Plasmaspheric Electron Density Distributions Sampled by Radio Plasma Imager on the IMAGE Satellite

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Abstract

Distribution of plasmaspheric density changes in response to plasma electrodynamical processes in both the ionosphere and magnetosphere. During a geomagnetic storm, for example, the plasmasphere can significantly diminish in size during the main phase of the storm and relax to regain its more normal size during recovery phase. During unusually quiet times, the plasmasphere can become quite large. The processes by which the plasmasphere is eroded and refilled are still areas of active research. Previous in situ observations (e.g., CRRES) have shown that the plasmasphere has a lot of structures, quite possibly results of plasma dynamical processes. Recent global EUV images obtained by IMAGE also reveal large-scale plasma structures as well as large-scale variations of the plasmasphere resulting from magnetospheric activities. In this paper, we investigate the large-scale plasmaspheric density variations as a function of solar wind and geomagnetic activities by analyzing a large collection of passive RPI observations of quasi-thermal noise through the plasmasphere obtained over the first year of the IMAGE mission. We will compare our results with existing models of plasmaspheric density distributions.

Introduction

- Large-scale plasmaspheric density model are needed in many space-plasma studies:
  - wave propagation, wave-particle interaction, and physics of coupling between the ionosphere and overlying regions.
- RPI on IMAGE, one of the *most sensitive* radio-wave detectors flown to-date, have produced high-quality electron density measurements throughout the plasmasphere/plasma trough regions.
- We will show the statistical trends of the inner magnetospheric density observed by RPI and compare the results with existing plasmaspheric density models

Existing Plasmaspheric Density Models

Ignoring *local-time, seasonal and solar-cycle effects*, we have:

(1) "Saturated-plasmasphere" model [*Carpenter and Anderson, 1992*]

$$\log_{10} n_e = -0.3145L + 3.9043 \qquad (D_{st} \sim 0)$$

(2) The "quiet-condition" model [*Gallagher et al., 2000*]

$$\log_{10} n_e = -0.79L + 5.3 \qquad (3\text{–day weighted } K_P < 1.3)$$

RPI Density Observations

- In situ "plasma line" observations (Figure 1) are used to determine the local electron plasma density
- Assuming an upper-hybrid frequency [$f_{uh} = \sqrt{(f_{pe}^2 + f_{ce}^2)}$] for the observed plasma line (Figure 2) , f_{pe} can be determined by using the T96 magnetic field model

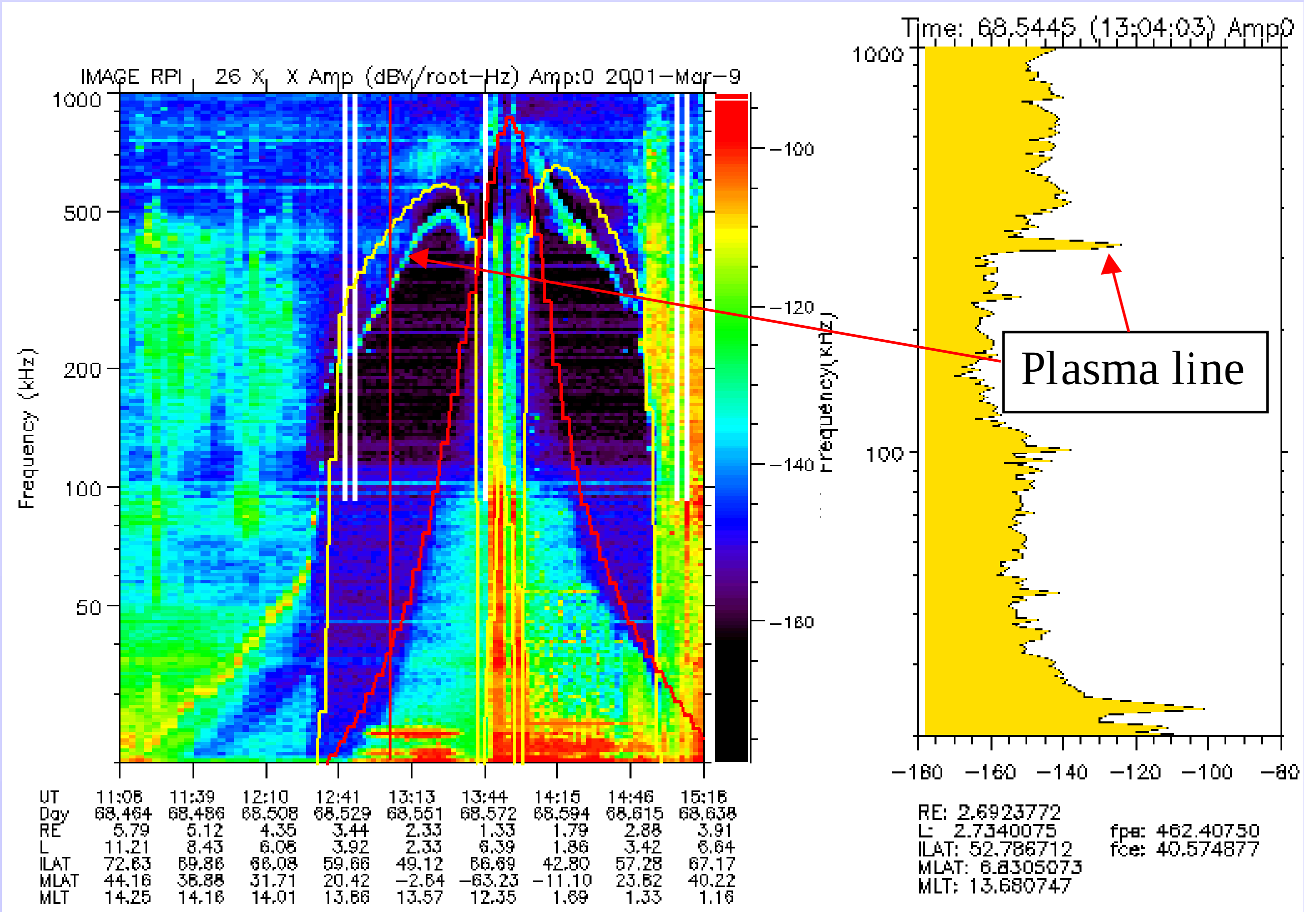
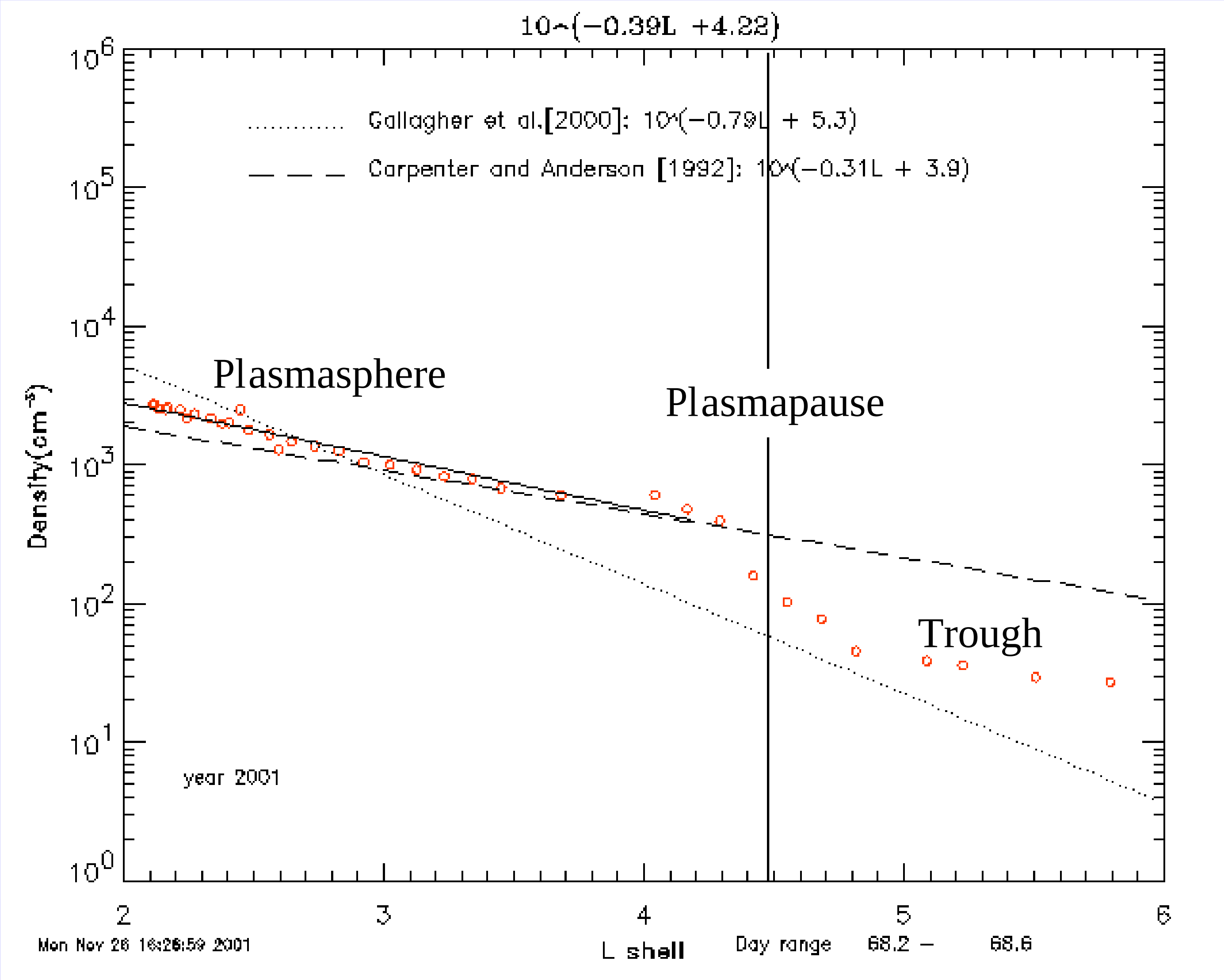


Figure 1 Figure 2

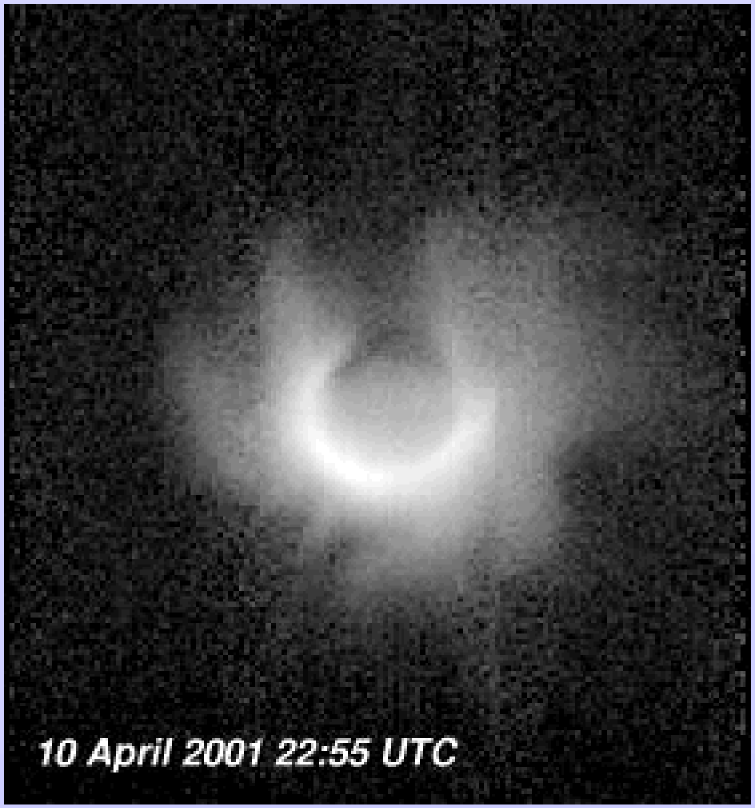
Plasmasphere/Plasma Trough density March 9, 2001

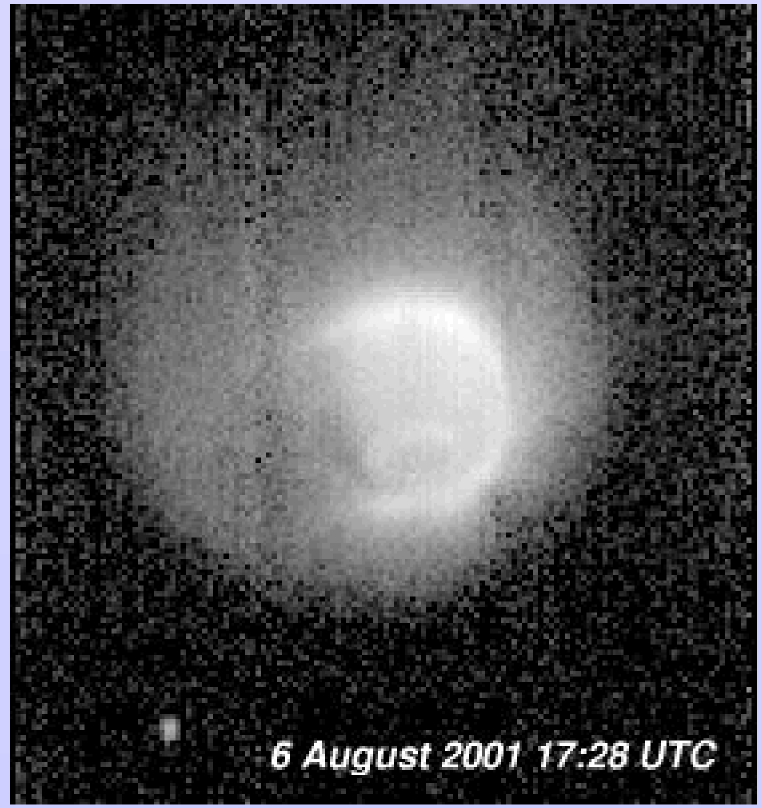


Plasmaspheric Density Data Base

- All RPI "plasma line" observations (May, 2000 through early June 2001) throughout the plasmasphere/plasma trough regions have been screened using the technique described above.
- Electron densities in a database are listed as functions of spacecraft locations (*L*, *GM*, *GSM*) and magnetospheric conditions as prescribed by *solar wind pressure*, *IMF*, D_{st}, *and* K_p.
- The database ignore all large-scale or internal plasma irregularities

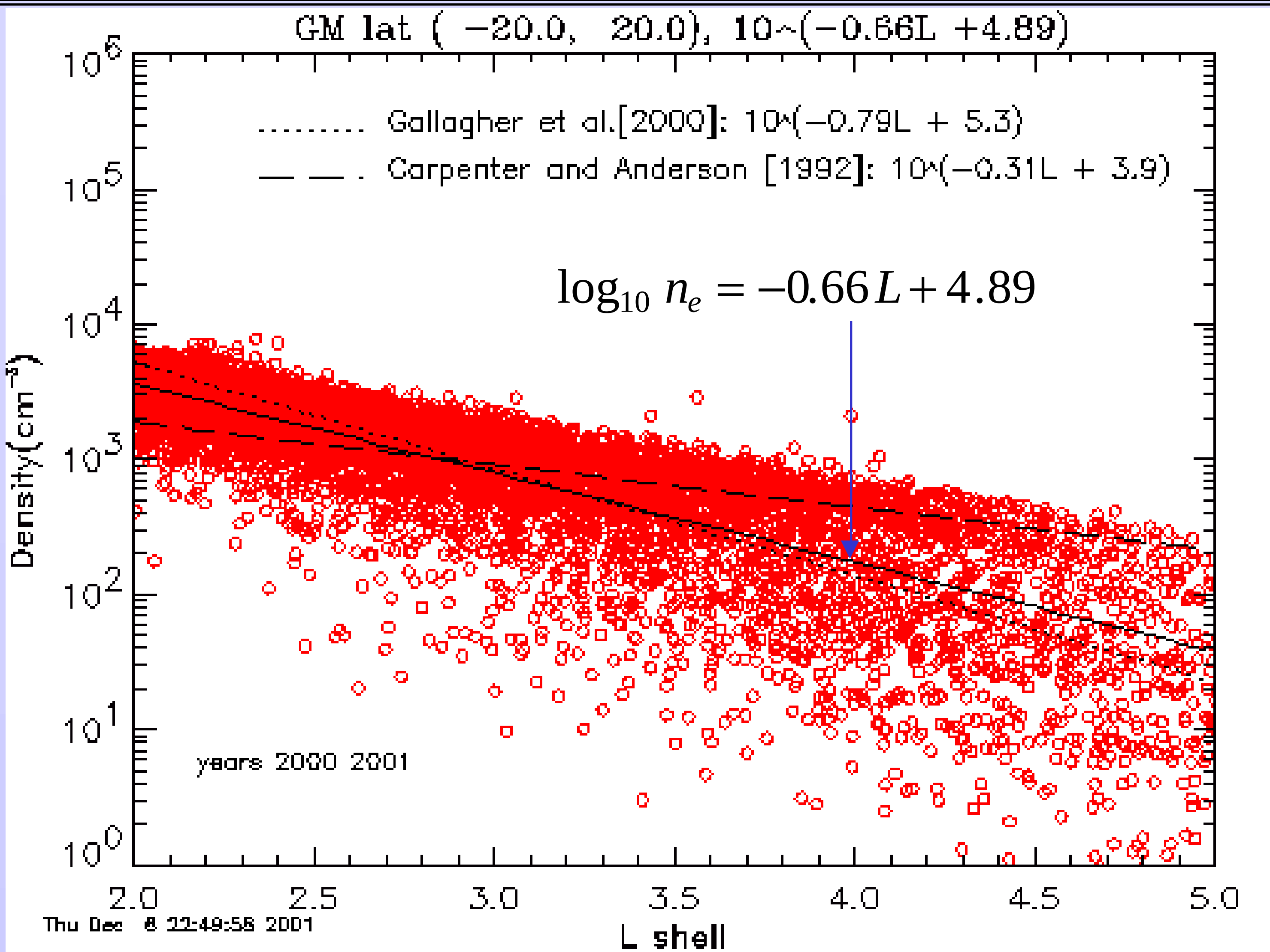
EUV Observations of Plasmaspheric Structures



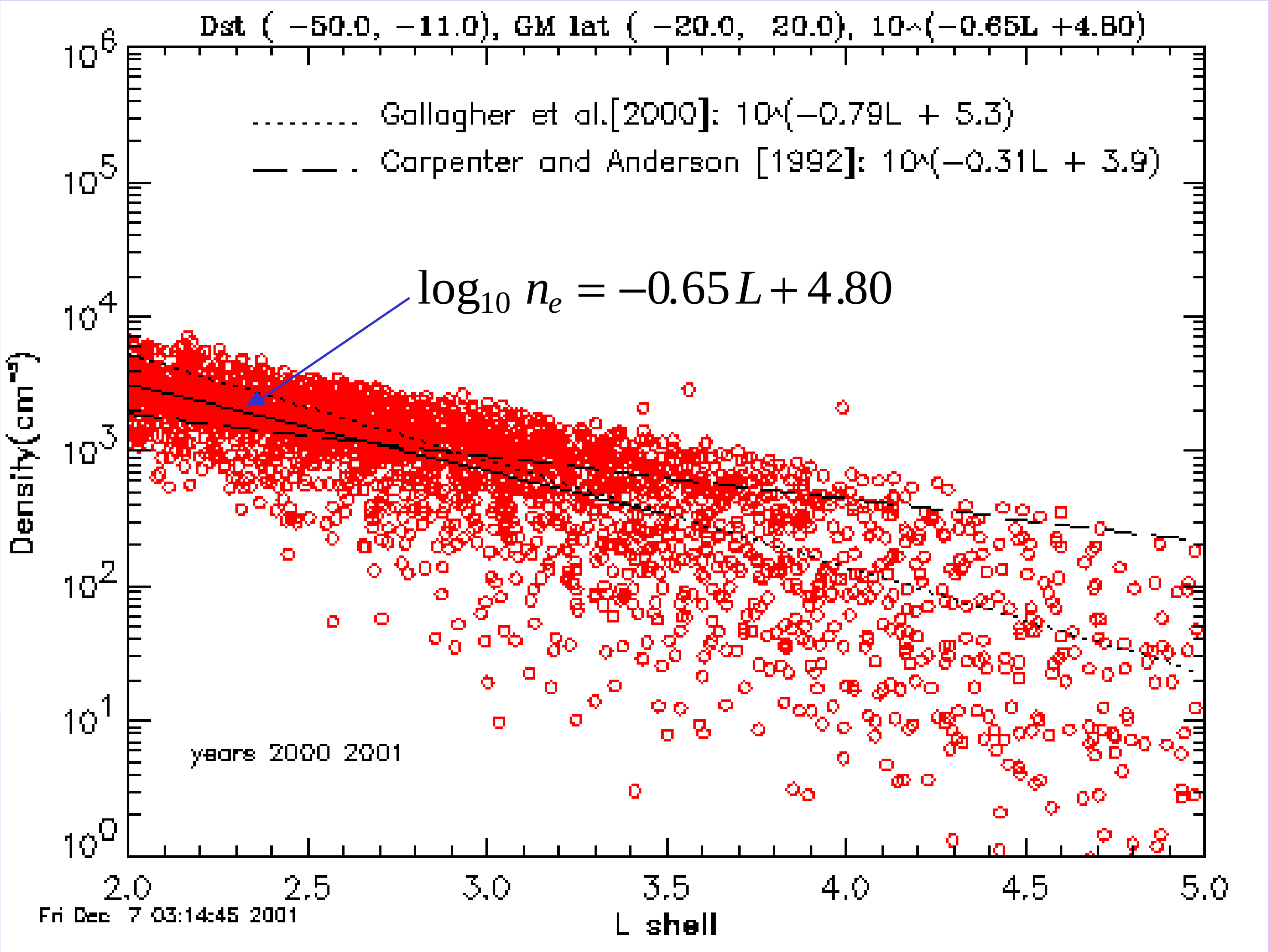


Plasmasphere can vary from being *highly-structured* to highly *non-structured.*

Overall L-Profile of Electron Density

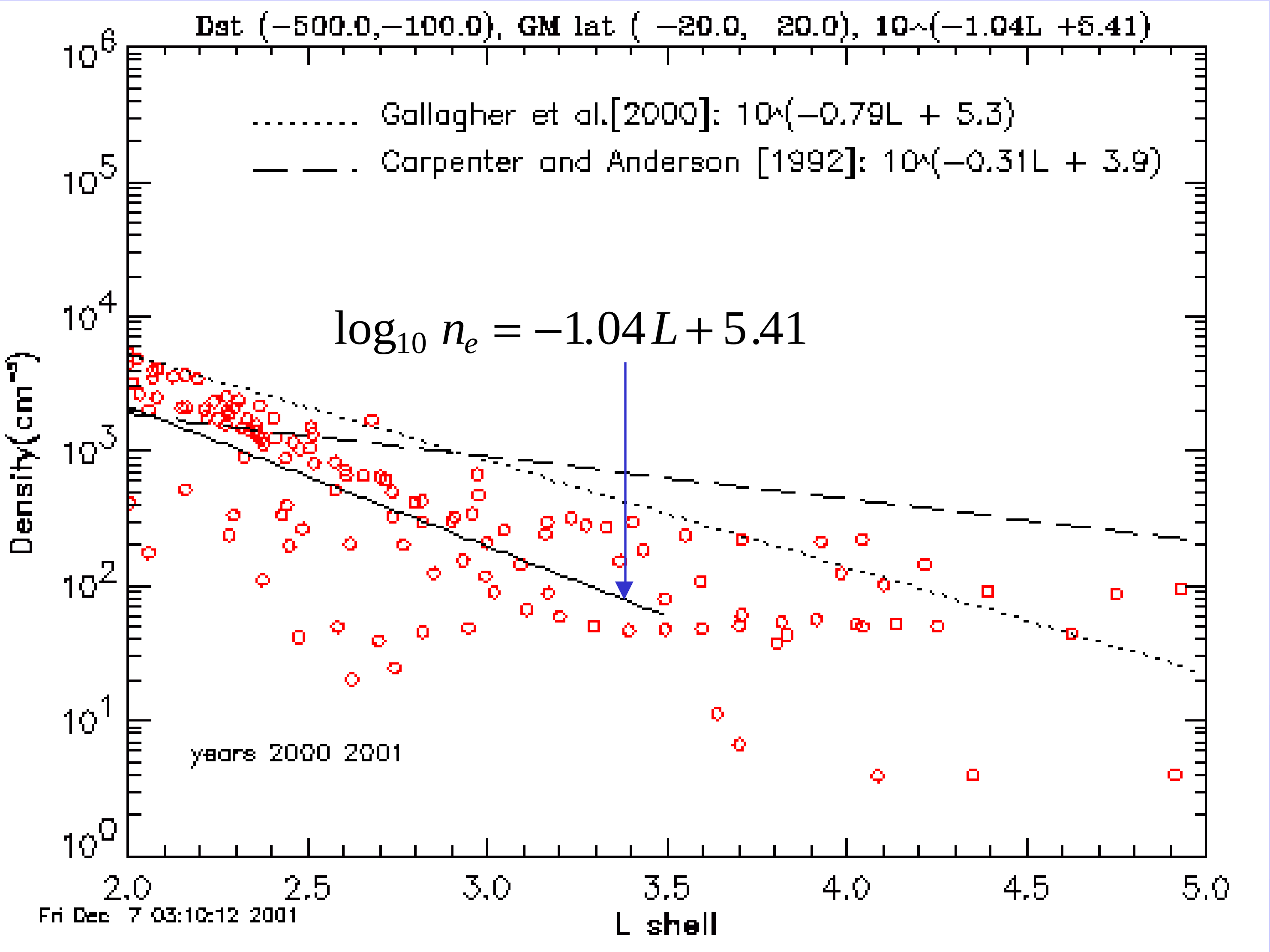


$-50 < D_{st} < -11$ nT

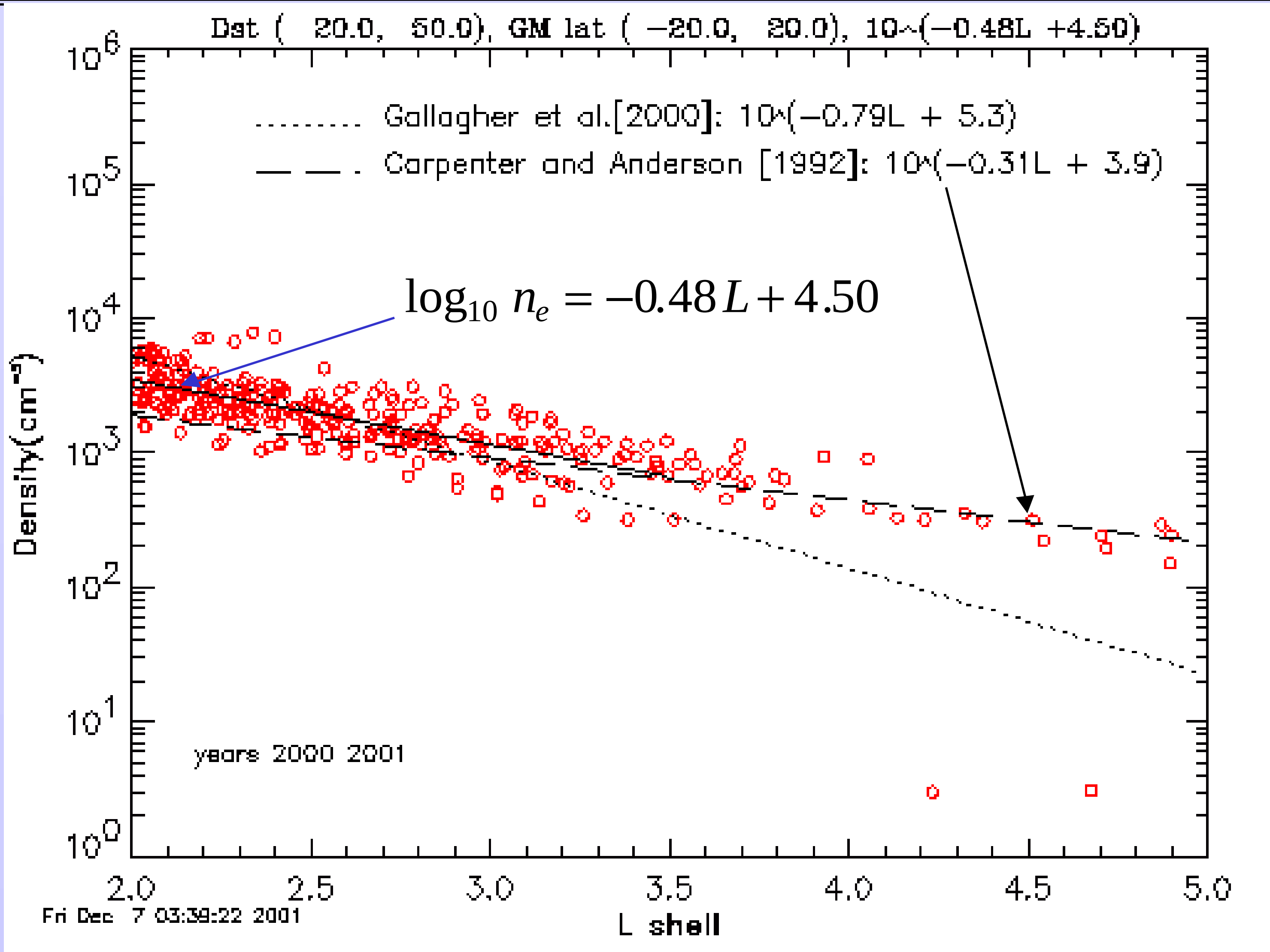


Dst (−50.0, −11.0), GM lat (−20.0, 20.0), 10^(−0.65L +4.80)
Gallagher et al.[2000]: 10^(−0.79L + 5.3)
Carpenter and Anderson [1992]: 10^(−0.31L + 3.9)
$\log_{10} n_e = -0.65L + 4.80$
Density(cm⁻³)
10⁶
10⁵
10⁴
10³
10²
10¹
10⁰
years 2000 2001
2.0
2.5
3.0
3.5
4.0
4.5
5.0
L shell
Fri Dec 7 03:14:45 2001

$-500 < D_{st} < -100$ nT

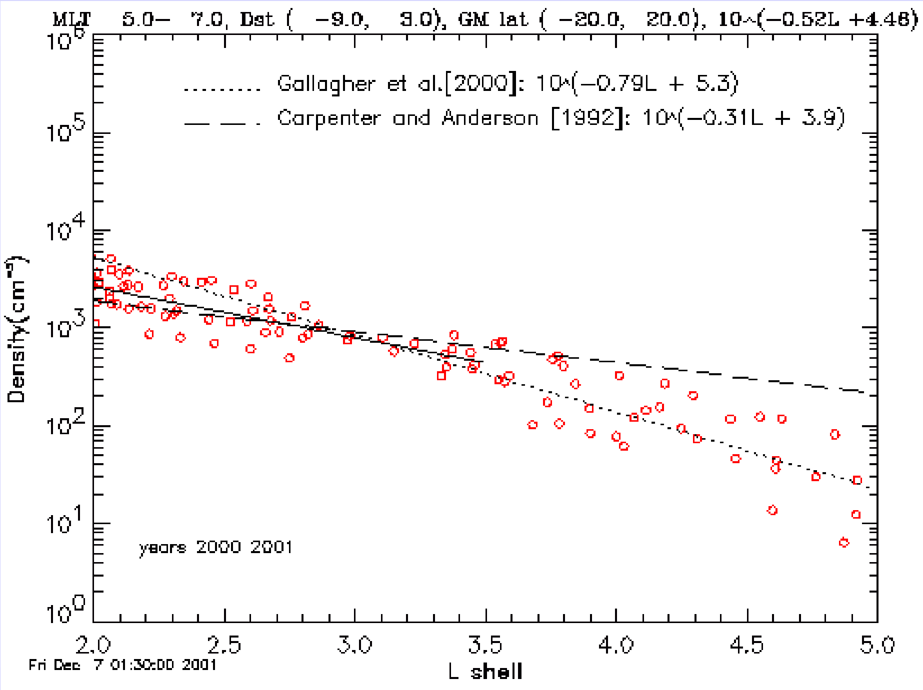


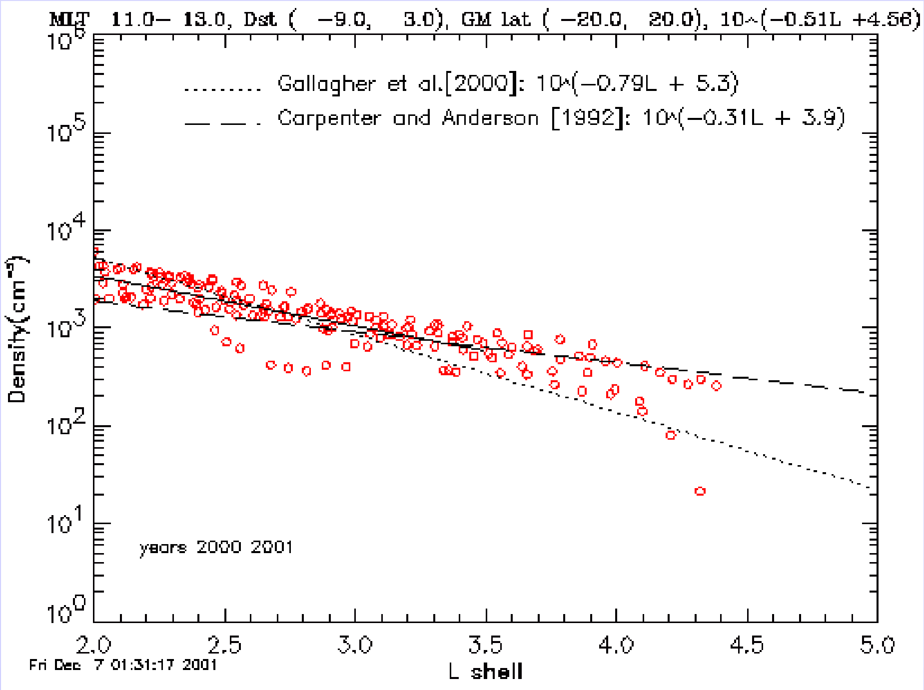
$20 < D_{st} < 50nT$


Dst (20.0, 50.0), GM lat (-20.0, 20.0), 10^(-0.48L +4.50)
Gallagher et al.[2000]: 10^(-0.79L + 5.3)
Carpenter and Anderson [1992]: 10^(-0.31L + 3.9)
$\log_{10} n_e = -0.48L + 4.50$
years 2000 2001
Density(cm^{-3})
L shell
Fri Dec 7 03:39:22 2001
2.0
2.5
3.0
3.5
4.0
4.5
5.0
10^0
10^1
10^2
10^3
10^4
10^5
10^6

Local-Time (Dawn-Noon)Variations

$-20 < \text{GMLat} < 20$ & $-9 < D_{st} < 3$





5-7 MLT

$\log_{10} n_e = -0.52L + 4.46$

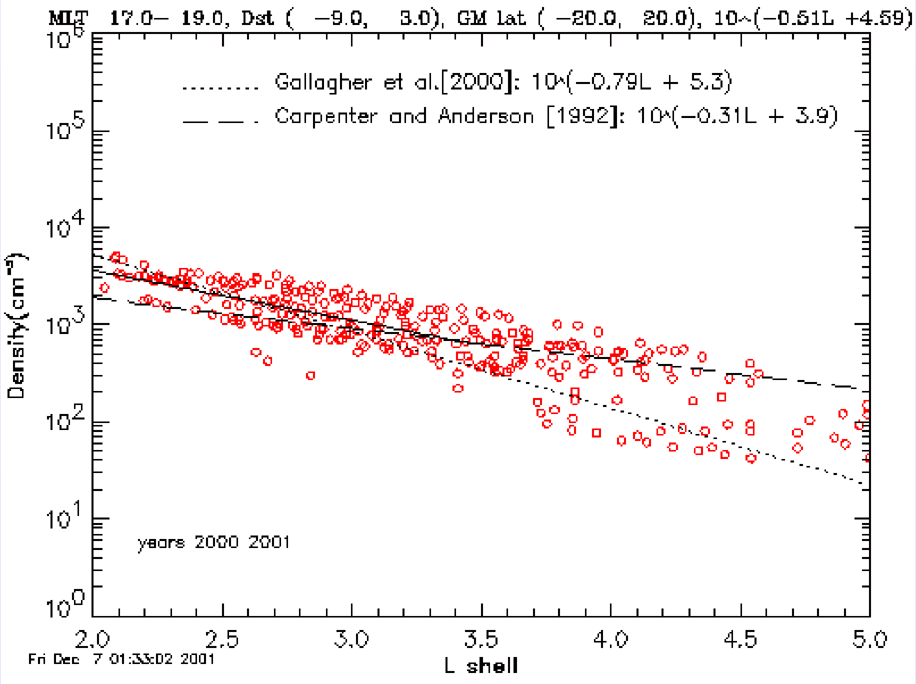
$2 < L_{fit} < 3.5$

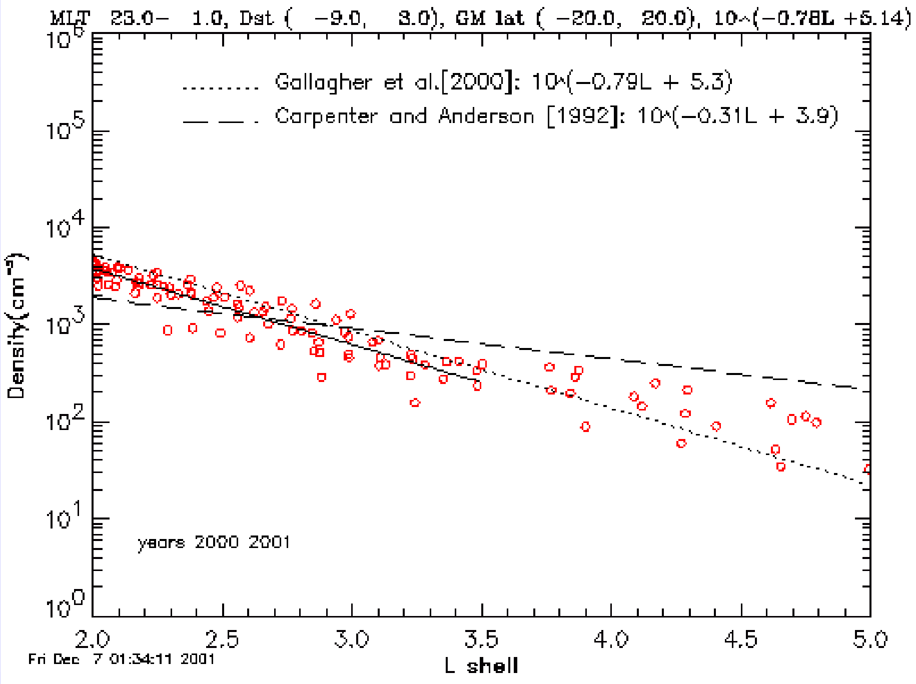
11-13 MLT

$\log_{10} n_e = -0.51L + 4.56$

Local-Time (Dusk-Midnight)Variations

-20 < GMLat < 20 & -9 < D_{st} < 3





17-19 MLT

$\log_{10} n_e = -0.51L + 4.59$

2 < L_{fit} < 3

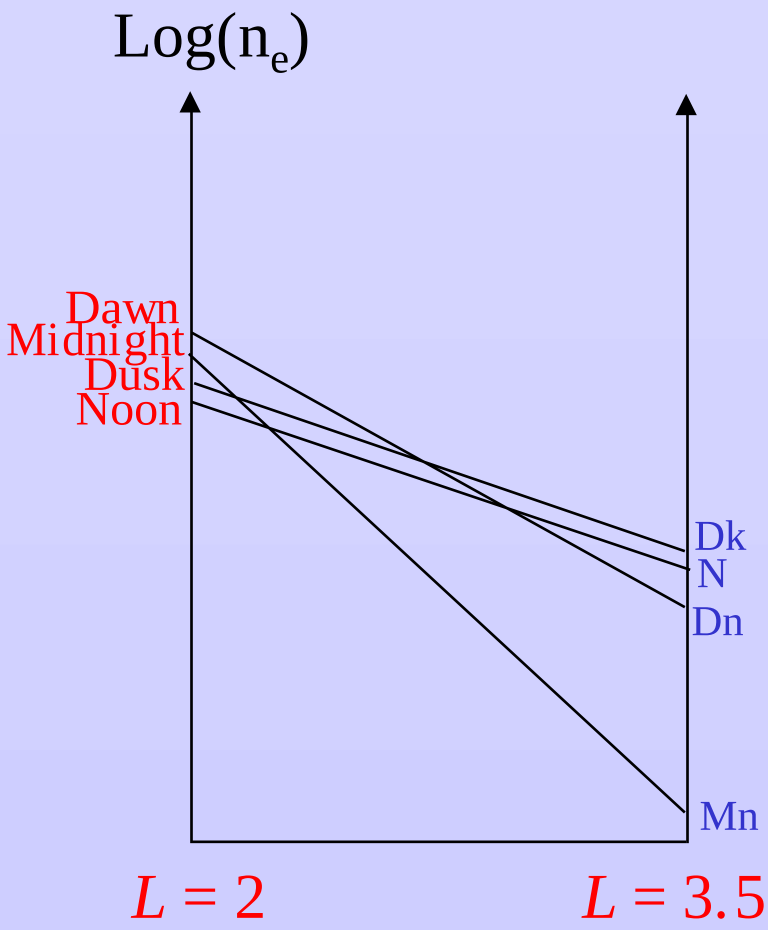
23-1 MLT

$\log_{10} n_e = -0.78L + 5.14$

Local-Time Variations of Core Plasmaspheric Density

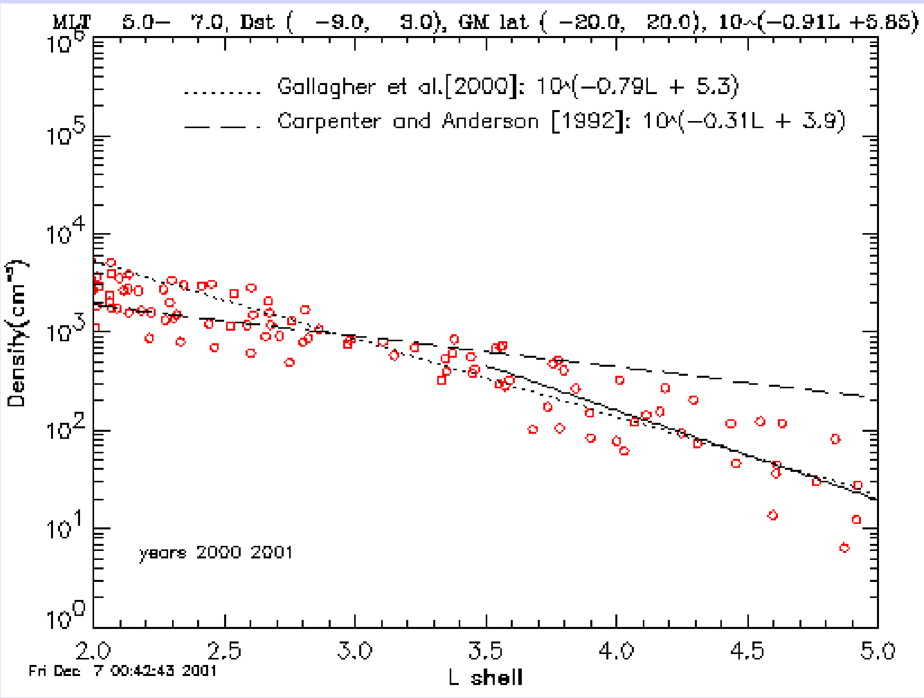
In 2 < L < 3.5:

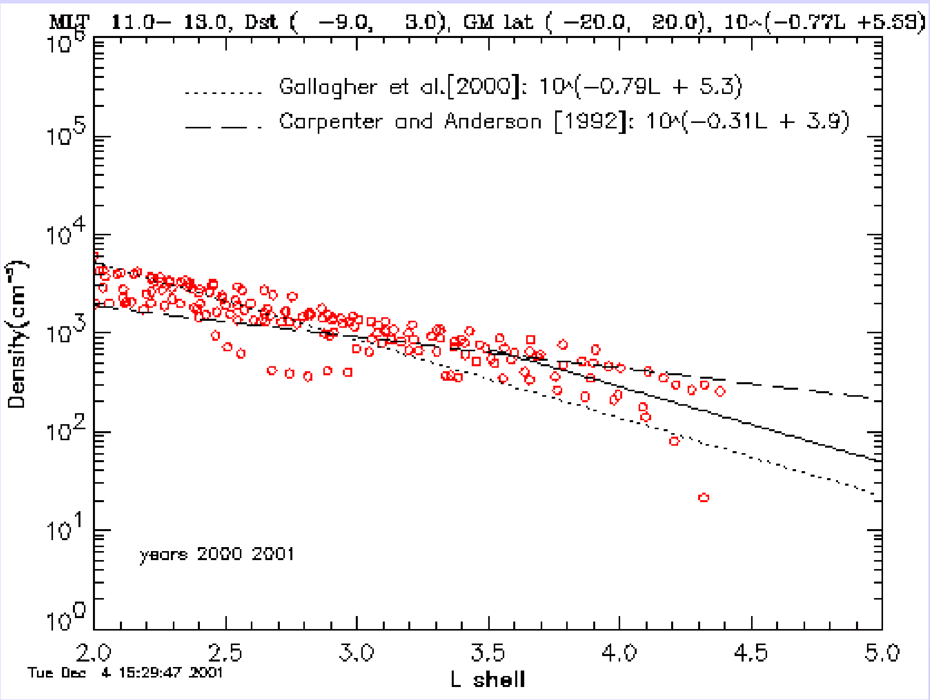
Dawn	$\log_{10} n_e = -0.52L + 4.46$
Noon	$\log_{10} n_e = -0.51L + 4.56$
Dusk	$\log_{10} n_e = -0.51L + 4.59$
Midnight	$\log_{10} n_e = -0.78L + 5.14$



Local-Time (Dawn-Noon)Variations

$-20 < \text{GMLat} < 20$ & $-9 < D_{st} < 3$





5-7 MLT

$$\log_{10} n_e = -0.91L + 5.85$$

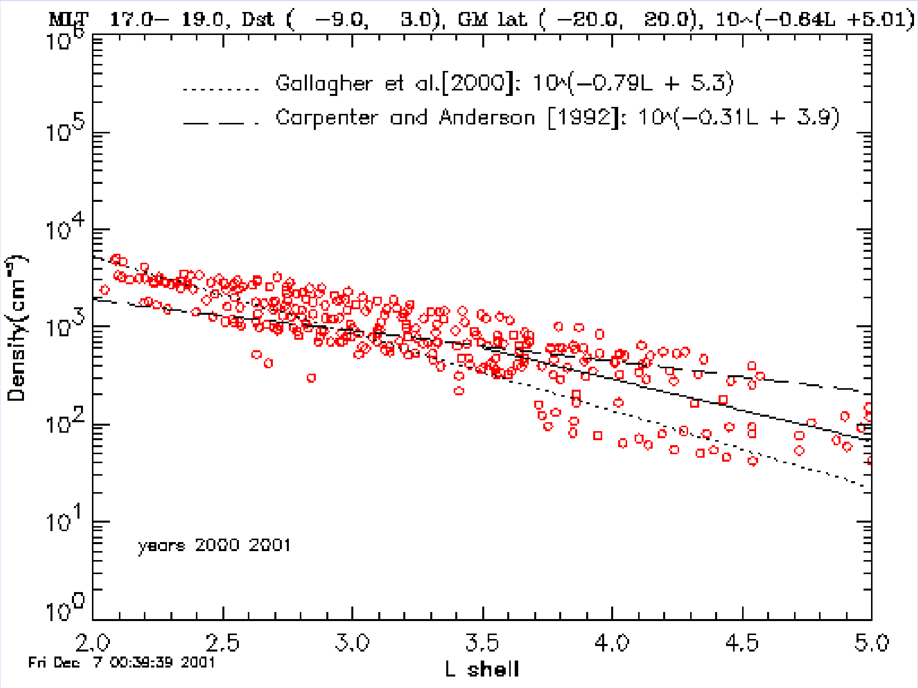
$3.5 < L_{fit} < 5$

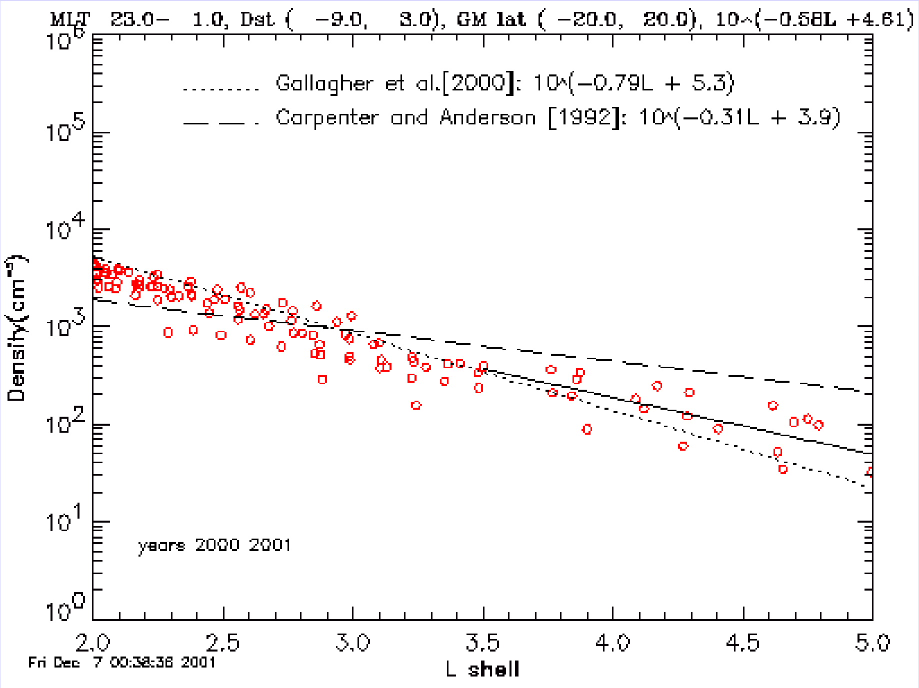
11-13 MLT

$$\log_{10} n_e = -0.77L + 5.59$$

Local-Time (Dusk-Midnight)Variations

$-20 < \text{GMLat} < 20 \quad \& \quad -9 < D_{st} < 3$





17-19 MLT

$$\log_{10} n_e = -0.64L + 5.01$$

$3.5 < L_{fit} < 5$

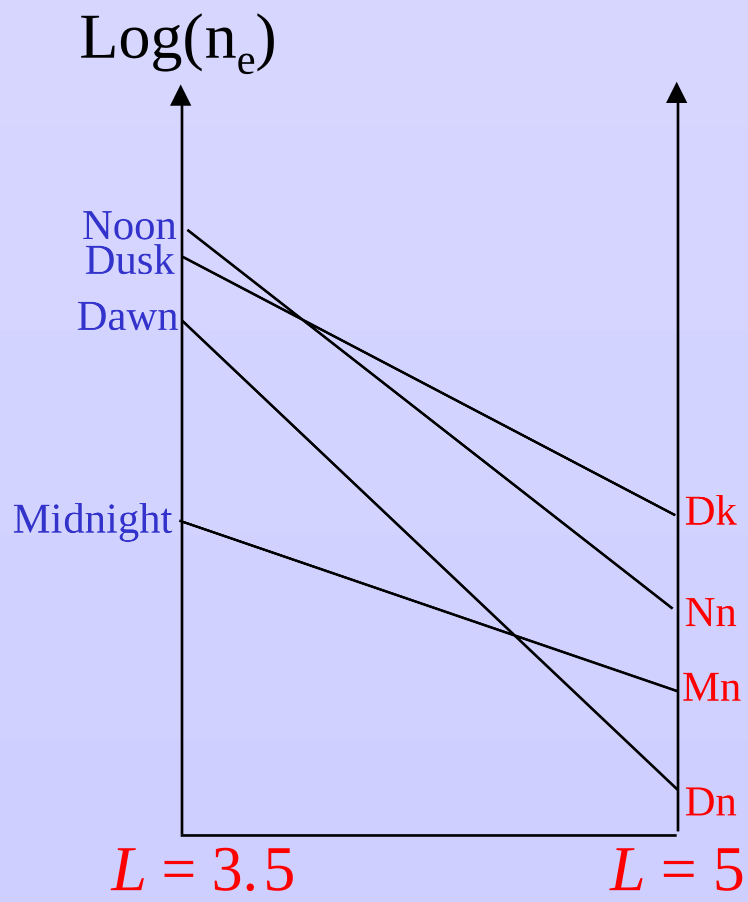
23-1 MLT

$$\log_{10} n_e = -0.58L + 4.61$$

Local-Time Variations in Trough Density

In 3.5 < *L* < 5:

Dawn	$\log_{10} n_e = -0.91L + 5.85$
Noon	$\log_{10} n_e = -0.77L + 5.59$
Dusk	$\log_{10} n_e = -0.64L + 5.01$
Midnight	$\log_{10} n_e = -0.58L + 4.61$



Summary

Plasma-line observations by RPI throughout the plasmasphere and plasma trough have been collected to produce an electron-density database for the inner magnetopshere. Log(n_e)-L profiles of plasmasphere have been obtained for different D_{st} levels. In addition, we found that:

- Within the core plasmasphere ($2 < L < 3$)
  - RPI data at all local-times tend to follow a linear log(n_e)-L relationship that is intermediate between the "saturated-plasmasphere" and "quiet-condition" models.
  - Log(n_e)-L relationship is rather uniform in LT, except near midnight where the density drops drastically with L
- In the trough region ($3.5 < L < 5$)
  - Density decreases more drastically with L at dawn/noon than in dusk/midnight