Electron density estimates of the radar scattering volume for the Radio Receiver Instrument (RRI)-SuperDARN experiment

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Outline

- Introduction
- Velocity comparisons
- Determining electron density in scattering volume
- The RRI instrument on ePOP
- Conclusions

Doppler Velocities in a Refractive Medium

- SuperDARN measures Doppler shift of ionospheric echo
- Velocity of a scatterer, v_s, is:

$$v_s = \frac{1}{2}\frac{\Delta f_D}{f}\frac{c}{n_s}$$

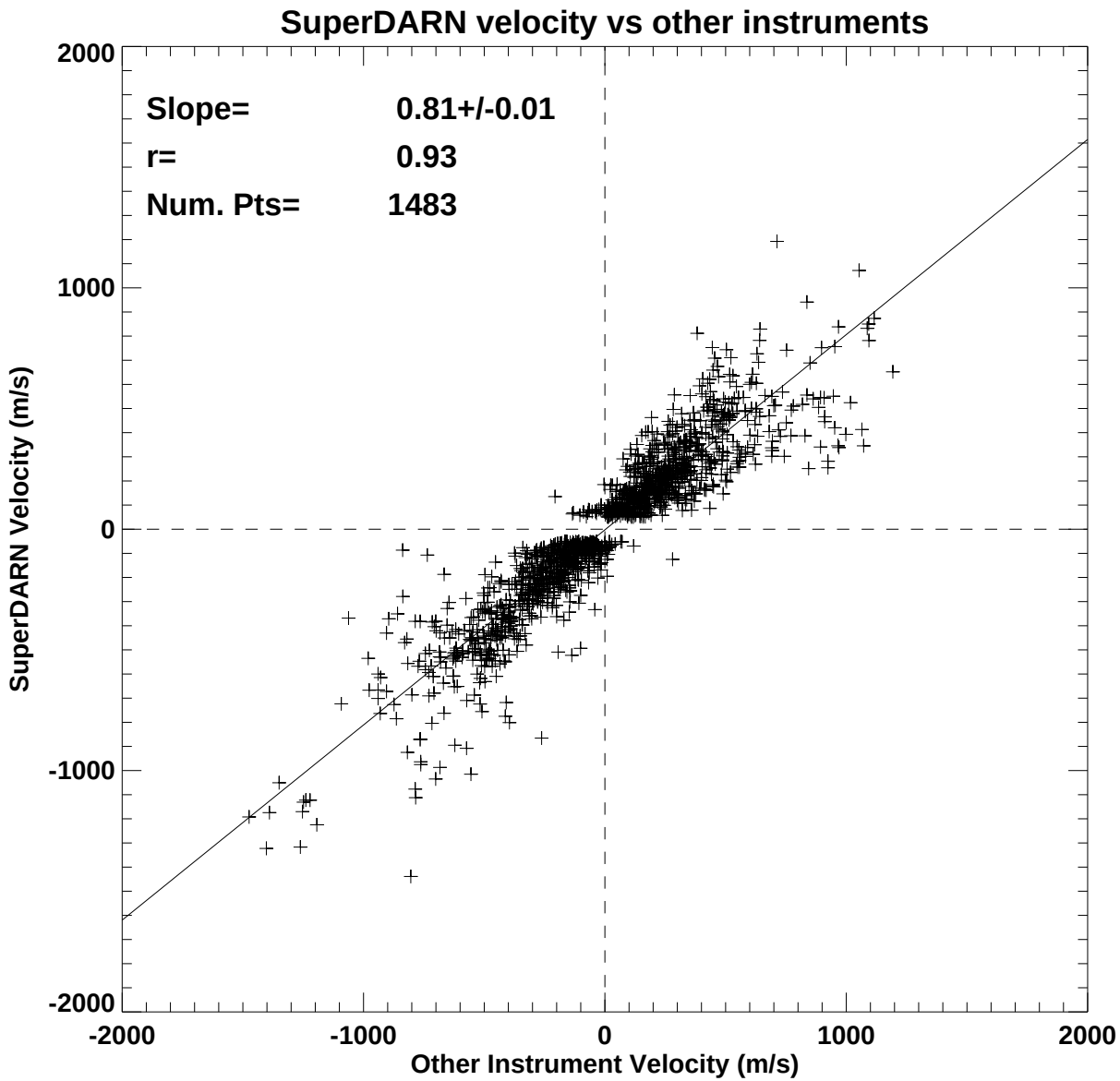
- Refractive index, n_s, has not been taken into account:

$$n_s = \sqrt{1 - f_p^2/f^2}$$

- Because n_s <1.0, SuperDARN underestimates velocity

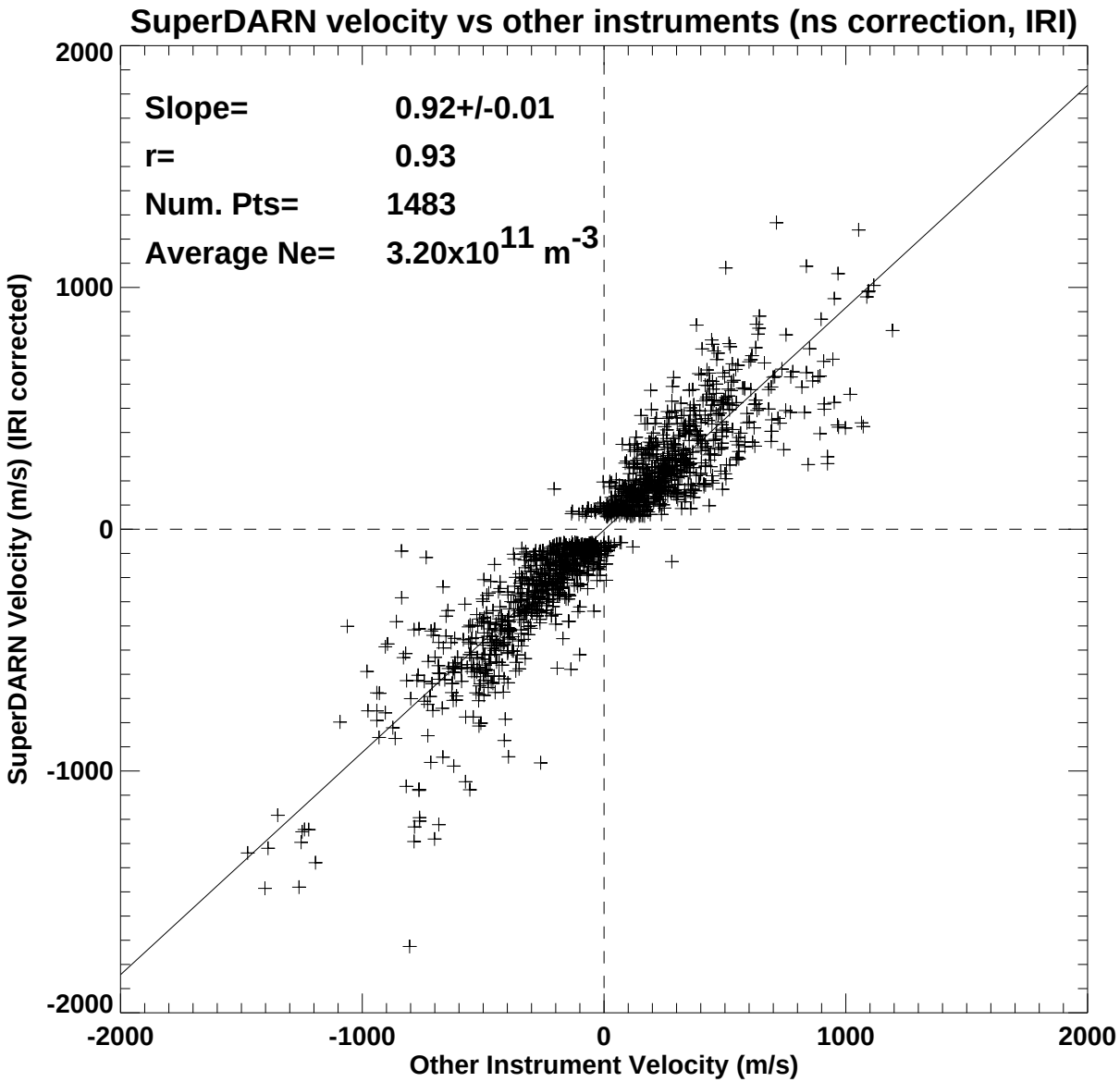
SuperDARN Velocity Comparisons

- Line-of-sight velocities compared:
  - Hankasalmi and EISCAT (1995–1999)
  - Various SuperDARN radars and DMSP (1999–2003)


SuperDARN velocity vs other instruments
Slope= 0.81+/-0.01
r= 0.93
Num. Pts= 1483
SuperDARN Velocity (m/s)
Other Instrument Velocity (m/s)
2000
1000
0
-1000
-2000
-2000
-1000
0
1000
2000

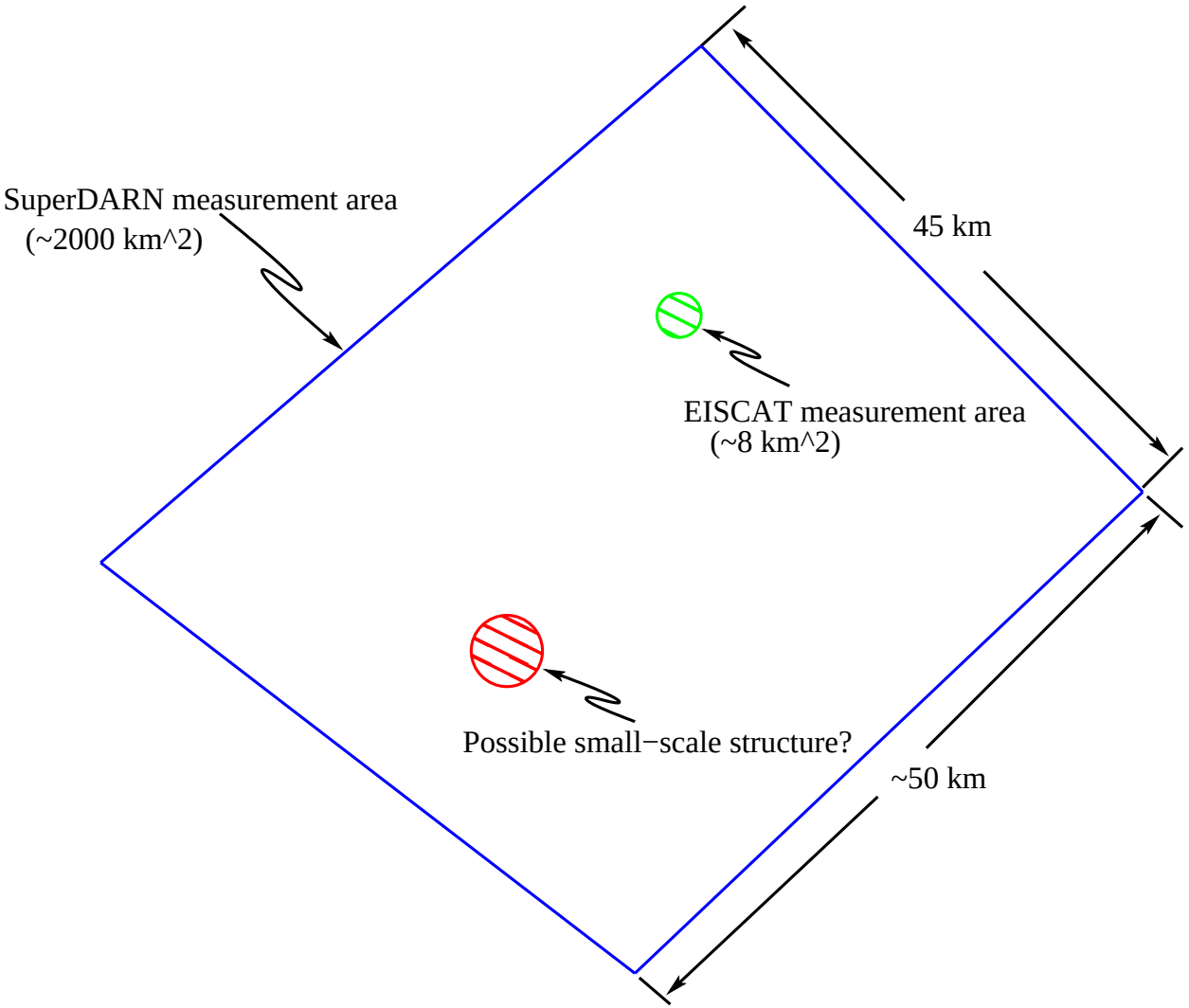
Refractive index estimates

- Problem: accurate refractive index estimates necessary for SuperDARN velocity measurements
- Solutions:
  - instruments to measure electron density (N_e)
  - elevation angle measurements by SuperDARN
  - International Reference Ionosphere (IRI) N_e values


SuperDARN velocity vs other instruments (ns correction, IRI)
Slope= 0.92+/-0.01
r= 0.93
Num. Pts= 1483
Average Ne= 3.20x10^11 m^-3
SuperDARN Velocity (m/s) (IRI corrected)
Other Instrument Velocity (m/s)
2000
1000
0
-1000
-2000
-2000
-1000
0
1000
2000

Velocity Comparison

- SuperDARN velocities ∼20% too low on average
- Typical average (background) n_s ∼0.9 (from IRI)
- Velocities only improved by 10%
- Theory: N_e in scattering volume of SuperDARN higher than background (and n_s lower)


SuperDARN measurement area
(~2000 km^2)
45 km
EISCAT measurement area
(~8 km^2)
Possible small−scale structure?
~50 km

Frequency shifting

- Velocity measured by SuperDARN v_m is lower than actual line-of-sight velocity v_s by a factor equal to refractive index n_s

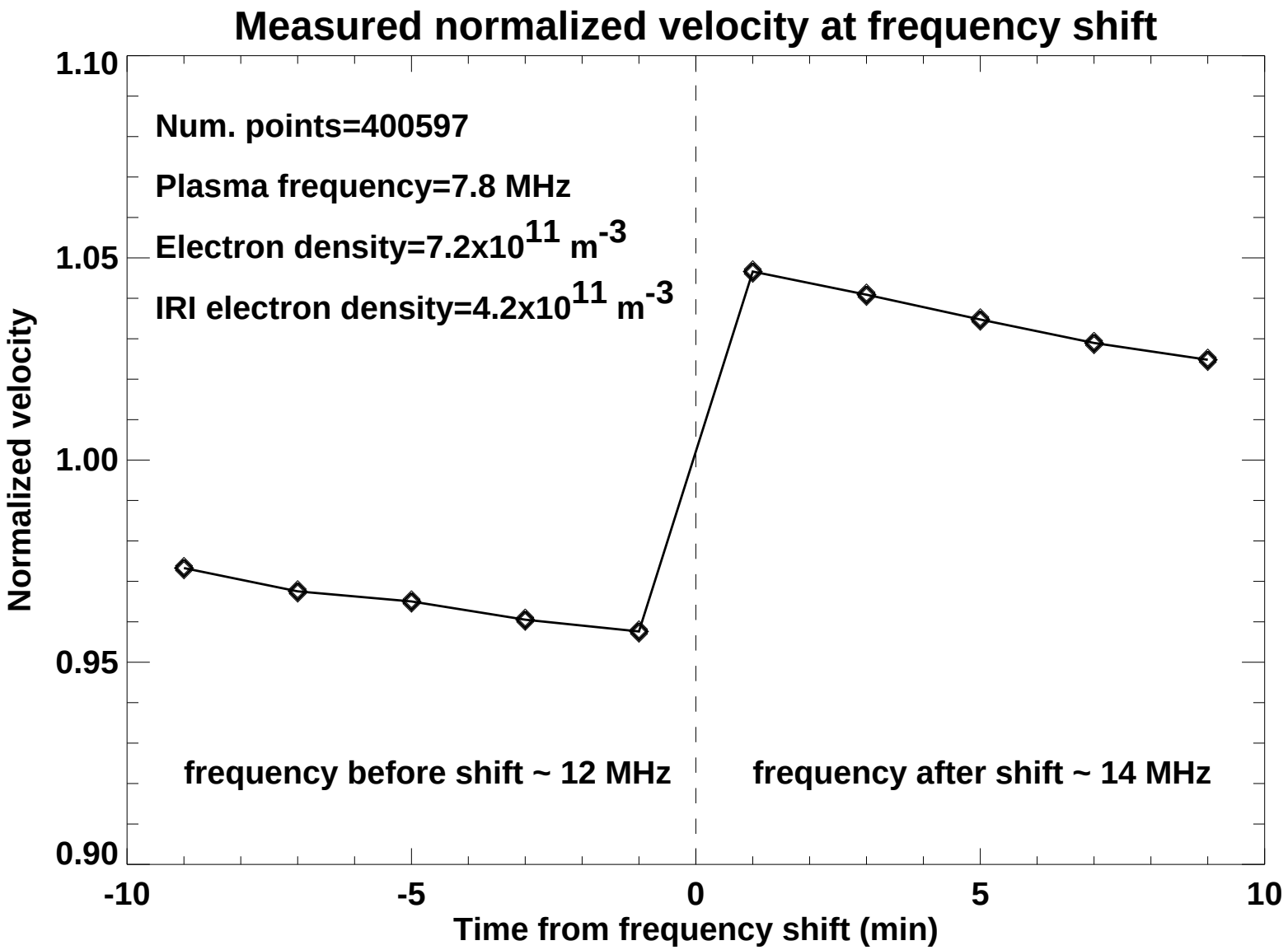
$$v_m = v_s n_s$$

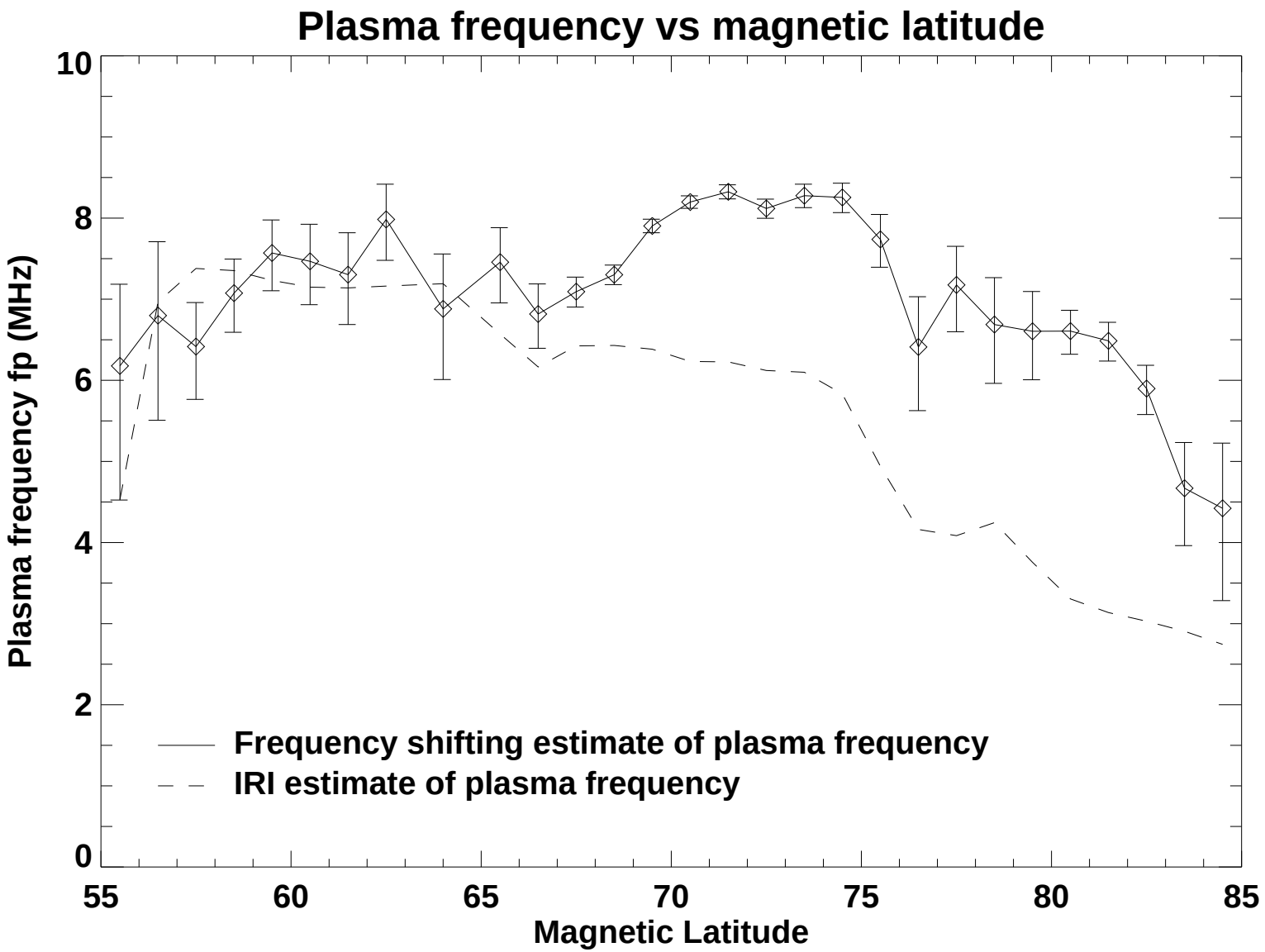
$$v_m = v_s \sqrt{1 - f_p^2 / f^2}$$

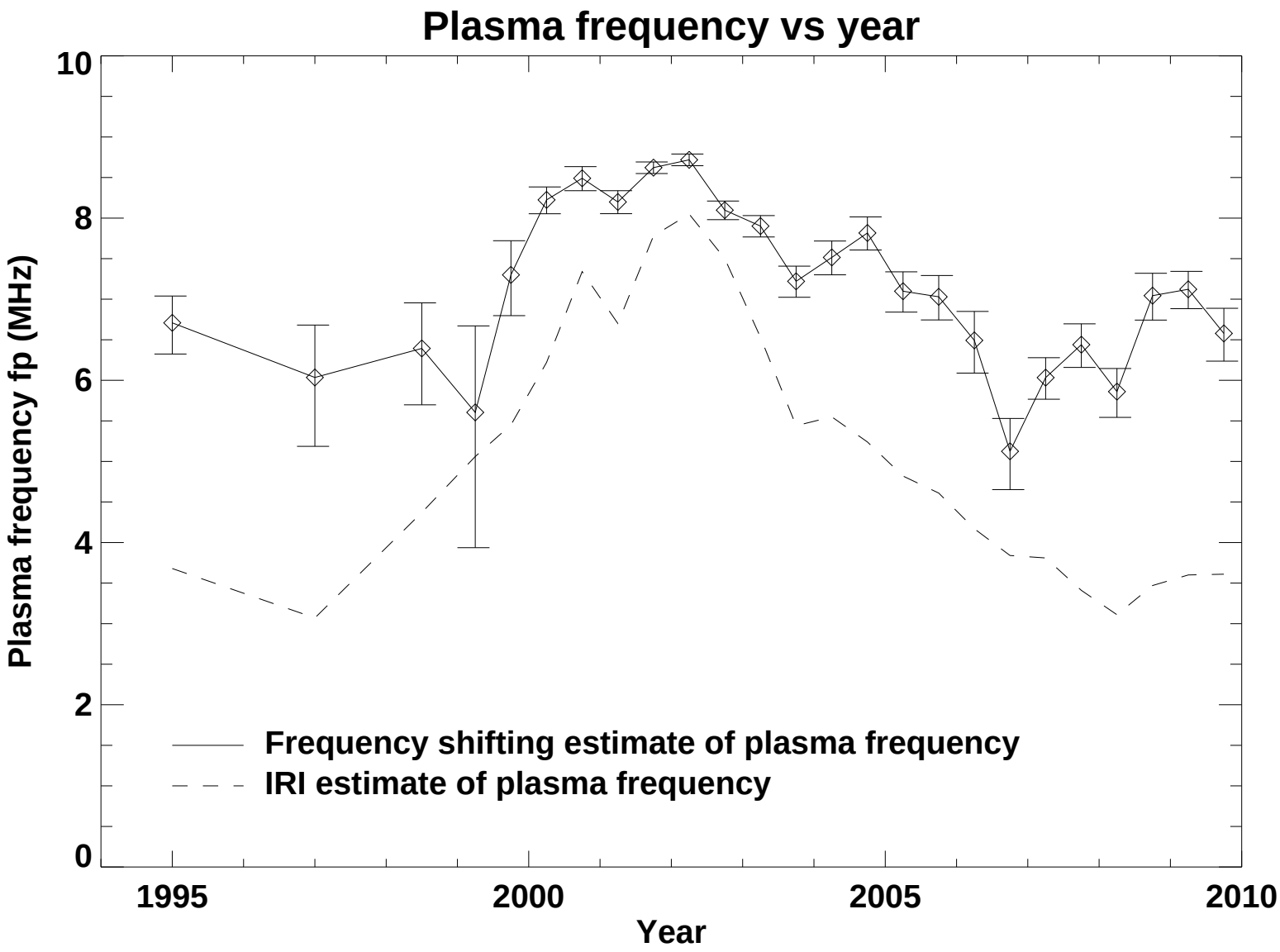
- Change of f causes change of v_m
- A measure of Δv_m from Δf gives estimate of f_p

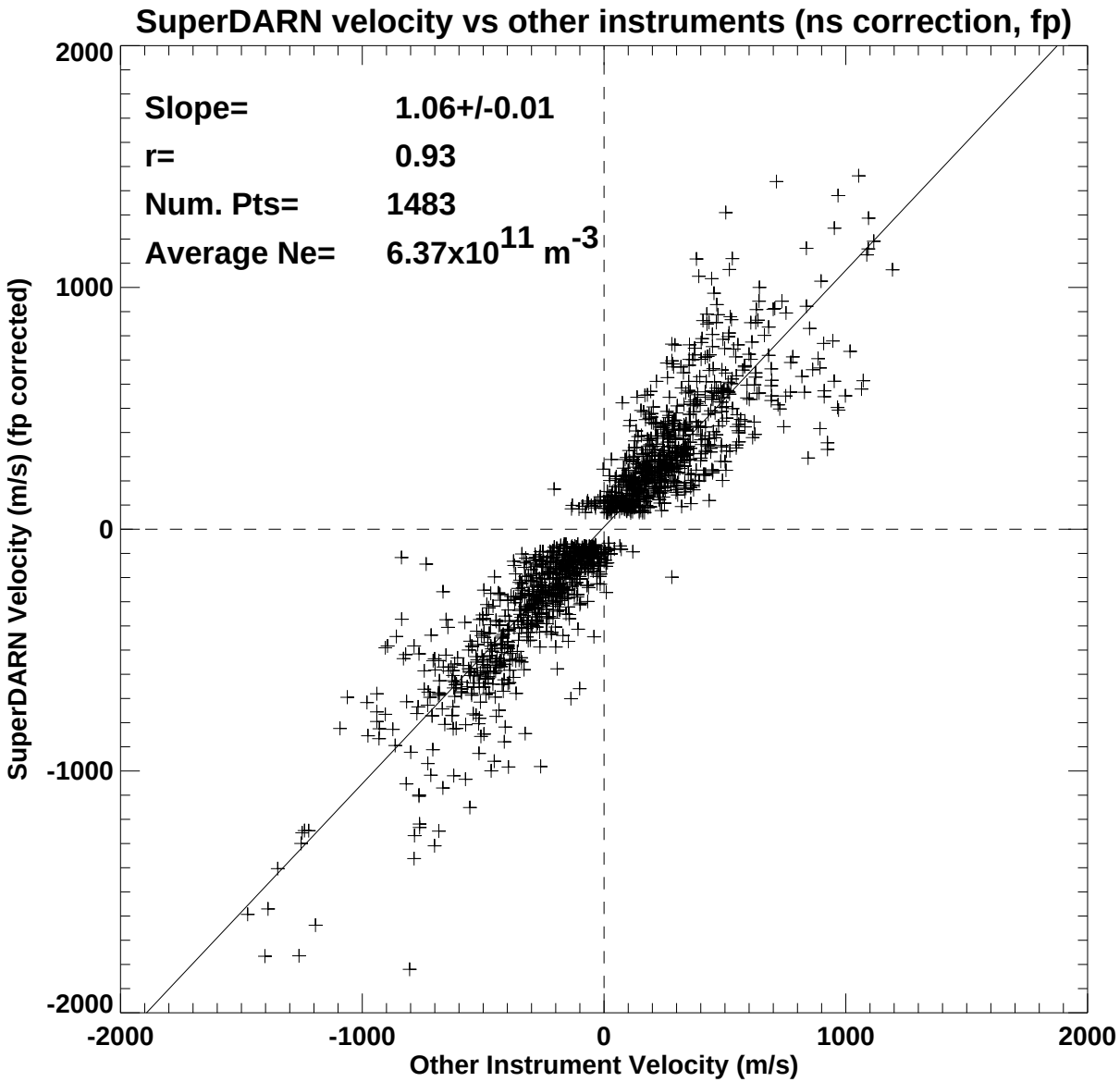
Frequency Shifting Analysis

- SuperDARN radars routinely change frequency
- All SuperDARN data used (nearly 20 years, over 20 radars)
- Frequency shifts of $>$0.5 MHz examined
- Superposed epoch analysis of velocities before and after shifts performed

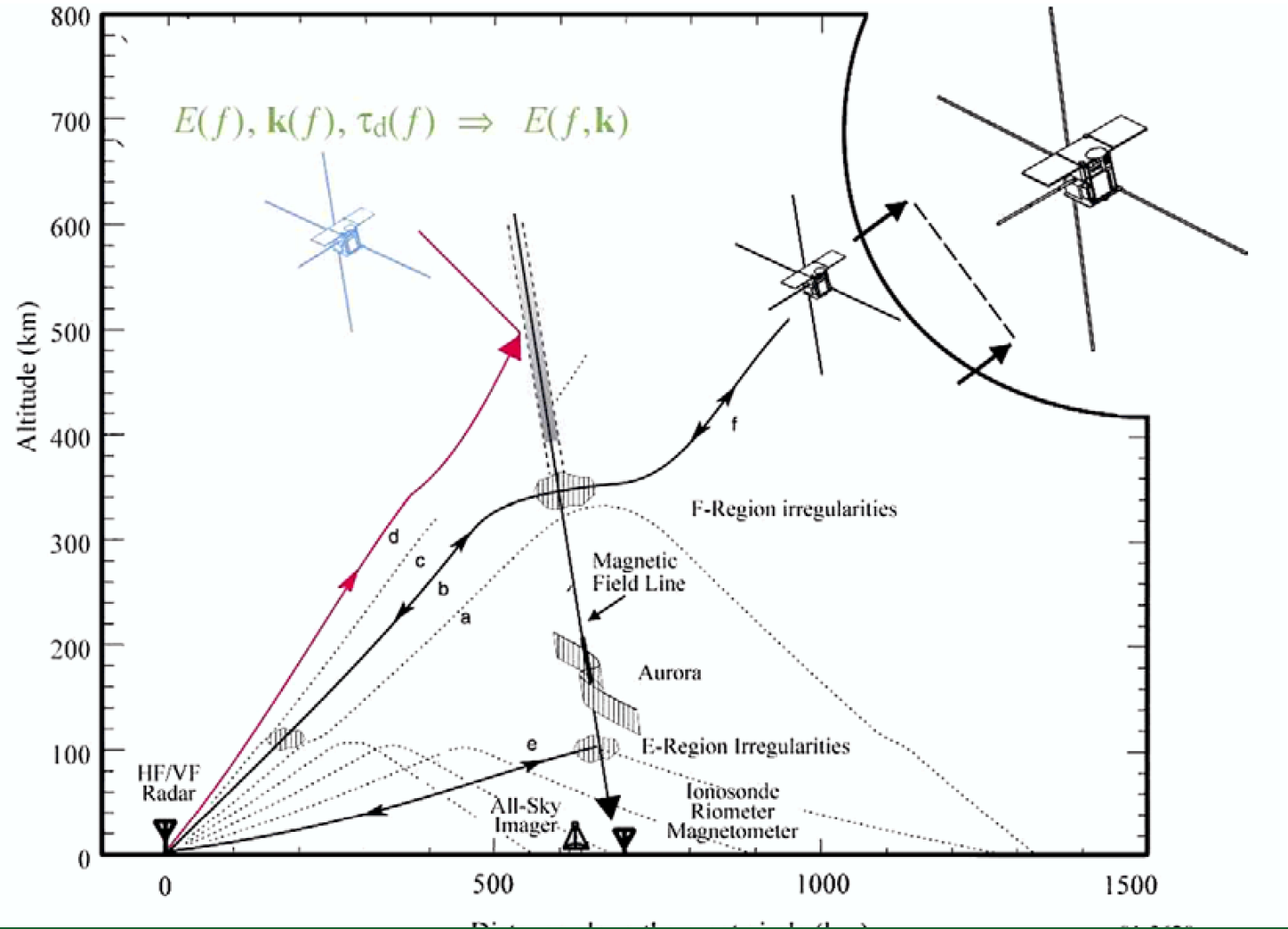

Measured normalized velocity at frequency shift
Num. points=400597
Plasma frequency=7.8 MHz
Electron density=7.2x10^11 m^-3
IRI electron density=4.2x10^11 m^-3
frequency before shift ~ 12 MHz
frequency after shift ~ 14 MHz
Normalized velocity
1.10
1.05
1.00
0.95
0.90
-10
-5
0
5
10
Time from frequency shift (min)

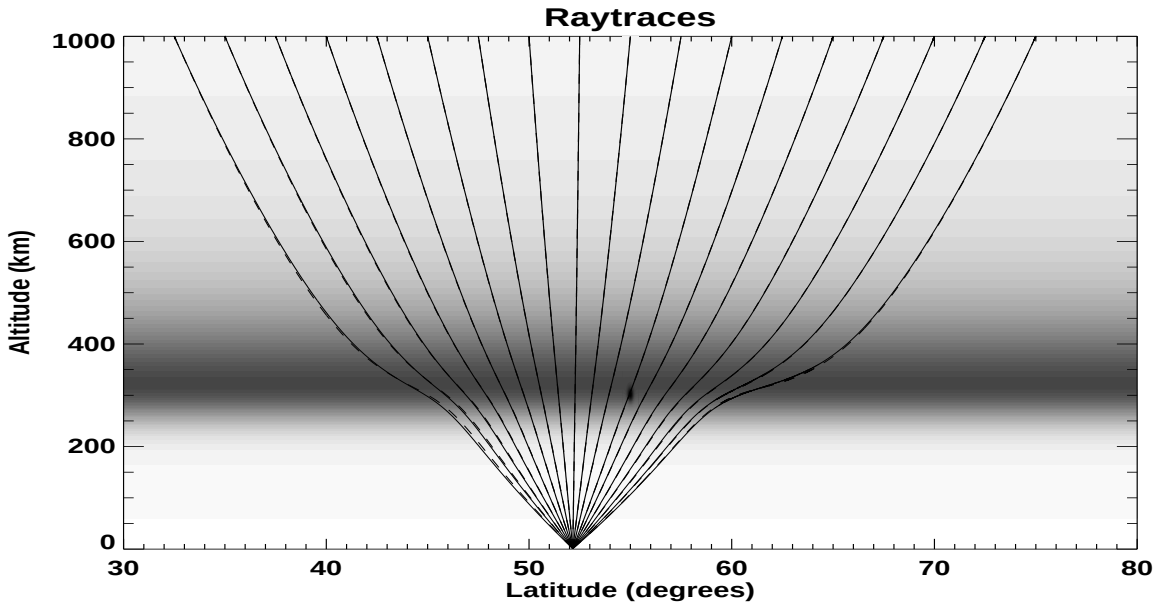

Plasma frequency vs magnetic latitude
Plasma frequency fp (MHz)
Magnetic Latitude
0
2
4
6
8
10
55
60
65
70
75
80
85
Frequency shifting estimate of plasma frequency
IRI estimate of plasma frequency

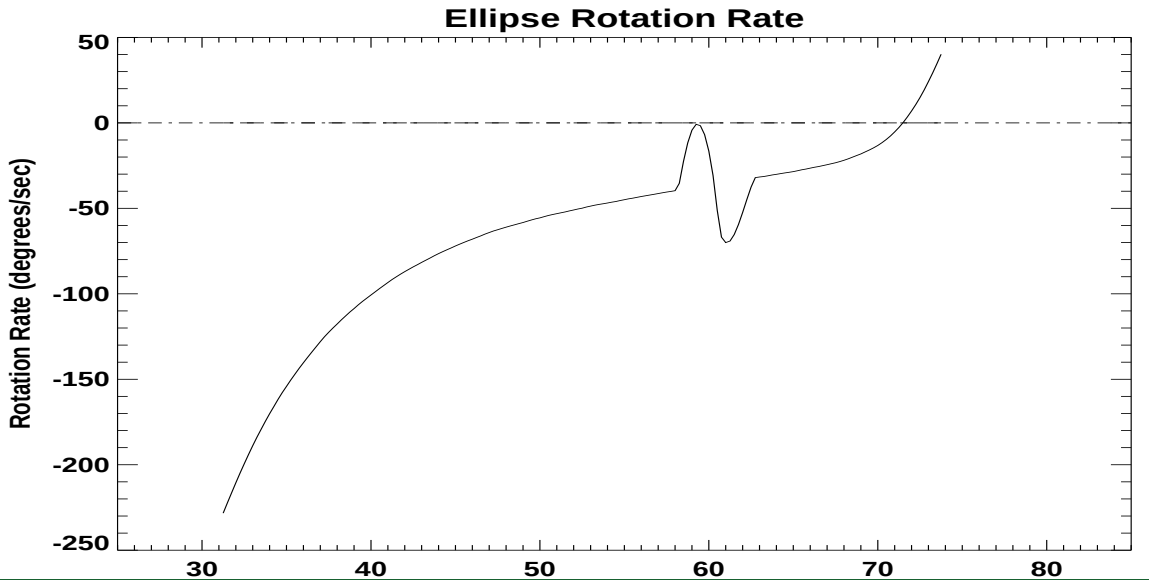

Plasma frequency vs year
Plasma frequency fp (MHz)
10
8
6
4
2
0
1995
2000
2005
2010
Year
Frequency shifting estimate of plasma frequency
IRI estimate of plasma frequency


SuperDARN velocity vs other instruments (ns correction, fp)
Slope= 1.06+/-0.01
r= 0.93
Num. Pts= 1483
Average Ne= 6.37x10^11 m^-3
SuperDARN Velocity (m/s) (fp corrected)
Other Instrument Velocity (m/s)
2000
1000
0
-1000
-2000
-2000
-1000
0
1000
2000

RRI-SuperDARN experiment




Raytraces
Altitude (km)
1000
800
600
400
200
0
30
40
50
60
70
80
Latitude (degrees)


Ellipse Rotation Rate
Rotation Rate (degrees/sec)
50
0
-50
-100
-150
-200
-250
30
40
50
60
70
80

Conclusions

- Less-than-unity n_s causes underestimation of line-of-sight velocities by SuperDARN
- Various methods have been developed to estimate refractive index
- Results indicate that electron density in SuperDARN scattering volume is significantly higher than background
- Application of new measured refractive index values from frequency shifting analysis improves velocities
- ePOP measurements of scattering volume are greatly anticipated