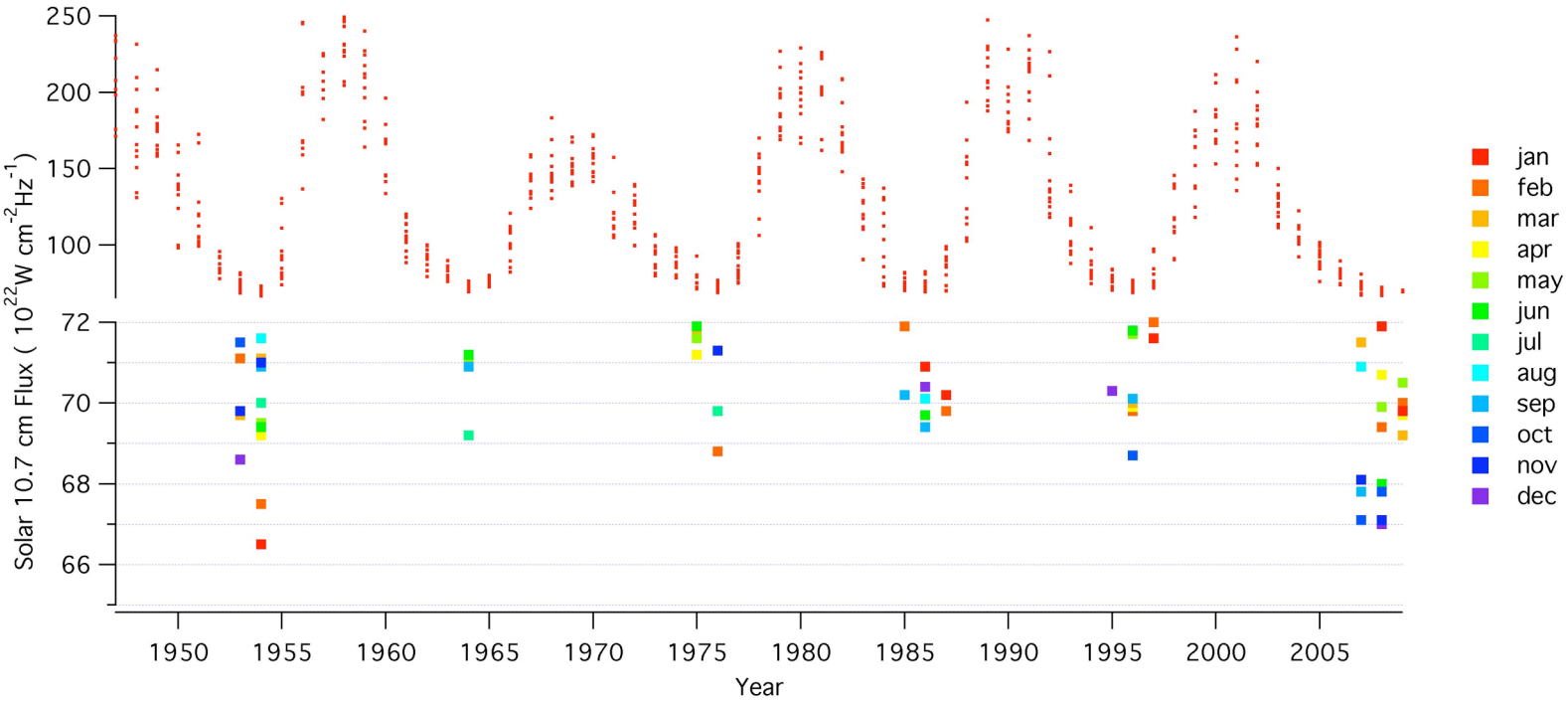
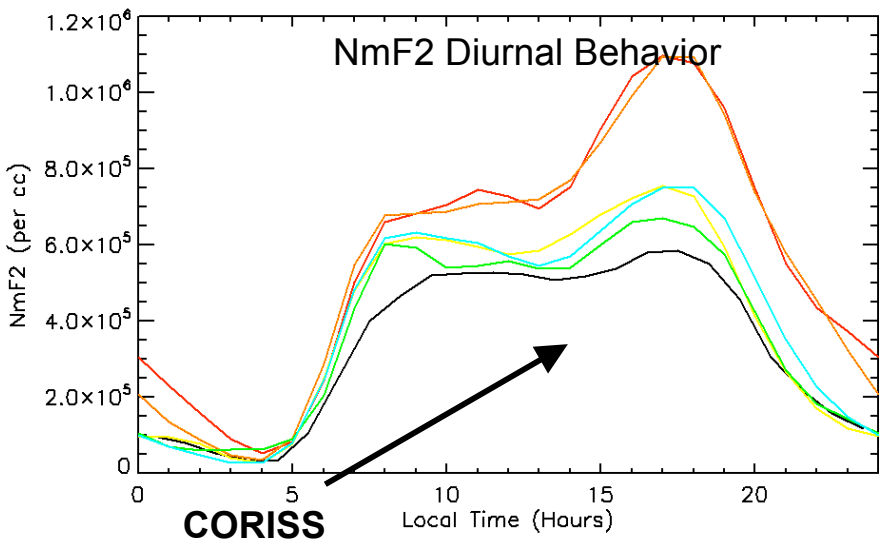
New Results from the C/NOFS Program

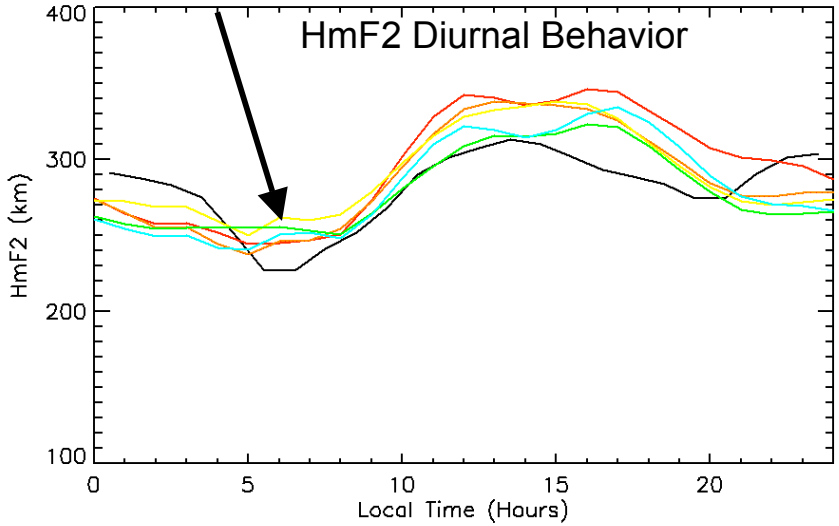
The C/NOFS Team and Science Community

A view of the Ionosphere in a Prolonged Solar Minimum



Thin and Contracted Ionosphere Revealed in GPS Occultation





Strauss and Bishop, 2009

Climatology:
(SSN=0)

Latitude +7.5º
Longitude +30º

Mid-April
Mid-May
Mid-June
Mid-July
Mid-August

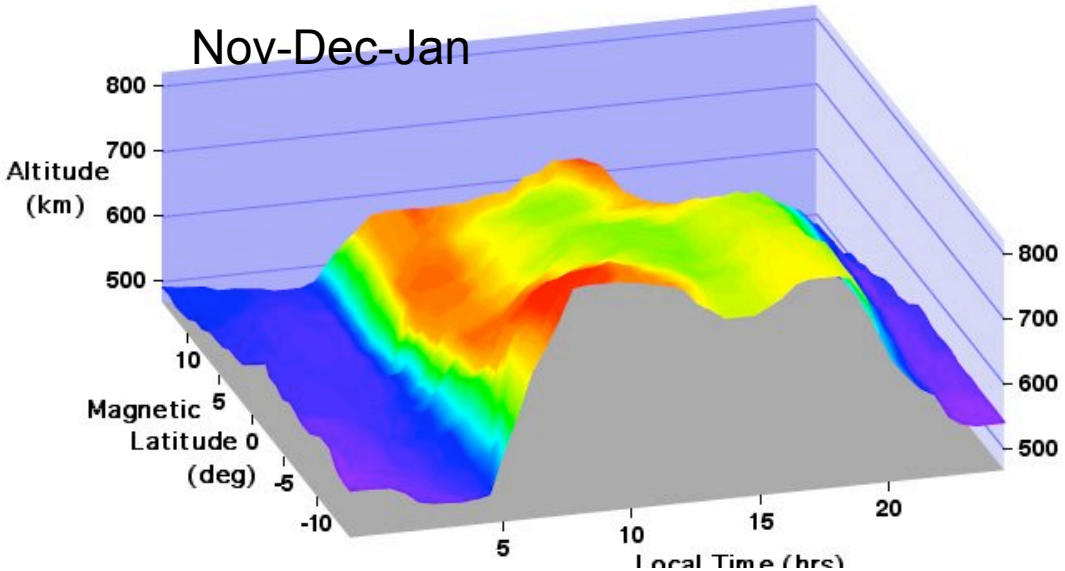
- **HmF2**

- Max 300 km during daytime
- Min 240 km during nighttime

- **NmF2**

- 1 x10^6 cm^{-3} at pre-sunset max.
- 4 x 10^4 cm^{-3} at pre-sunrise min

O+/H+ Transition Height - The extent of the ionosphere

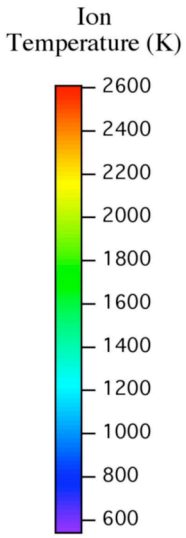


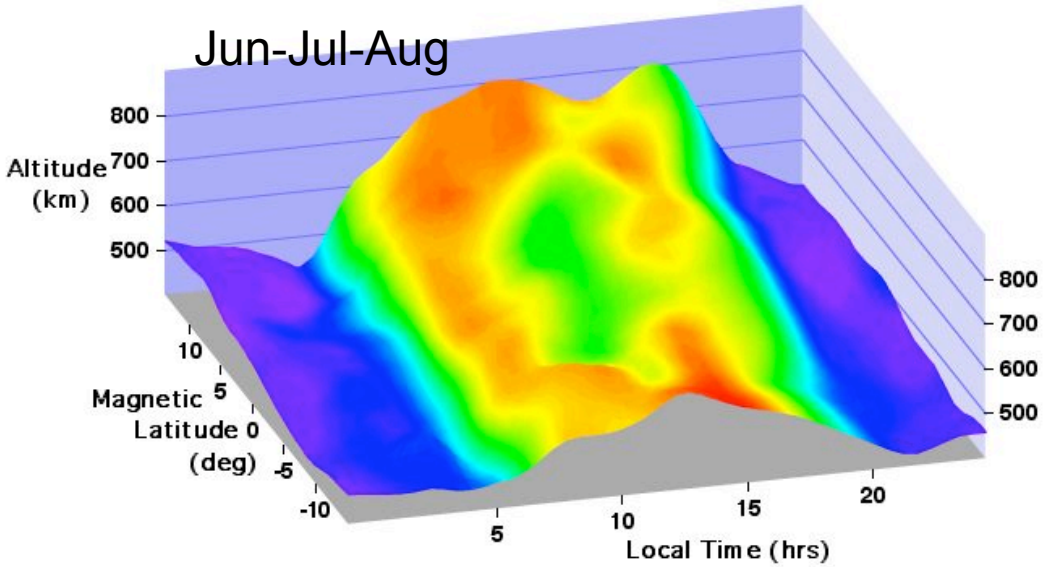
- **Seasonal Hemispheric Asymmetry**

- 800 km during daytime summer
- 650 km during daytime winter
- 440 km at night pre-sunrise

- **Post sunrise temperature surge**

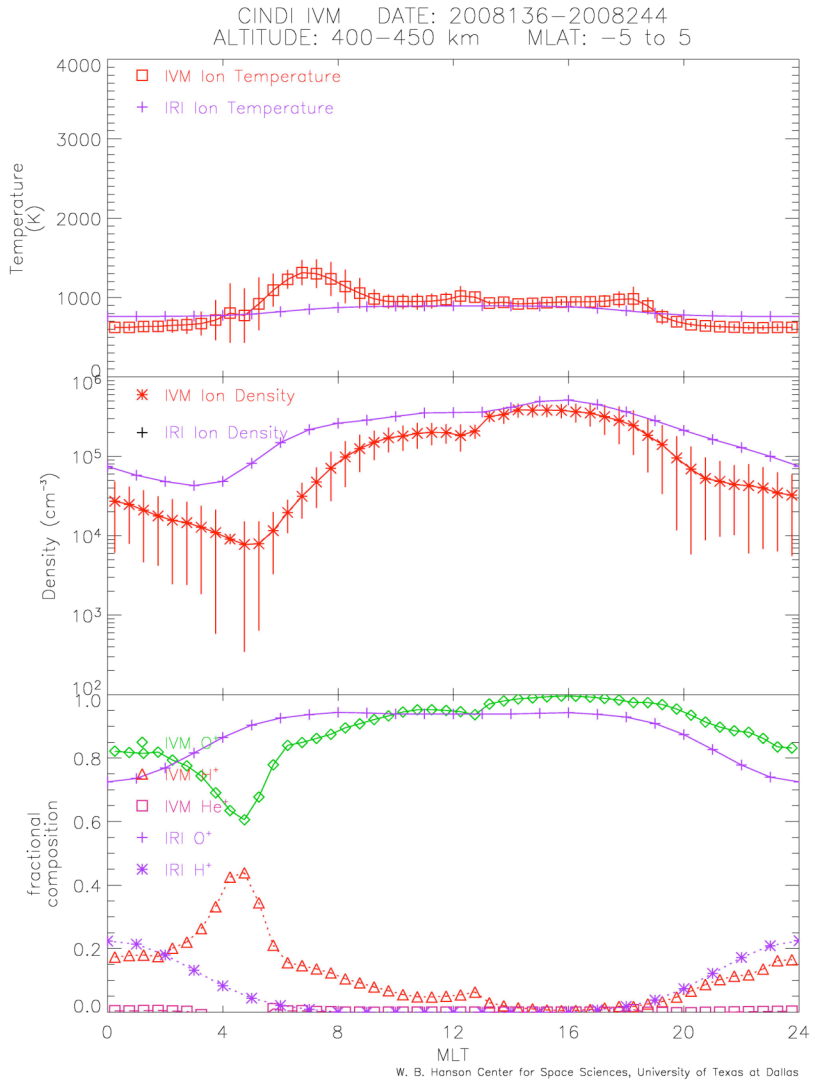
- 2600 K at transition altitude.





Heelis et al., 2009

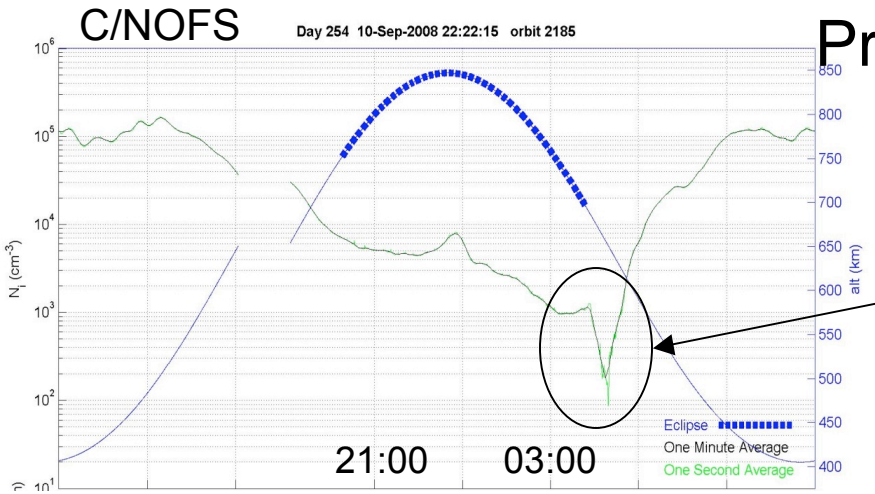
The Background Topside Ionosphere near 400 km !!



- Ion Temperature
  - 900 K during daytime
  - 600 K at night
- Total Ion Density
  - < 4 x 10^5 cm^{-3} during daytime
  - < 9 x 10^3 cm^{-3} pre-sunrise
  - Highly variable local minima near sunrise
- Ion Composition
  - 100% O+ during daytime
  - 50% O+ 50% H+ at night

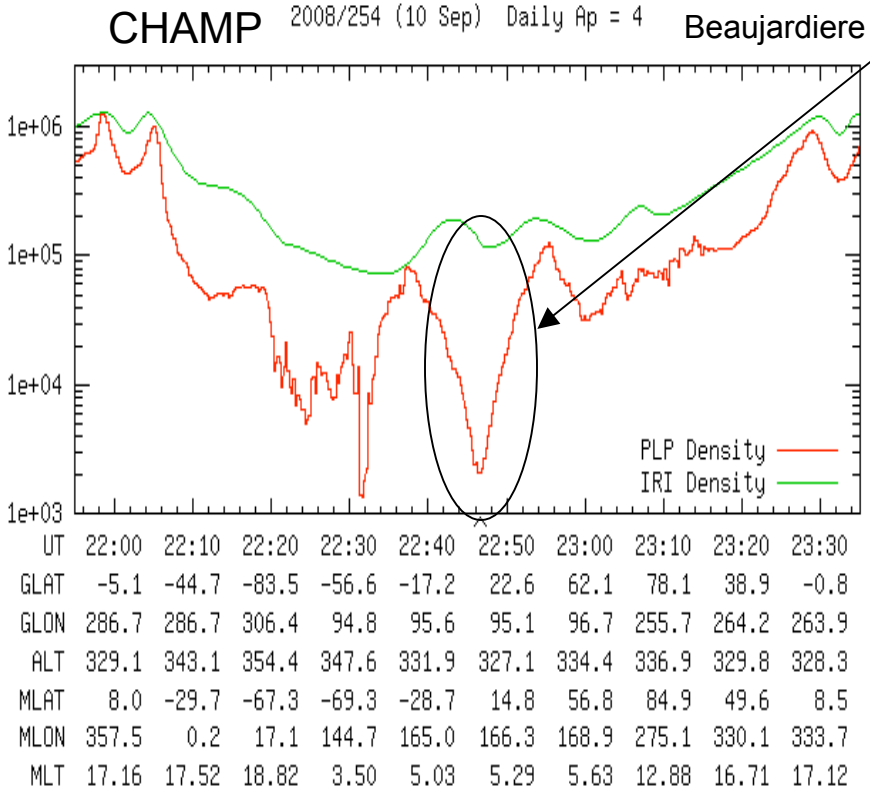
Coley et al. 2009

Pre-sunrise F-region ion density 2-Dimensional Picture



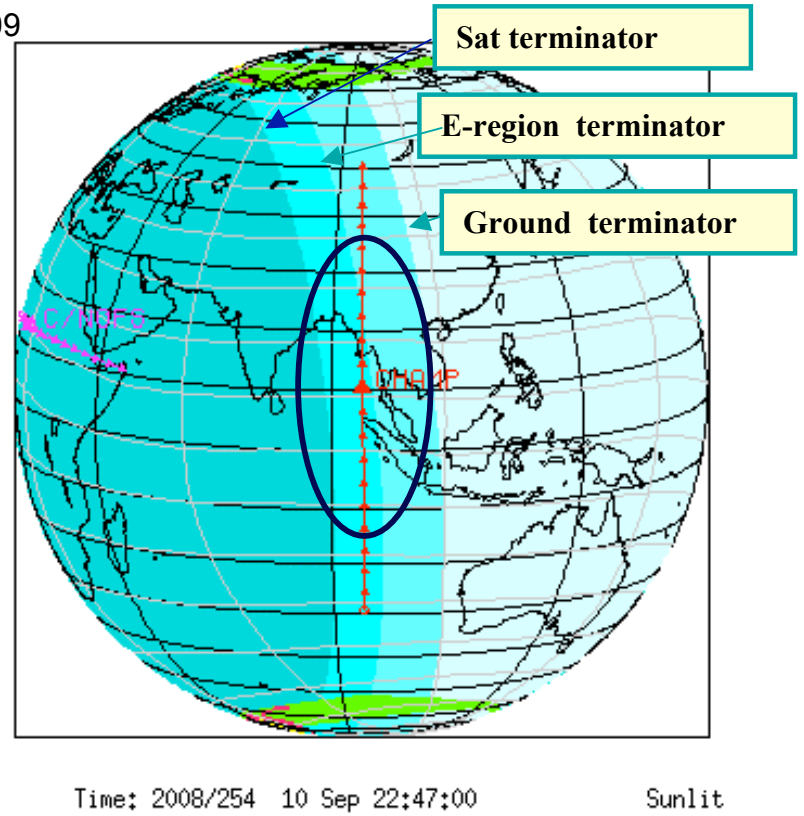
- **C/NOFS Local Minimum**
  - Local time extent of ~1 hour

- **CHAMP Local Minimum**
  - Latitude extent ~40 degrees



UT	22:00	22:10	22:20	22:30	22:40	22:50	23:00	23:10	23:20	23:30
GLAT	-5.1	-44.7	-83.5	-56.6	-17.2	22.6	62.1	78.1	38.9	-0.8
GLON	286.7	286.7	306.4	94.8	95.6	95.1	96.7	255.7	264.2	263.9
ALT	329.1	343.1	354.4	347.6	331.9	327.1	334.4	336.9	329.8	328.3
MLAT	8.0	-29.7	-67.3	-69.3	-28.7	14.8	56.8	84.9	49.6	8.5
MLON	357.5	0.2	17.1	144.7	165.0	166.3	168.9	275.1	330.1	333.7
MLT	17.16	17.52	18.82	3.50	5.03	5.29	5.63	12.88	16.71	17.12

Beaujardiere et al., 2009

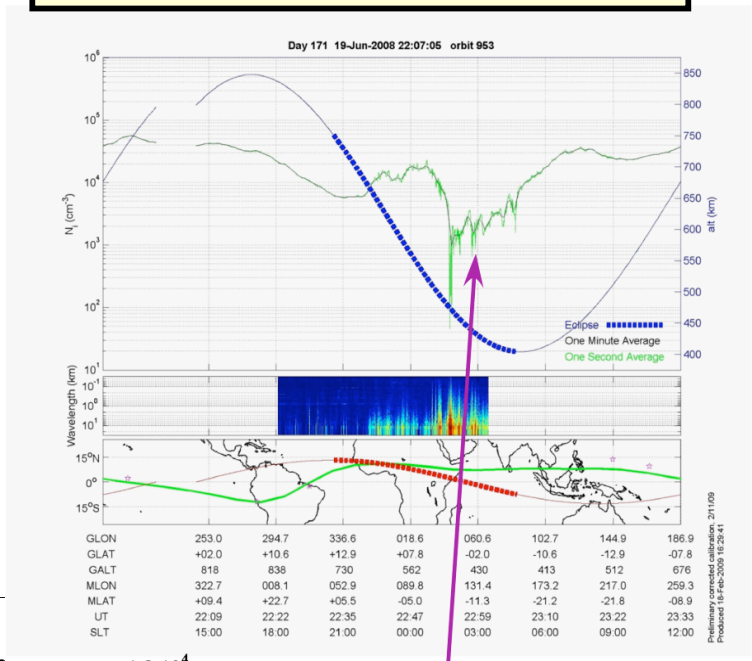


Anomalies in Equatorial Ion and Neutral Densities

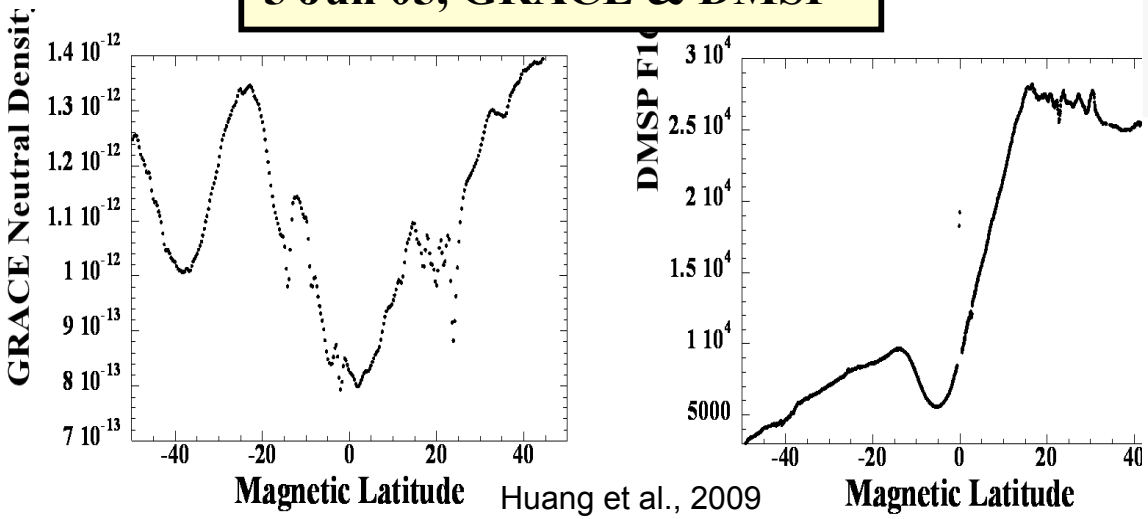
C/NOFS and DMSP suggest
- Local minimum in ion density at the equator
- Irregularities appear after sunset.
- Irregularities frequently maximize in intensity near midnight

DMSP and GRACE suggest
- Local minimum in ion density accompanied by local minimum in neutral density near 450 km
- Anomaly is extended in local time from 20:00 to sunrise

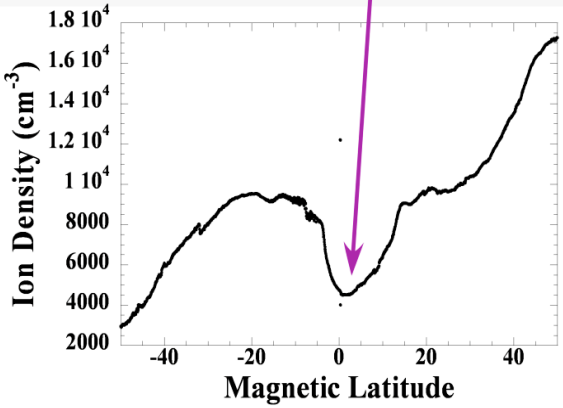
19 Jun 08, C/NOFS & DMSP



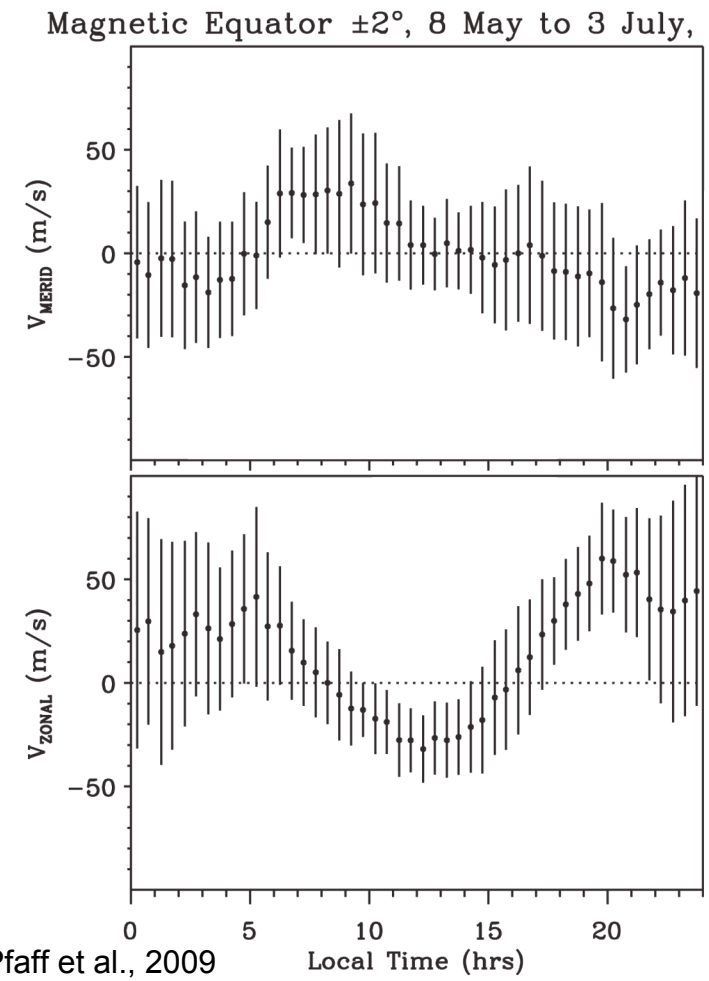
5 Jun 05, GRACE & DMSP



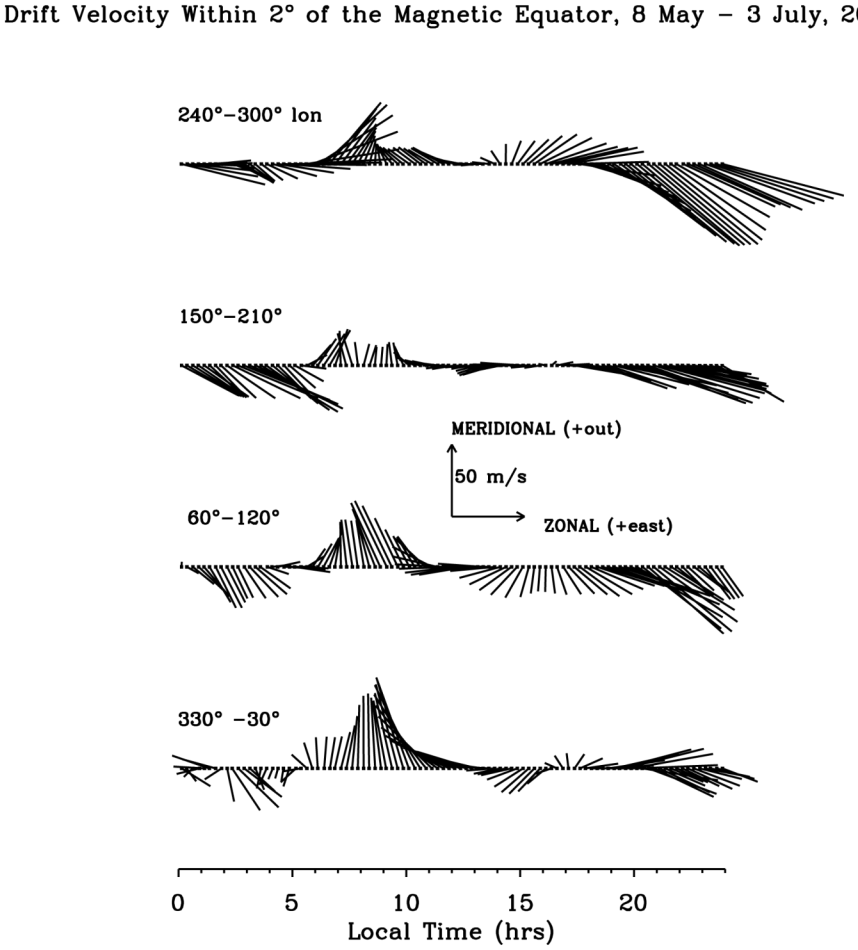
Huang et al., 2009



Ionospheric Conductivity, Winds and E-fields are different from expectations

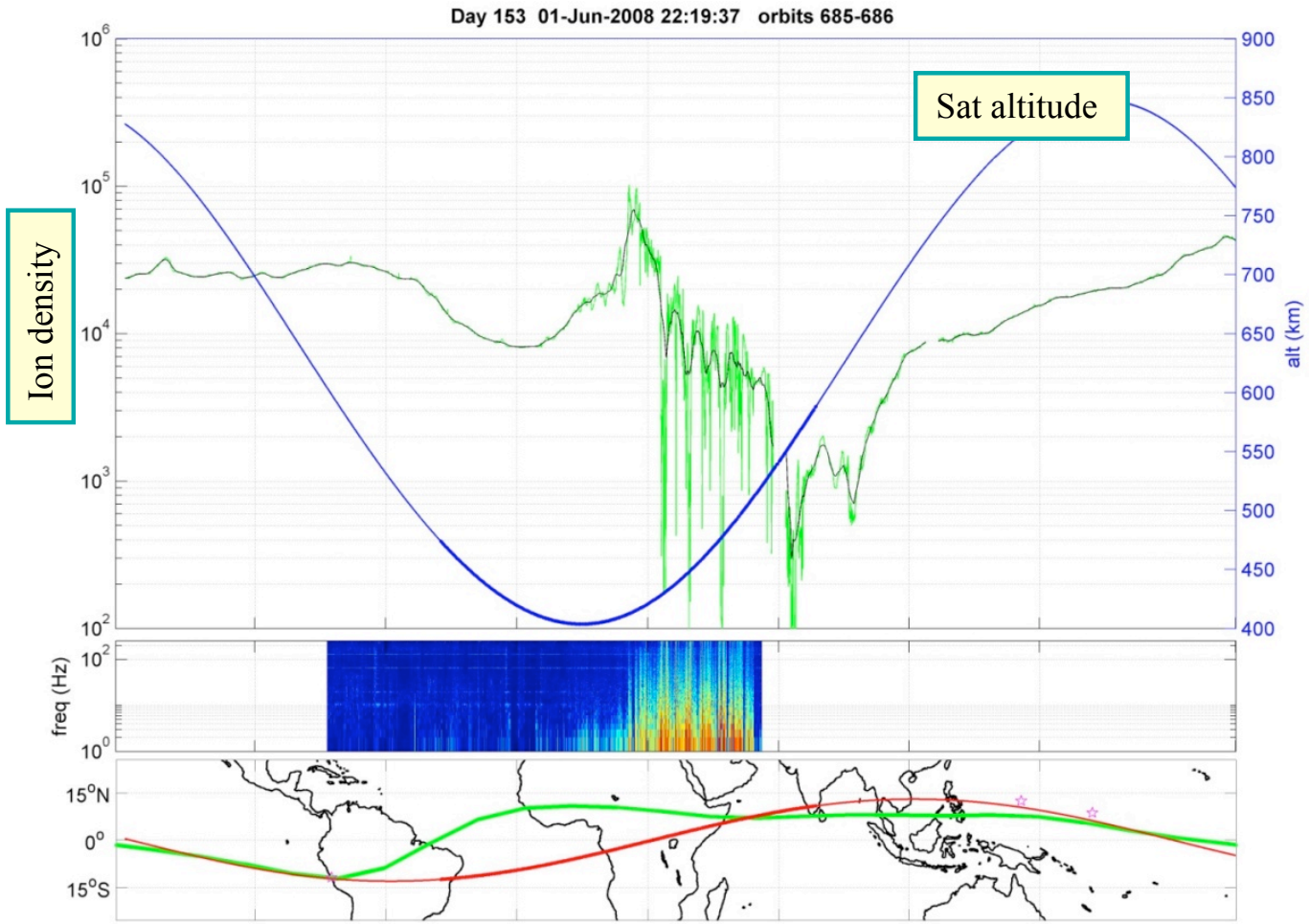


Pfaff et al., 2009



Equatorial Ion Drifts are small and downward after local noon
Strong Longitude variations

Nightime Ion Density Structure

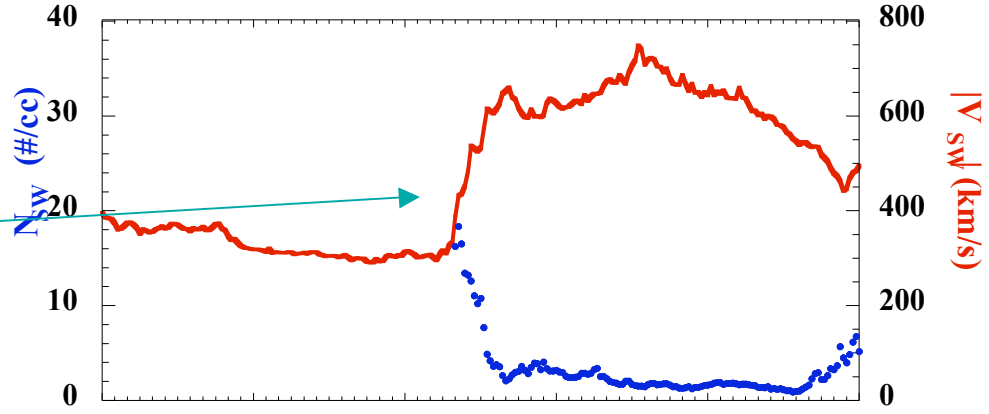


De La Beaujardiere et al., 2009

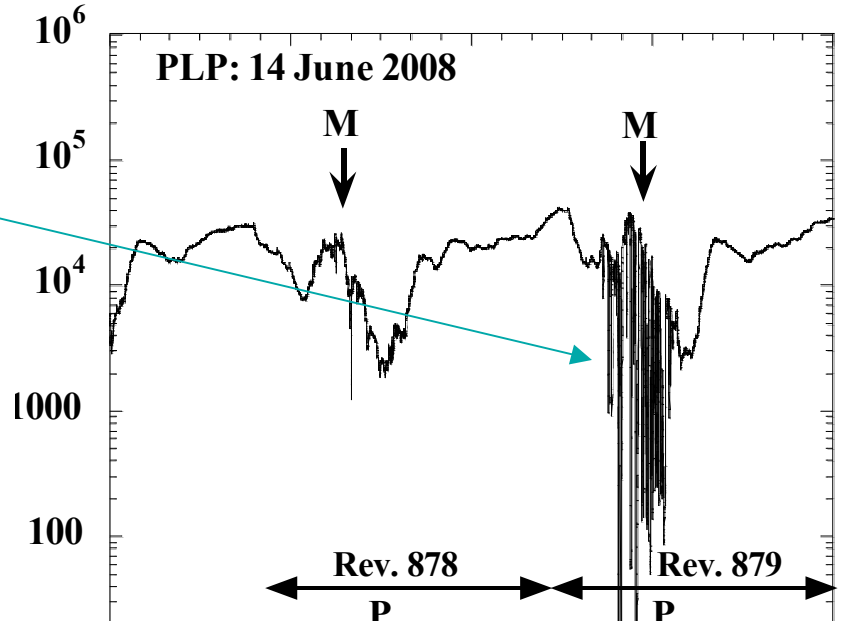
Frequently appears later than expected ~22 hrs
Persists longer than expected toward pre-sunrise
Frequently does not look like convectional bubbles

Dramatic Sensitivity to Interplanetary Medium

Interplanetary parameters:
step-function increase in solar wind velocity (300 to 600 km/s)

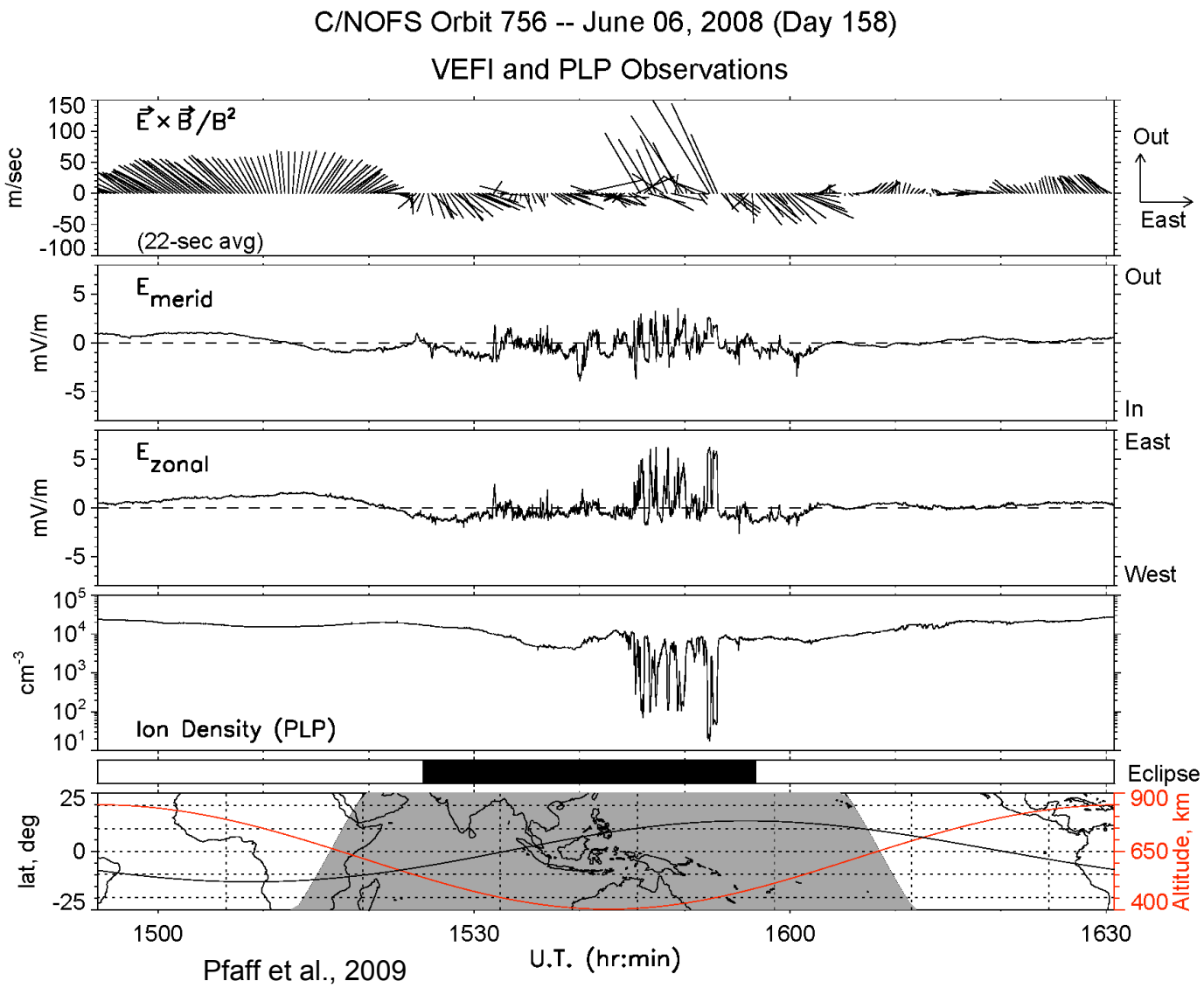


Plasma density responds immediately
•Scintillation-producing irregularities



Burke et al. 09

Bubble Structures in Ion Density consistent with R-T Instability

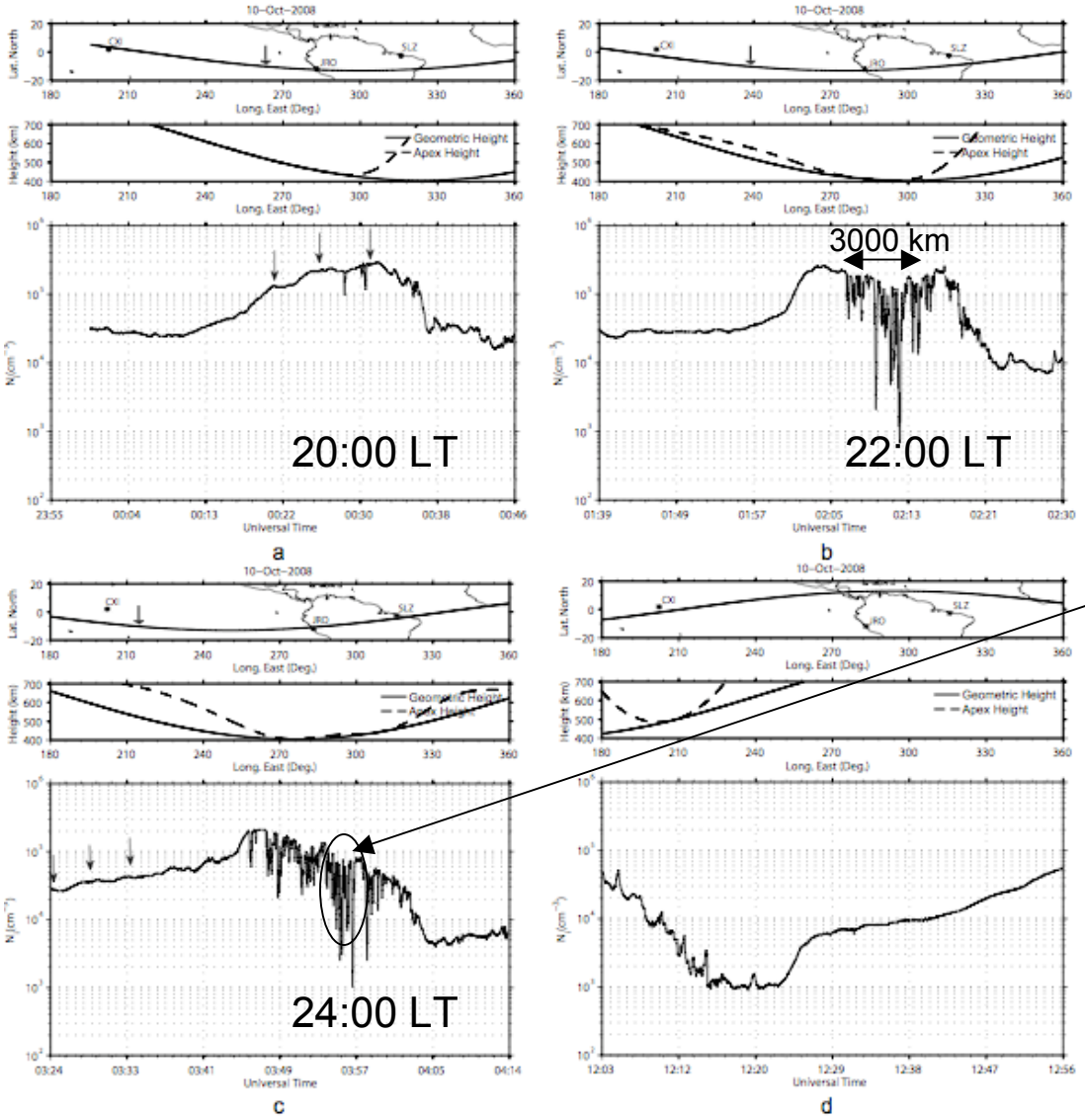


Pfaff et al., 2009

Depleted plasma regions moving upward

Deepest depletions have largest upward drifts at a given altitude.

Seeds and weak ExB drifts create bubble structure after sunset



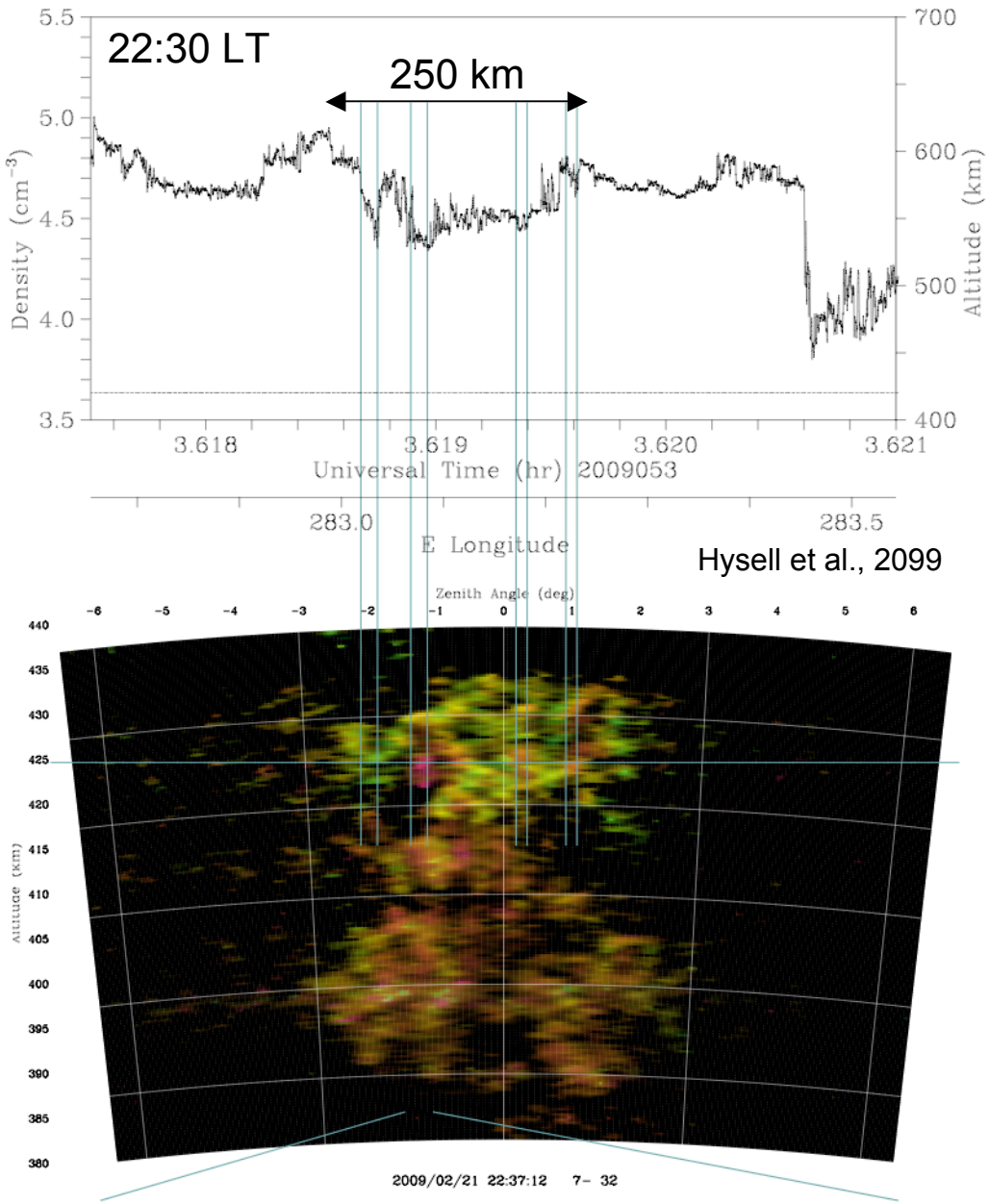
Kelley et al., 2009

Large scale (wave-like) undulations seen prior to bubble formation

Bubbles associated with elevated background density produced by weak pre-reversal enhancement.

Fully developed (decaying) bubbles seen at midnight

Structure in density and dynamics inside a bubble



Hysell et al., 2099

C/NOFS views the top of structure extending up to 430 km.

Radar reveals km-scale structure in altitude moving in different directions.

Inertial (collisionless) effects important near 450 km

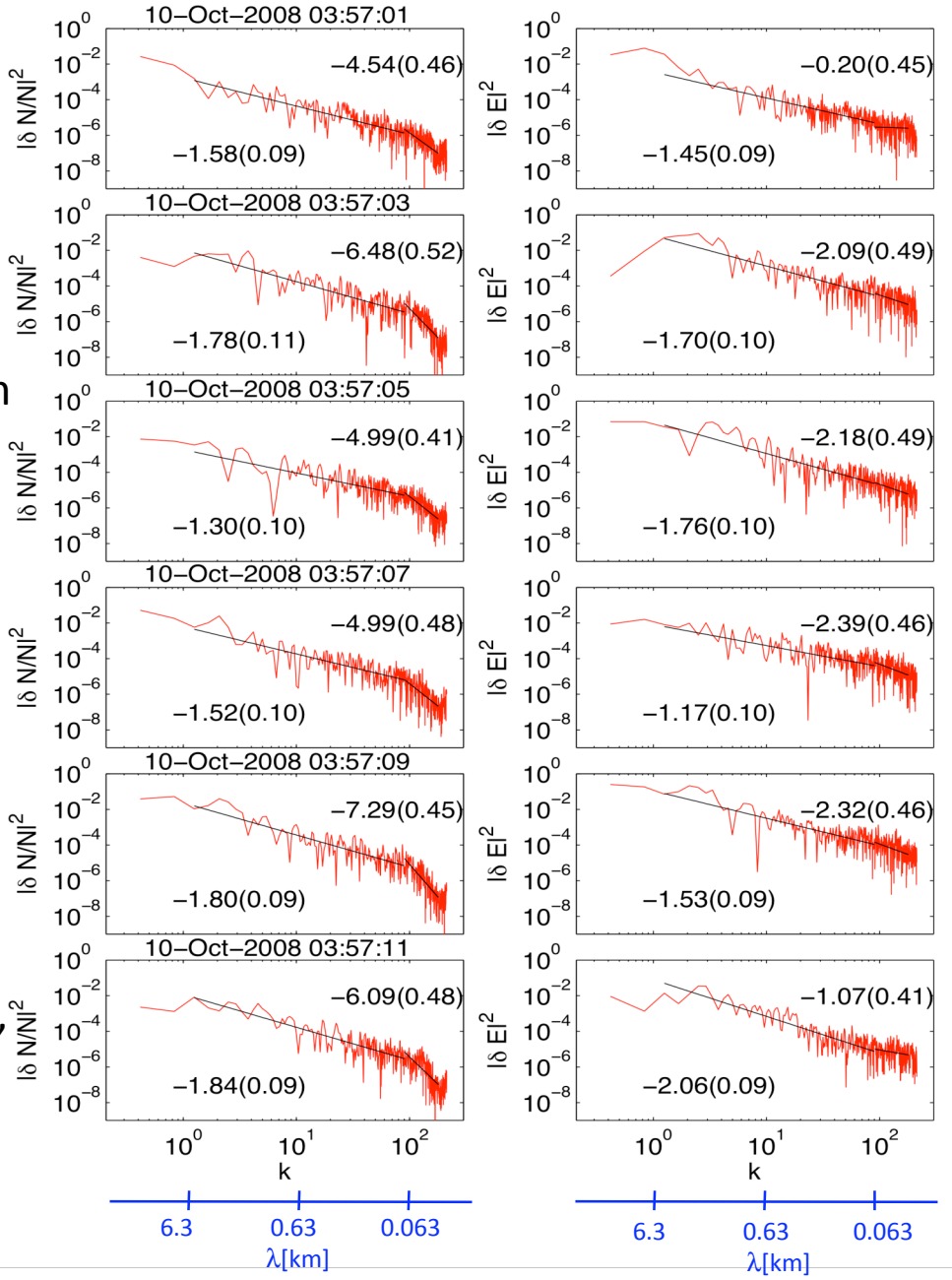
Initial results indicate: Rodrigues et al., 2009

- Power spectra: $P(k) \alpha k^{-p}$
- $P_{Ni}(k) \alpha P_{Ezonal}(k)$, for $\lambda > 70$ m
- Spectral slopes near p=-5/3, for $\lambda > 70$ m
- Variability in p ($\sigma = 0.2$ for N_i and $\sigma = 0.3$ for E_{zonal})
- The -5/3 slopes suggest inertial flows but:

- No spectral break around 1 km.
- No enstrophy (p=-3) subrange observed.

- Steep slopes ($|P| > 4$) for $\lambda < 70$ m in P_{ni}, not observed in P_E

- Suggests change in the physics.
- Diffusive regime [$P_{Ni}(k) \alpha k^{-2} P_{Ezonal}(k)$]



Summary

Ionosphere during an extended solar minimum shows characteristics that challenge our understanding.

- Ionosphere and Atmosphere are contracted - occupy a volume that does not extend into space as far as usual.
  - Lower than usual values for HmF2 and NmF2 by day and night.
- Bulk of neutral atmosphere lies below 400 km
  - Ionosphere at 450 km is 50% light ions at night
  - Ionosphere and Neutral Atmosphere is cold 800K by day 600K by night
- Background ExB deviates significantly from usual diurnal pattern
  - Weak or downward drifts after local noon are common.
- Very small upward drifts and low neutral density significantly reduce the ion-neutral collision frequency in the bottom side at night
  - Small PRE will induce bubble formation.
  - Interplanetary medium readily induces drifts that spawn irregularities.
- Inertial (collionless) effects are evident at much lower altitudes than might be expected.
  - Temporal evolution and spectral shape of irregularities will be different.