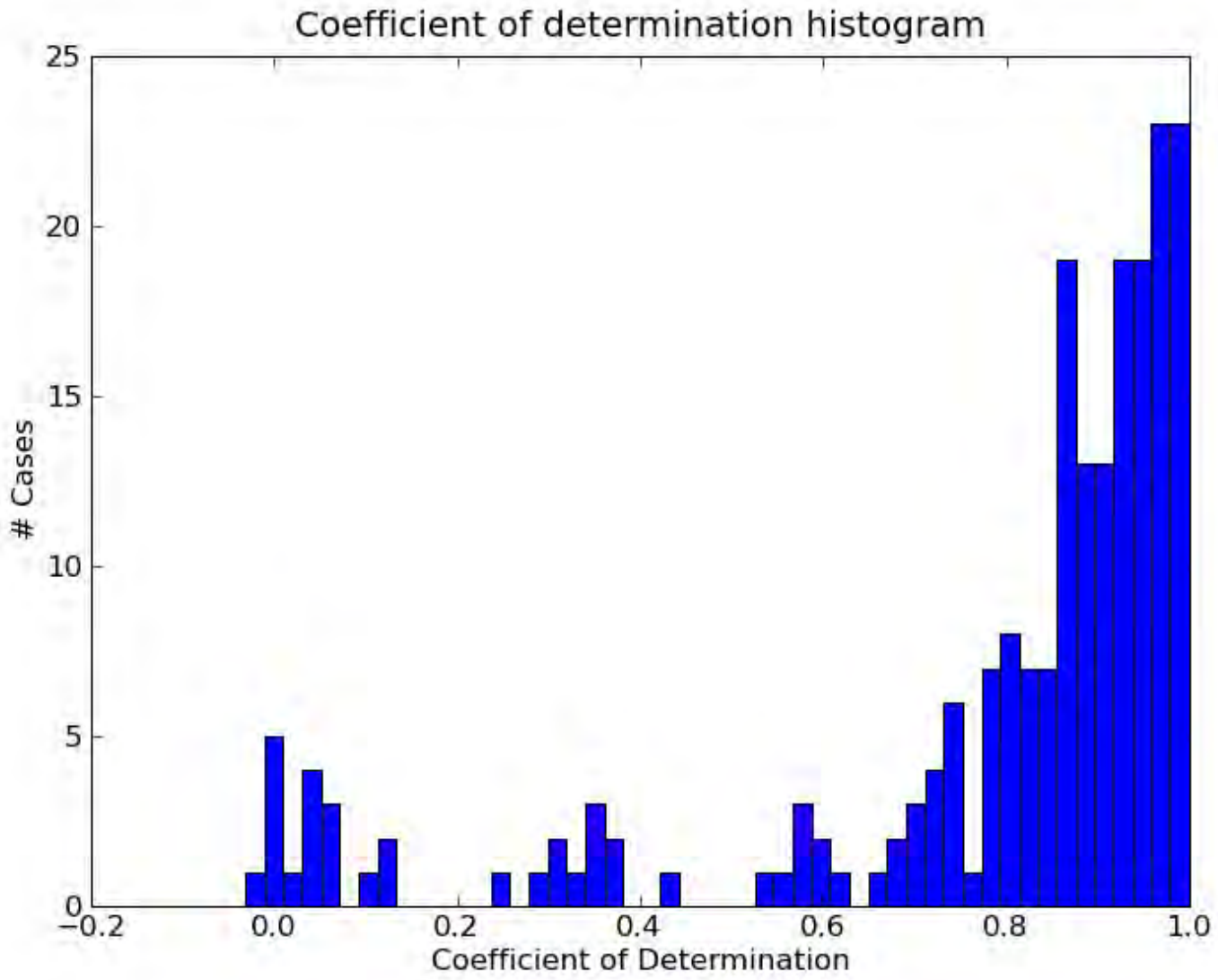

Altitude vs Electron Density at Magnetic Latitude = 60.67
Electron Density (log10(1/m3))
12.0
11.8
11.6
11.4
11.2
Scan Number: 997
Midpoint date and time: 1990-09-20 21:35:20
200
300
400
500
600
700
800
900
1000
Altitude (km)

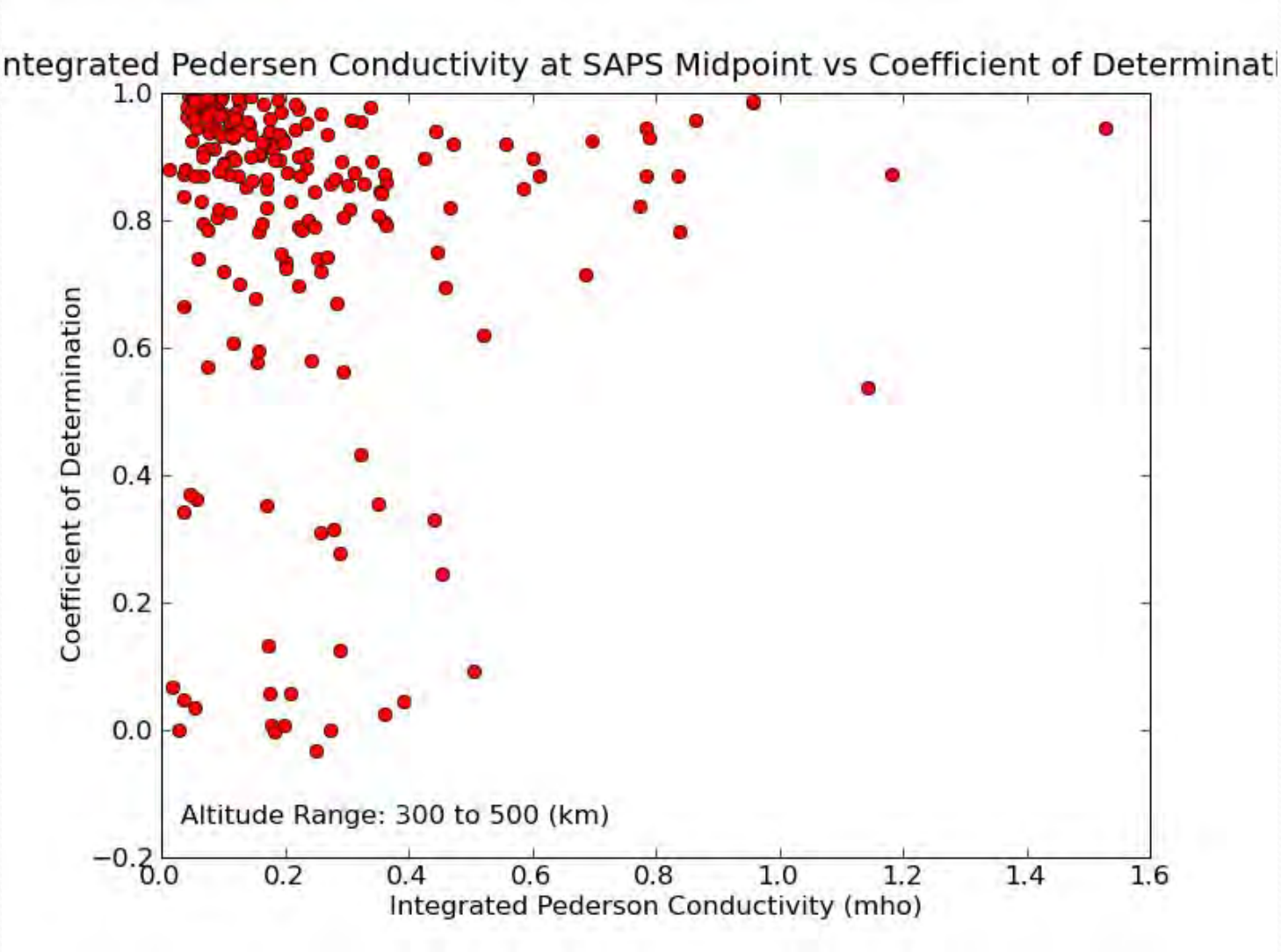

Altitude vs Electron Density at Magnetic Latitude = 61.3
Electron Density (log10(1/m3))
11.5
11.4
11.3
11.2
11.1
11.0
10.9
10.8
300
350
400
450
500
550
600
650
700
750
Altitude (km)
Scan Number: 1012
Midpoint date and time: 1991-02-12 02:21:44

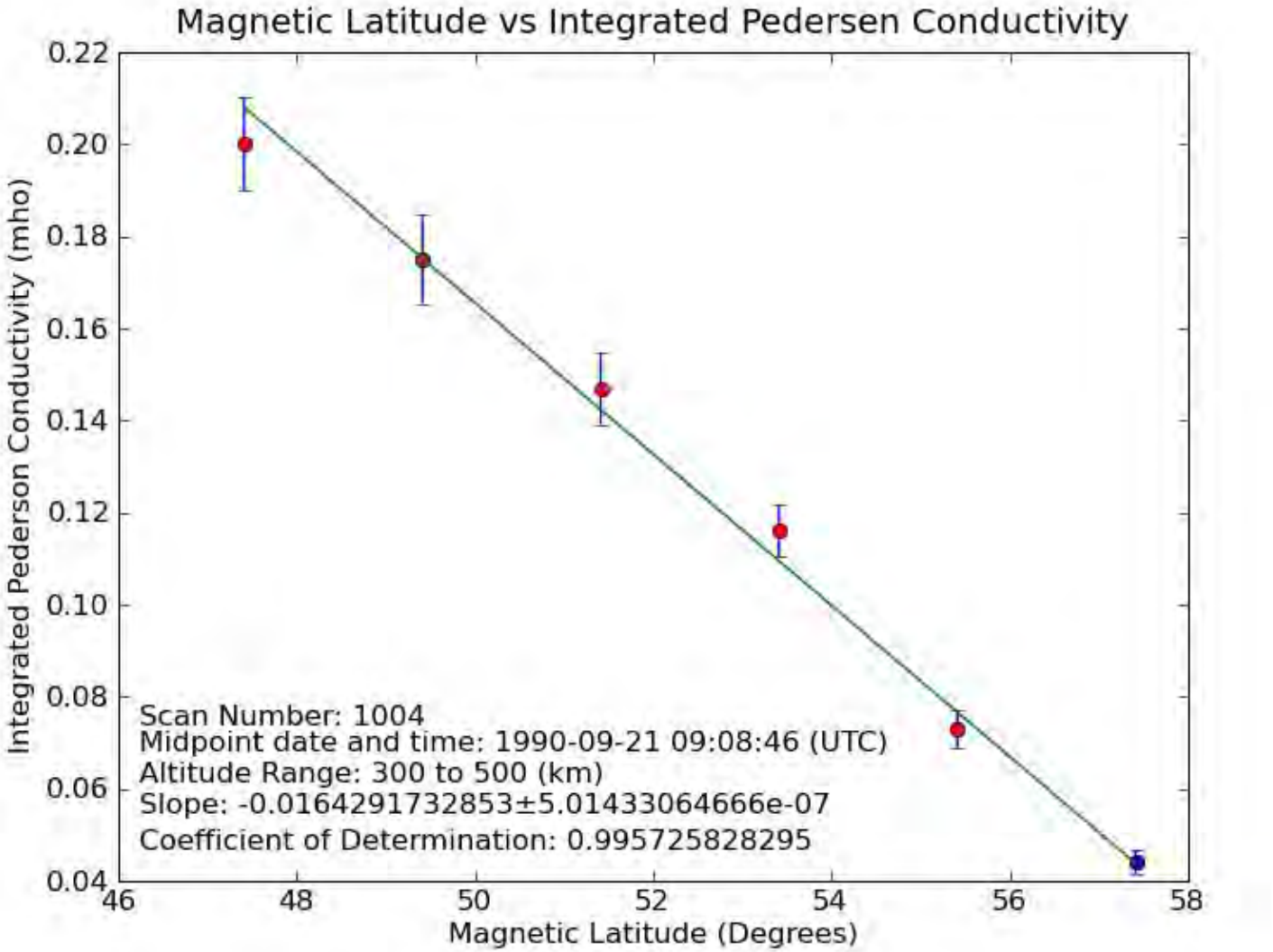

Distance from 400 vs Percent of Points Contained in Range
Percent of Points in Range (%)
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
500
600
Distance from 400 (km)

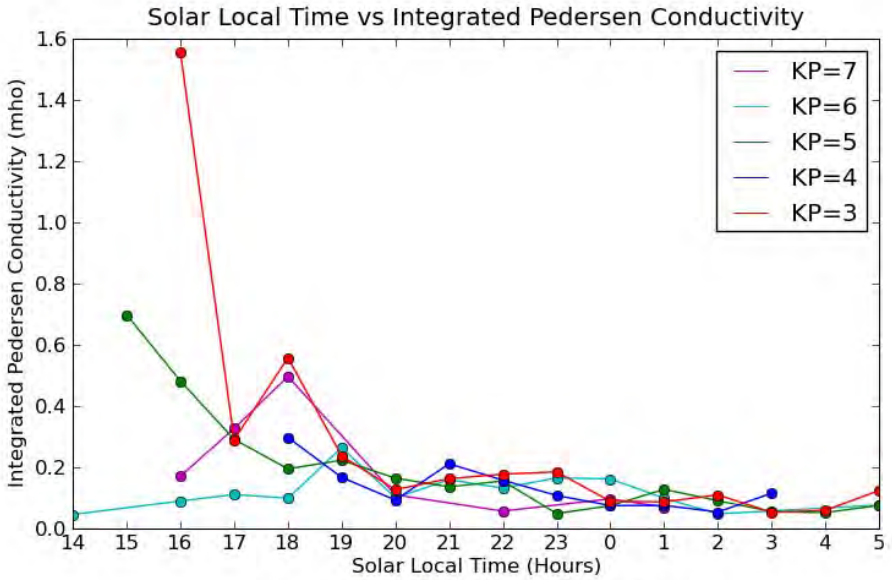

Slope histogram
# Cases
Slope (mho/degrees)
40
35
30
25
20
15
10
5
0
−0.40
−0.35
−0.30
−0.25
−0.20
−0.15
−0.10
−0.05
0.00
0.05

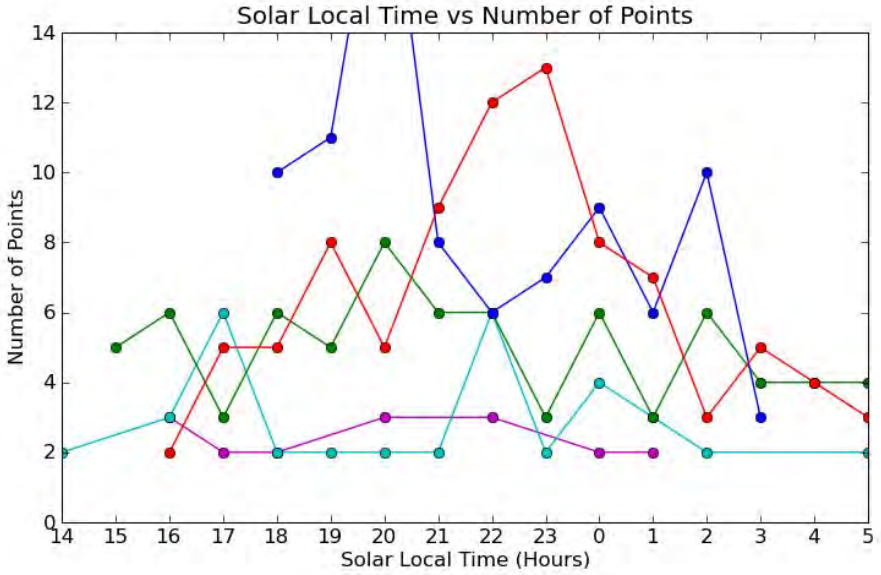

Integrated Pedersen Conductivity at SAPS Midpoint vs Slope
Slope (mho/degrees)
Integrated Pederson Conductivity (mho)
0.05
0.00
−0.05
−0.10
−0.15
−0.20
−0.25
−0.30
−0.35
−0.40
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
Altitude Range: 300 to 500 (km)
Slope: -0.129143106667±2.19193967394e-12
Coefficient of Determination: 0.402245996434

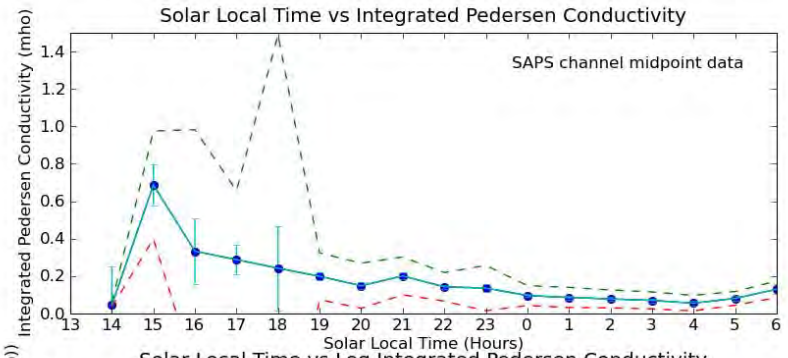

Coefficient of determination histogram
# Cases
Coefficient of Determination
25
20
15
10
5
0
−0.2
0.0
0.2
0.4
0.6
0.8
1.0

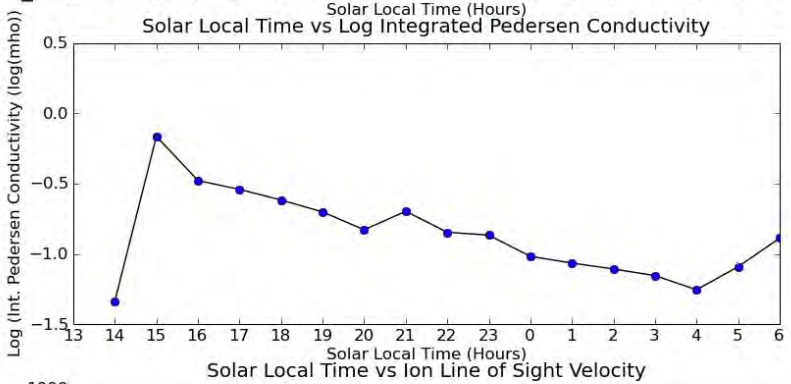

ntegrated Pedersen Conductivity at SAPS Midpoint vs Coefficient of Determinati
Coefficient of Determination
Integrated Pederson Conductivity (mho)
Altitude Range: 300 to 500 (km)
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6

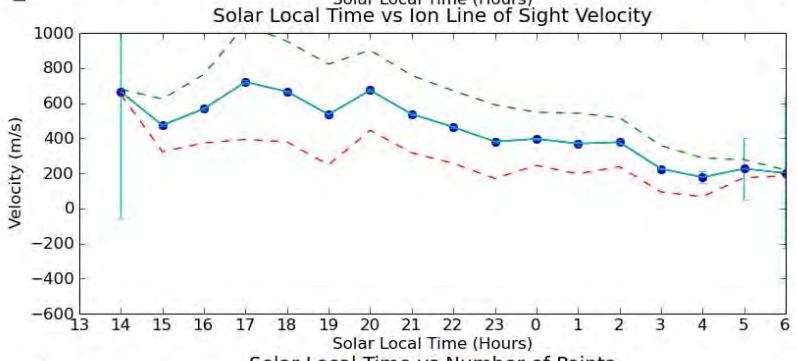

Magnetic Latitude vs Integrated Pedersen Conductivity
Integrated Pederson Conductivity (mho)
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
46
48
50
52
54
56
58
Magnetic Latitude (Degrees)
Scan Number: 1004
Midpoint date and time: 1990-09-21 09:08:46 (UTC)
Altitude Range: 300 to 500 (km)
Slope: -0.0164291732853±5.01433064666e-07
Coefficient of Determination: 0.995725828295

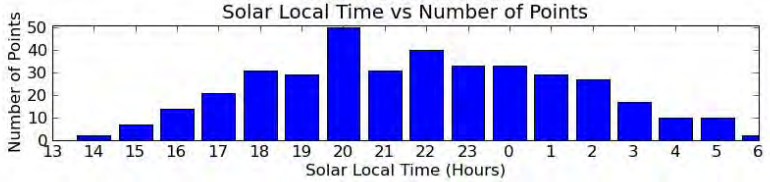

Solar Local Time vs Integrated Pedersen Conductivity
Integrated Pedersen Conductivity (mho)
Solar Local Time (Hours)
KP=7
KP=6
KP=5
KP=4
KP=3
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
14
15
16
17
18
19
20
21
22
23
0
1
2
3
4
5

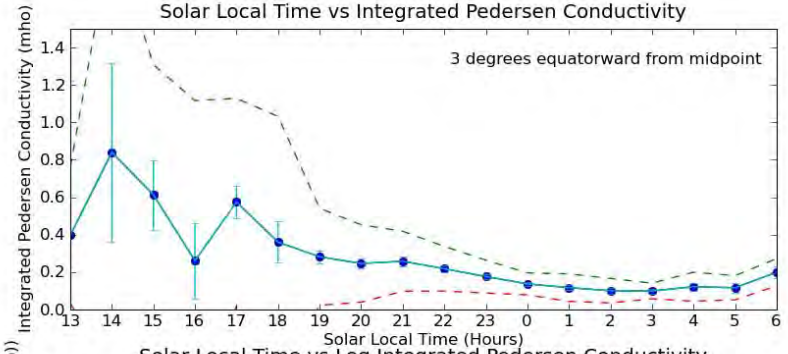

Solar Local Time vs Number of Points
Number of Points
Solar Local Time (Hours)
0
2
4
6
8
10
12
14
14
15
16
17
18
19
20
21
22
23
0
1
2
3
4
5

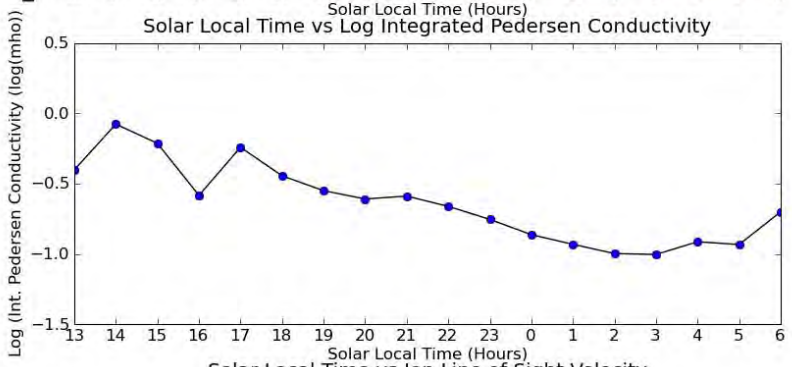

Solar Local Time vs Integrated Pedersen Conductivity
SAPS channel midpoint data
Integrated Pedersen Conductivity (mho)
Solar Local Time (Hours)

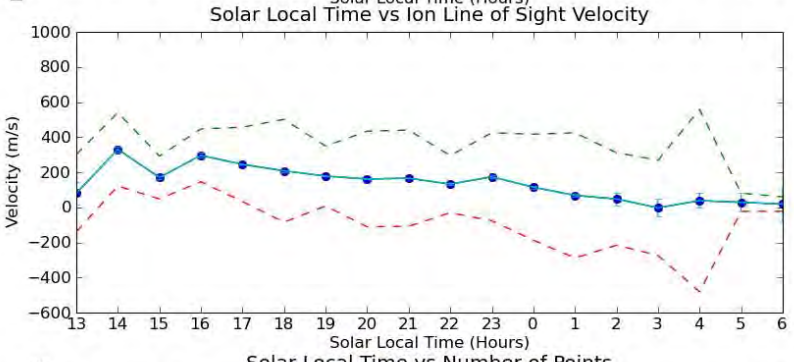

Solar Local Time vs Log Integrated Pedersen Conductivity
Log (Int. Pedersen Conductivity (log(mho))
Solar Local Time (Hours)

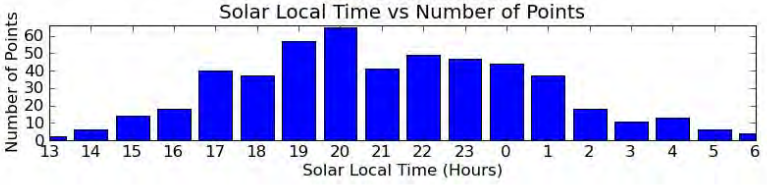

Solar Local Time vs Ion Line of Sight Velocity
Velocity (m/s)
Solar Local Time (Hours)

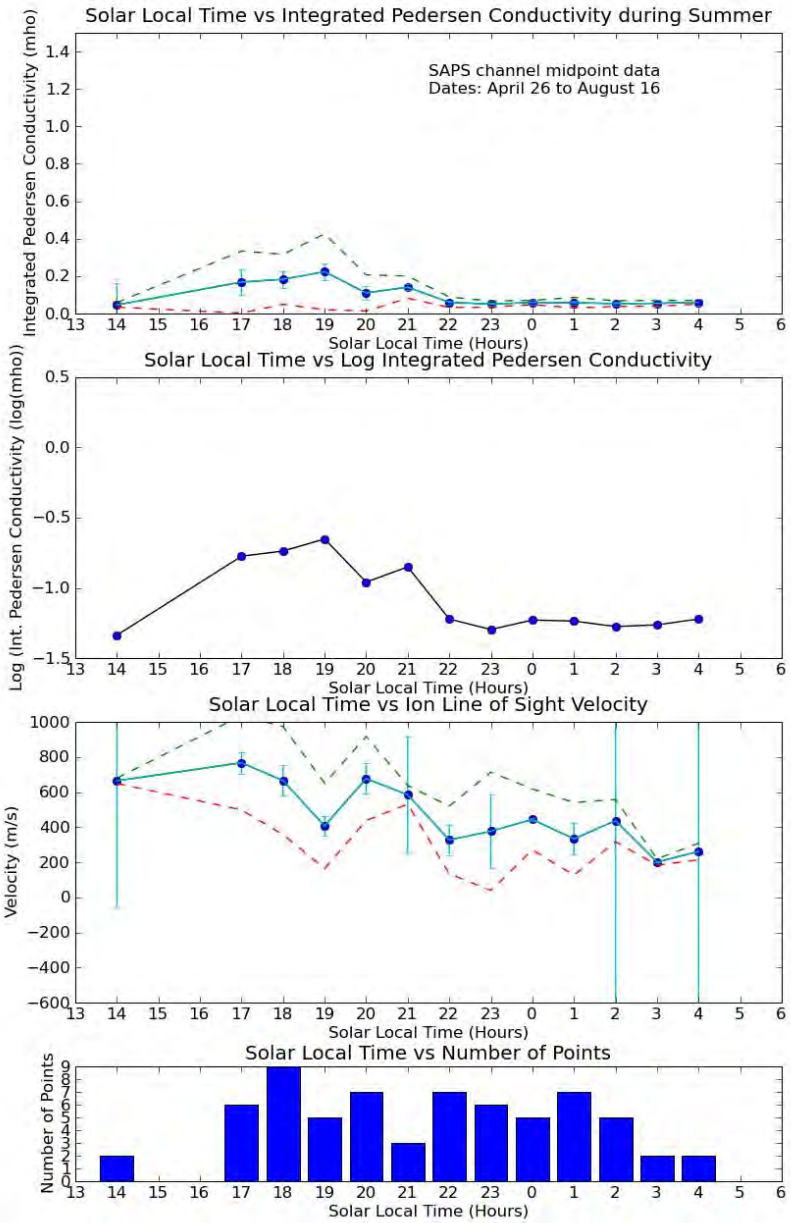

Solar Local Time vs Number of Points
Number of Points
Solar Local Time (Hours)

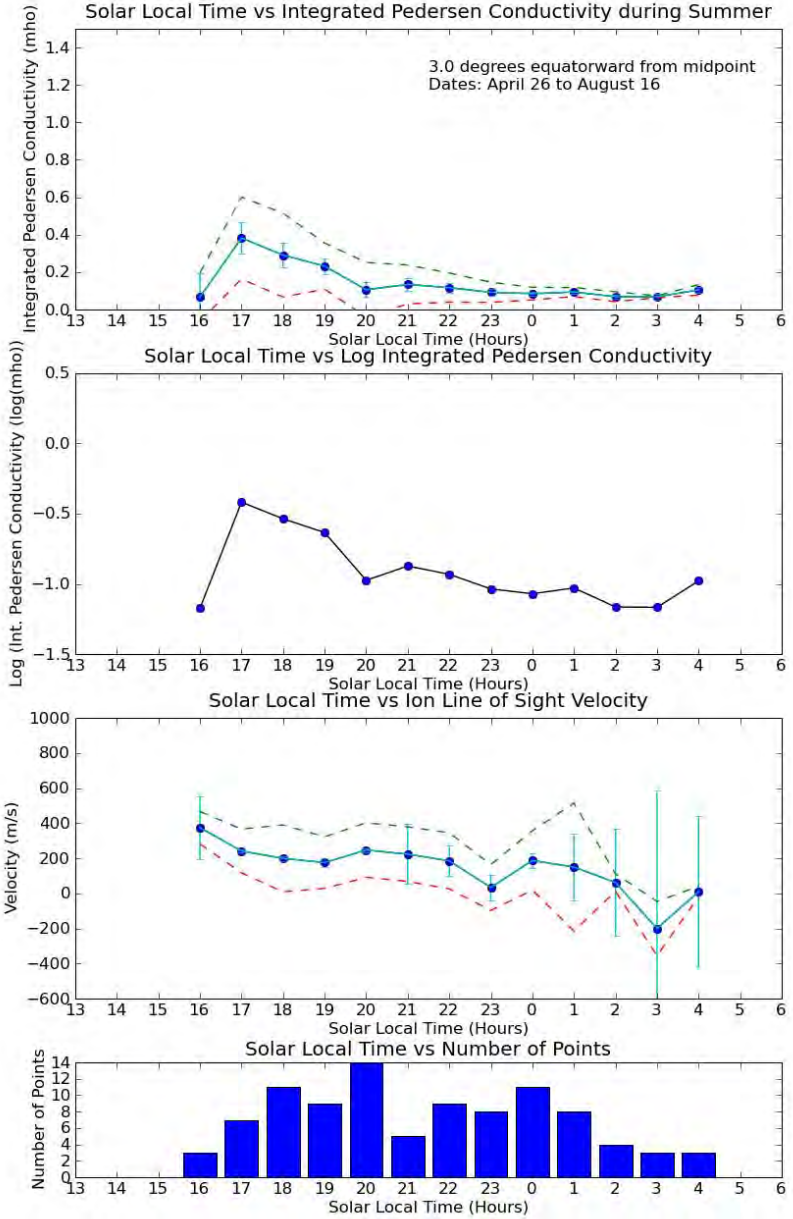

Solar Local Time vs Integrated Pedersen Conductivity
3 degrees equatorward from midpoint
Integrated Pedersen Conductivity (mho)
Solar Local Time (Hours)

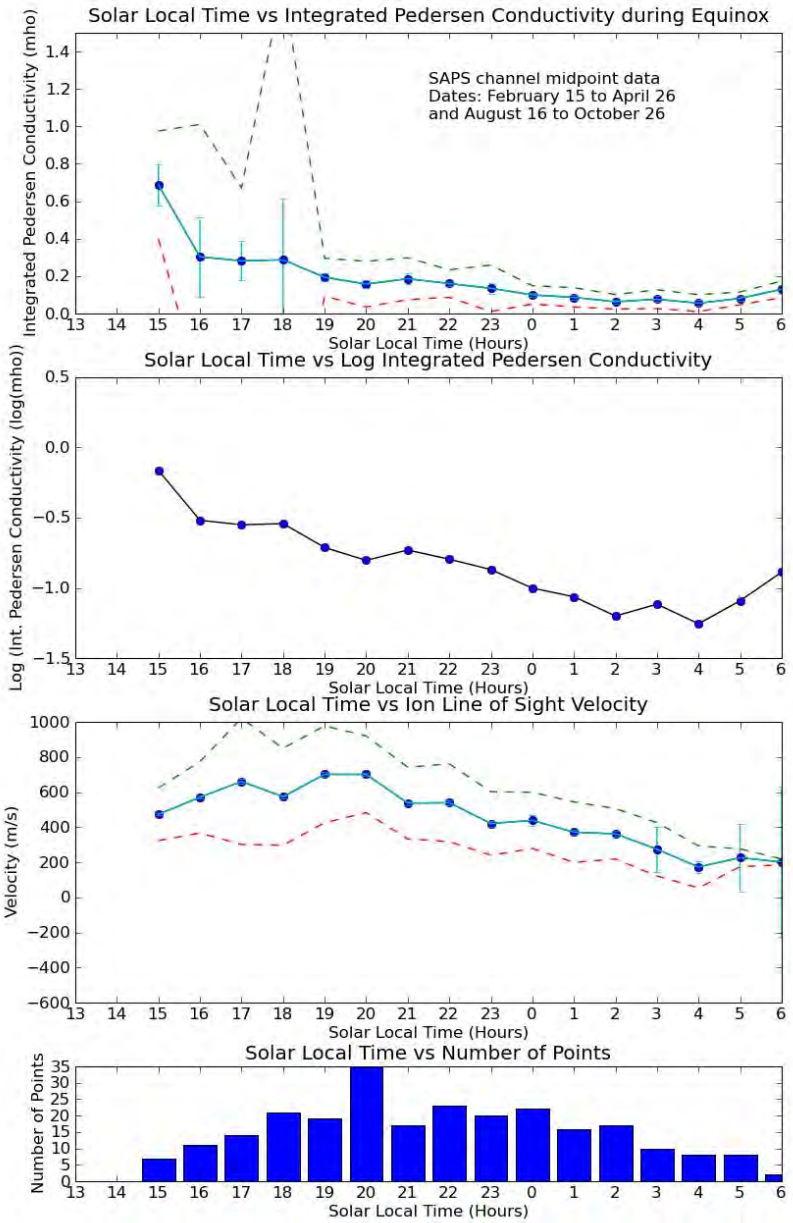

Solar Local Time vs Log Integrated Pedersen Conductivity
Log (Int. Pedersen Conductivity (log(mho))
Solar Local Time (Hours)

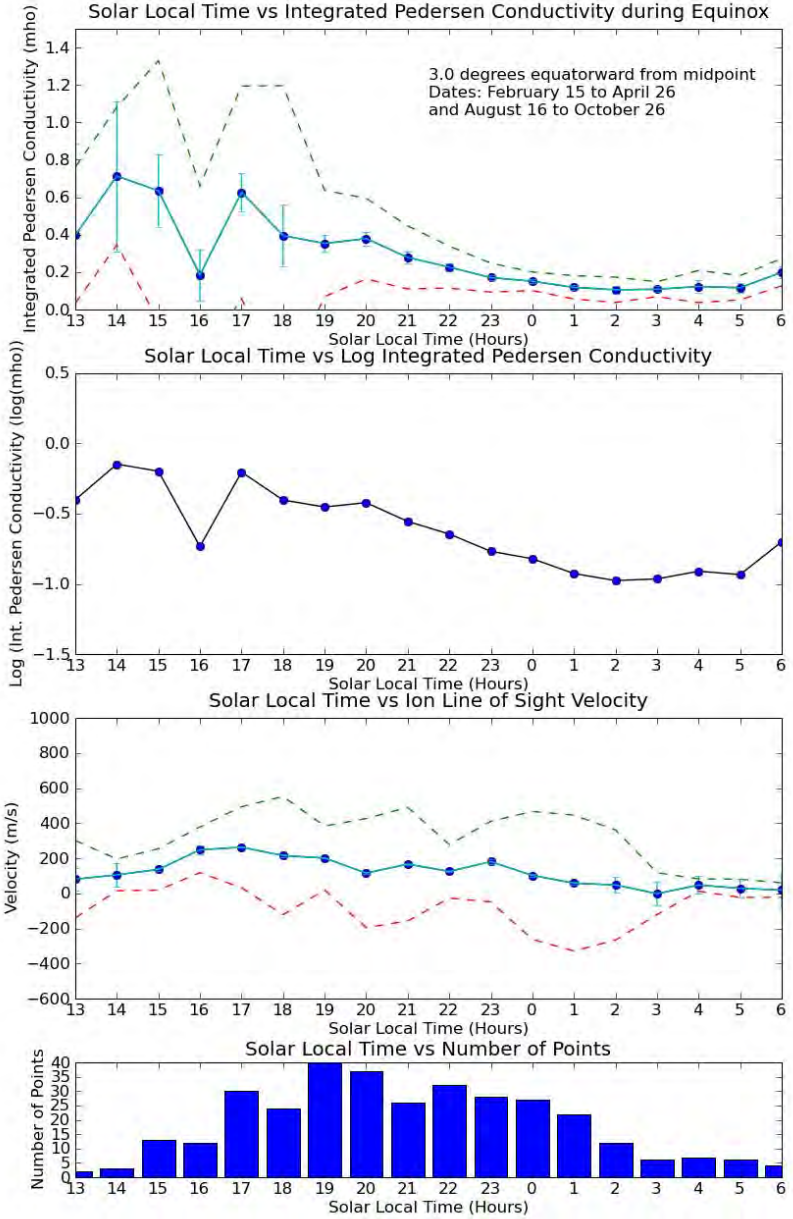

Solar Local Time vs Ion Line of Sight Velocity
Velocity (m/s)
Solar Local Time (Hours)

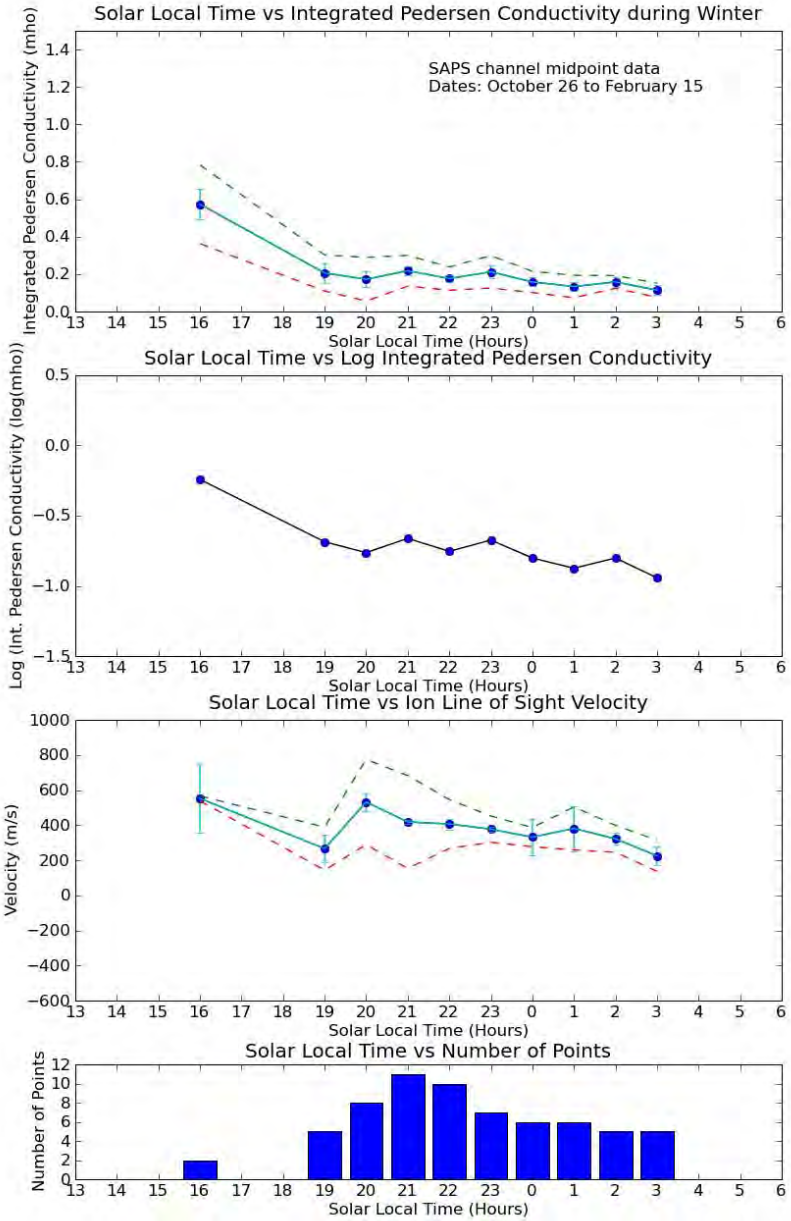

Solar Local Time vs Number of Points
Number of Points
Solar Local Time (Hours)

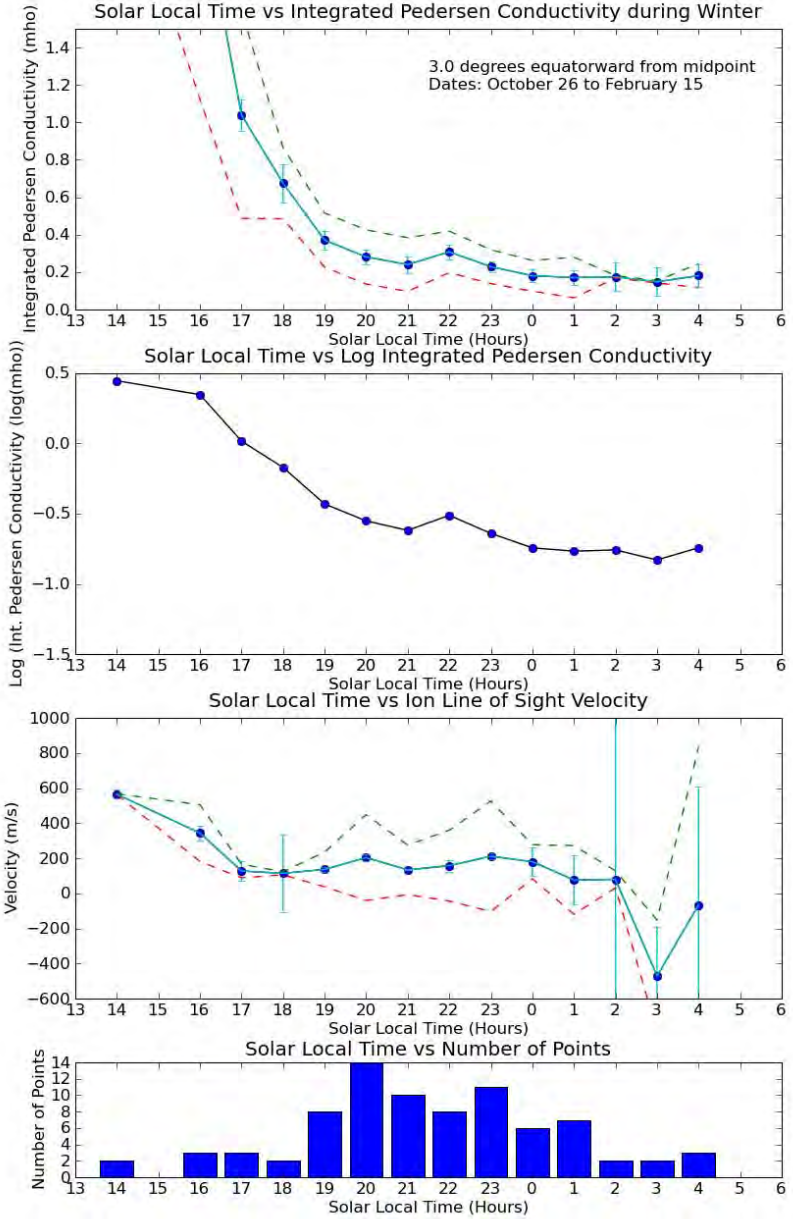

Solar Local Time vs Integrated Pedersen Conductivity during Summer
SAPS channel midpoint data
Dates: April 26 to August 16
Integrated Pedersen Conductivity (mho)
Solar Local Time (Hours)
Solar Local Time vs Log Integrated Pedersen Conductivity
Log (Int. Pedersen Conductivity (log(mho))
Solar Local Time (Hours)
Solar Local Time vs Ion Line of Sight Velocity
Velocity (m/s)
Solar Local Time (Hours)
Solar Local Time vs Number of Points
Number of Points
Solar Local Time (Hours)


Solar Local Time vs Integrated Pedersen Conductivity during Summer
3.0 degrees equatorward from midpoint
Dates: April 26 to August 16
Integrated Pedersen Conductivity (mho)
Solar Local Time (Hours)
Solar Local Time vs Log Integrated Pedersen Conductivity
Log (Int. Pedersen Conductivity (log(mho))
Solar Local Time (Hours)
Solar Local Time vs Ion Line of Sight Velocity
Velocity (m/s)
Solar Local Time (Hours)
Solar Local Time vs Number of Points
Number of Points
Solar Local Time (Hours)


Solar Local Time vs Integrated Pedersen Conductivity during Equinox
SAPS channel midpoint data
Dates: February 15 to April 26
and August 16 to October 26
Integrated Pedersen Conductivity (mho)
Solar Local Time (Hours)
Solar Local Time vs Log Integrated Pedersen Conductivity
Log (Int. Pedersen Conductivity (log(mho))
Solar Local Time (Hours)
Solar Local Time vs Ion Line of Sight Velocity
Velocity (m/s)
Solar Local Time (Hours)
Solar Local Time vs Number of Points
Number of Points
Solar Local Time (Hours)


Solar Local Time vs Integrated Pedersen Conductivity during Equinox
3.0 degrees equatorward from midpoint
Dates: February 15 to April 26
and August 16 to October 26
Integrated Pedersen Conductivity (mho)
Solar Local Time (Hours)
Solar Local Time vs Log Integrated Pedersen Conductivity
Log (Int. Pedersen Conductivity (log(mho))
Solar Local Time (Hours)
Solar Local Time vs Ion Line of Sight Velocity
Velocity (m/s)
Solar Local Time (Hours)
Solar Local Time vs Number of Points
Number of Points
Solar Local Time (Hours)


Solar Local Time vs Integrated Pedersen Conductivity during Winter
SAPS channel midpoint data
Dates: October 26 to February 15
Integrated Pedersen Conductivity (mho)
Solar Local Time (Hours)
Solar Local Time vs Log Integrated Pedersen Conductivity
Log (Int. Pedersen Conductivity (log(mho))
Solar Local Time (Hours)
Solar Local Time vs Ion Line of Sight Velocity
Velocity (m/s)
Solar Local Time (Hours)
Solar Local Time vs Number of Points
Number of Points
Solar Local Time (Hours)


Solar Local Time vs Integrated Pedersen Conductivity during Winter
3.0 degrees equatorward from midpoint
Dates: October 26 to February 15
Integrated Pedersen Conductivity (mho)
Solar Local Time (Hours)
Solar Local Time vs Log Integrated Pedersen Conductivity
Log (Int. Pedersen Conductivity (log(mho))
Solar Local Time (Hours)
Solar Local Time vs Ion Line of Sight Velocity
Velocity (m/s)
Solar Local Time (Hours)
Solar Local Time vs Number of Points
Number of Points
Solar Local Time (Hours)