Energy inputs uncertainty: total amount, distribution and correlation between different forms of energy

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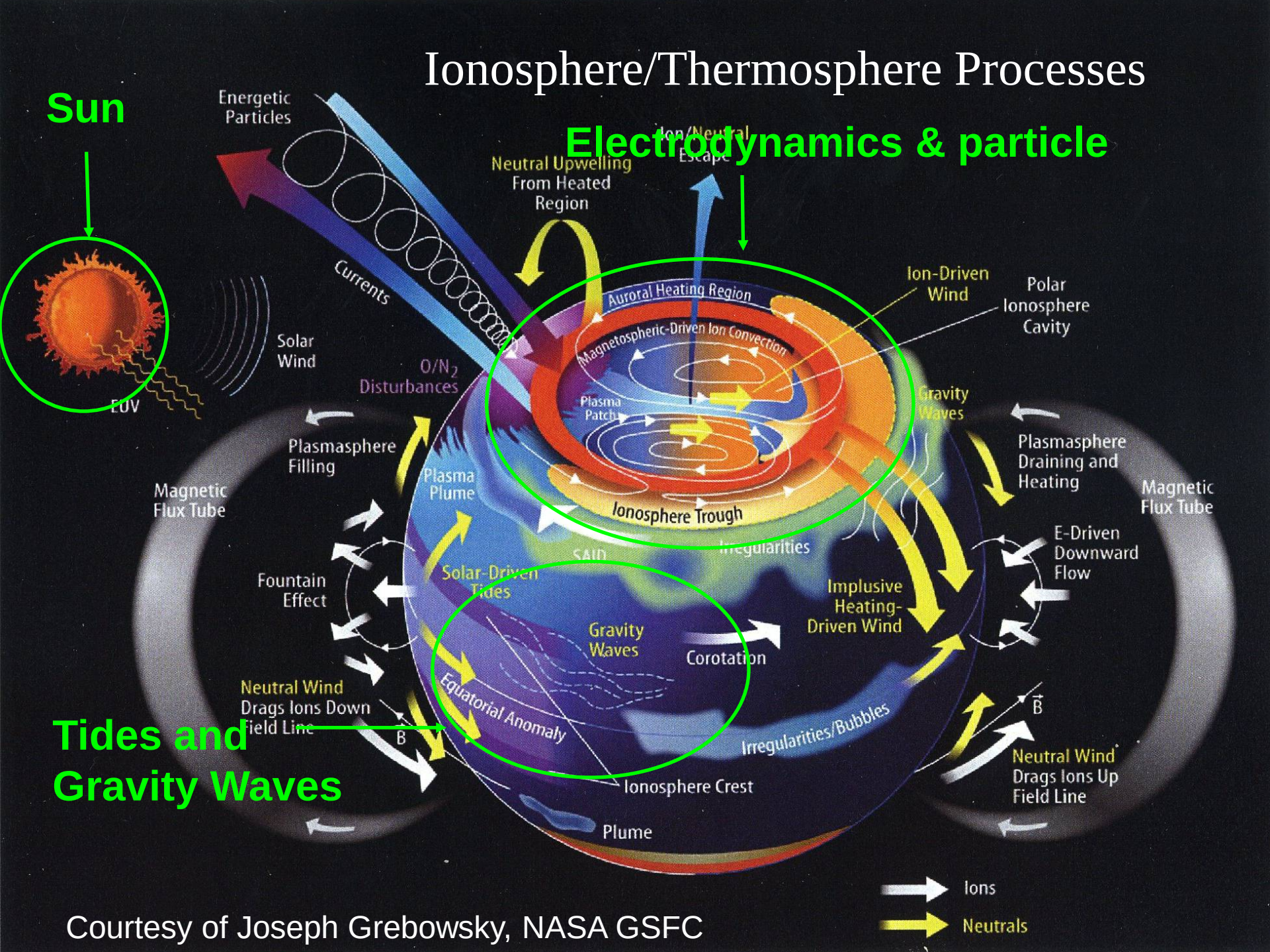
Ionosphere/Thermosphere Processes



Courtesy of Joseph Grebowsky, NASA GSFC

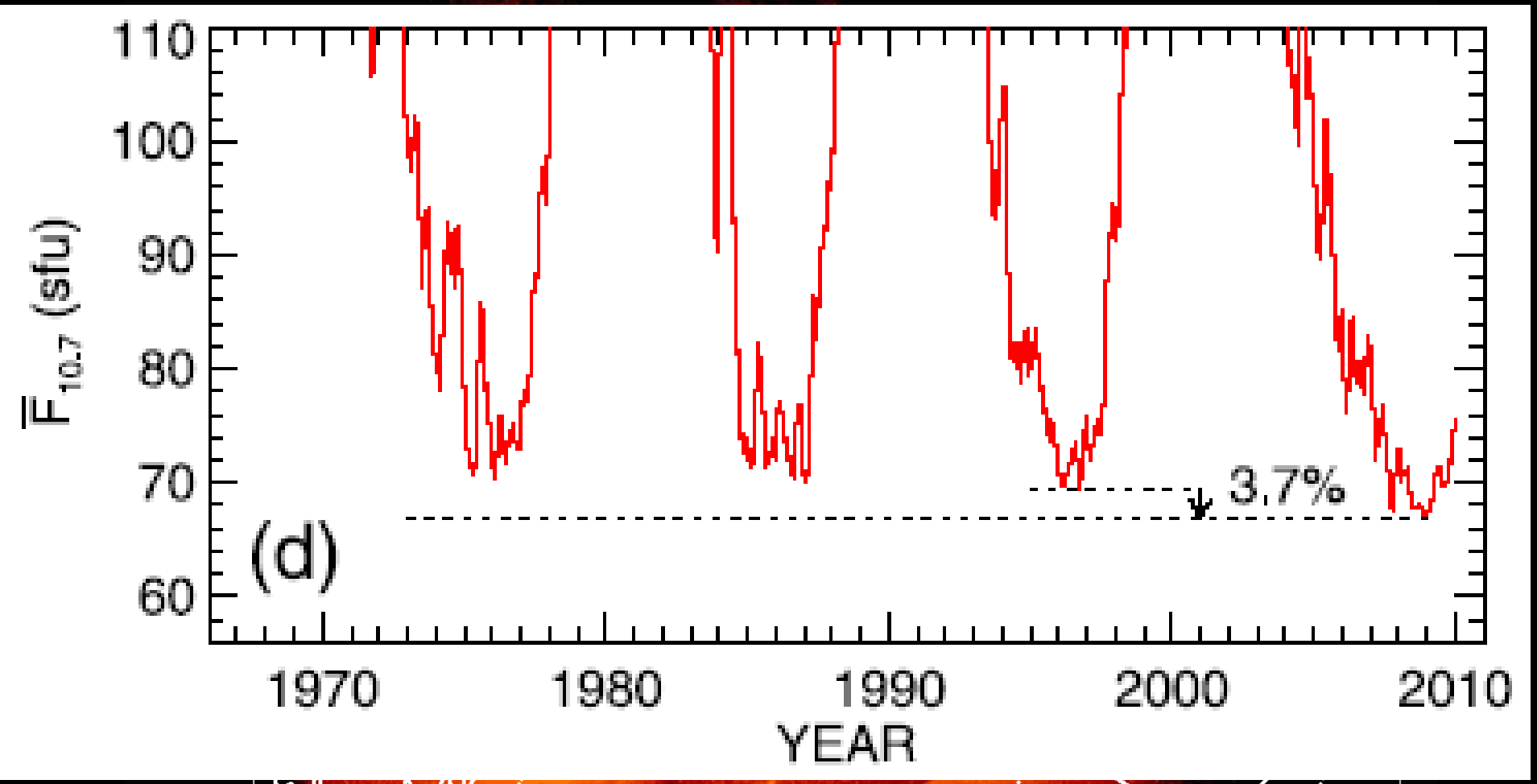
Outline:

1. Total amount
2. Distribution
   1) 2-D distribution: Joule heating & particle precipitation
   2) Altitudinal distribution

3. Correlation between particle precipitation & Poynting flux

1. Total amount:
Different Energy inputs in solar cycle 23

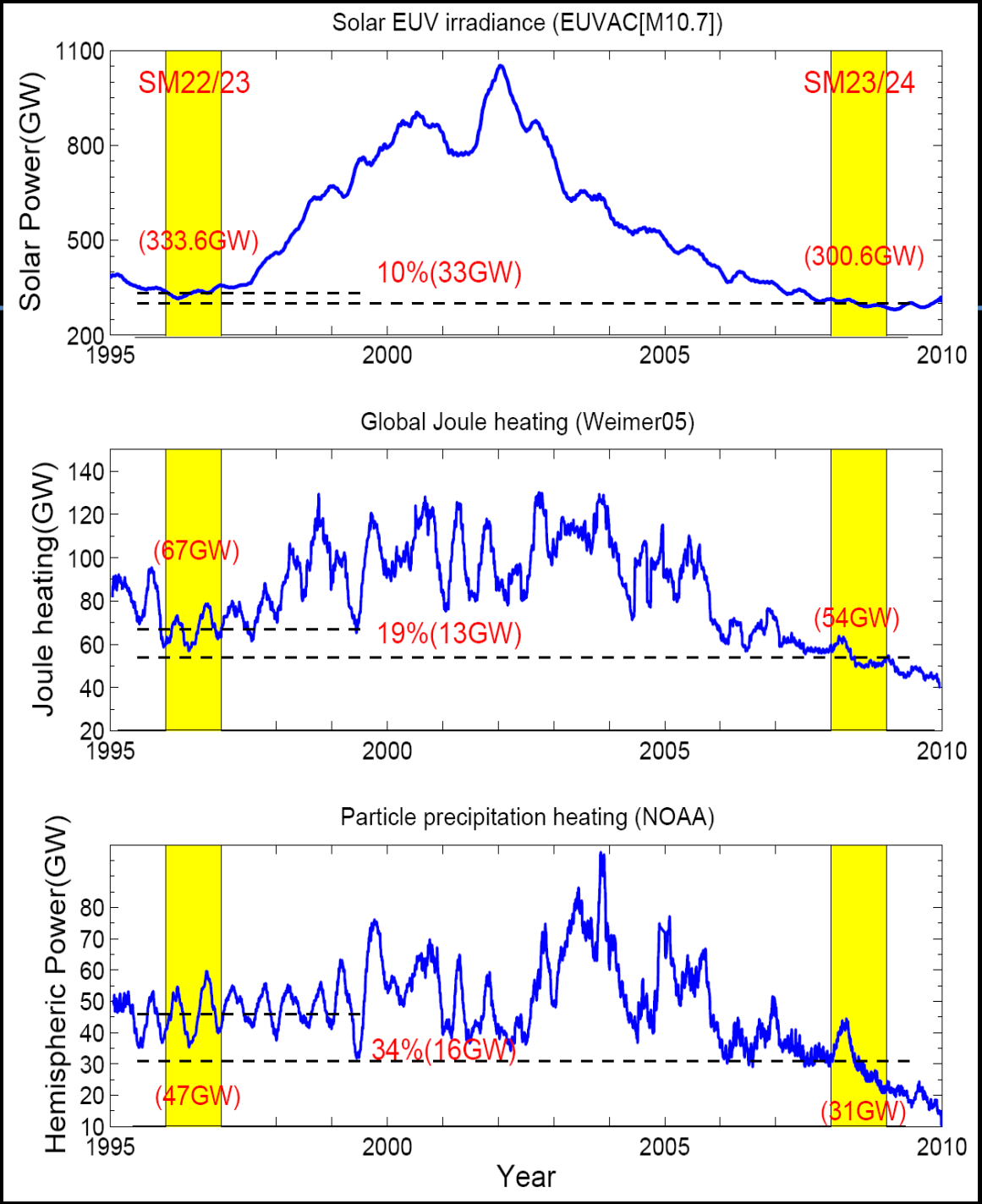
Solar Cycles



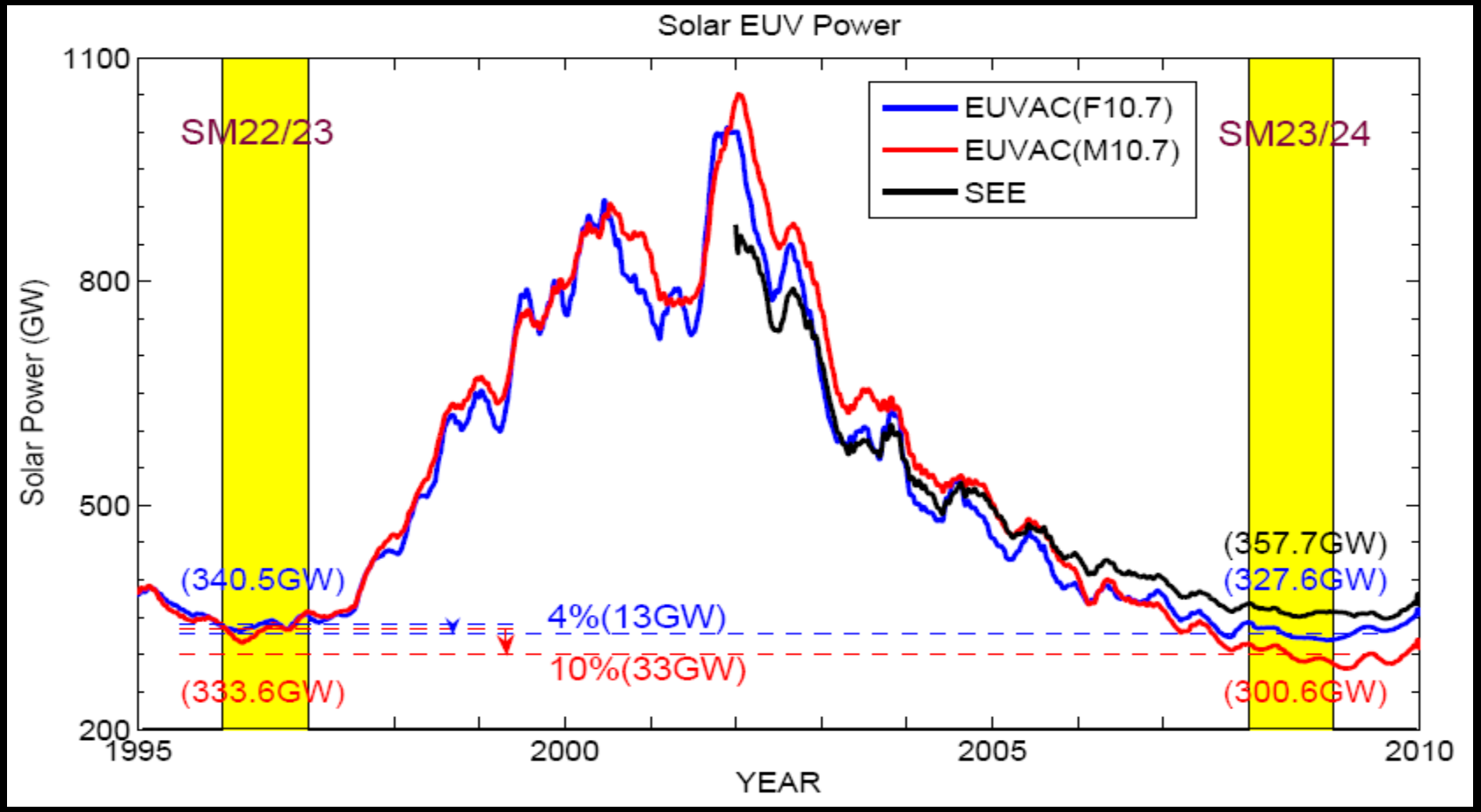
- The anomalously low solar extreme ultraviolet (EUV) irradiance in 2008 has been observed.

Annual energy input decreases from 1996 to 2008

- Solar EUV: ↓33GW
- Joule Heating: ↓13GW
- Particle Precipitation: ↓16GW
- Total decrease of geomagnetic energy (13GW + 16GW) is comparable to that of solar EUV irradiance (33GW).



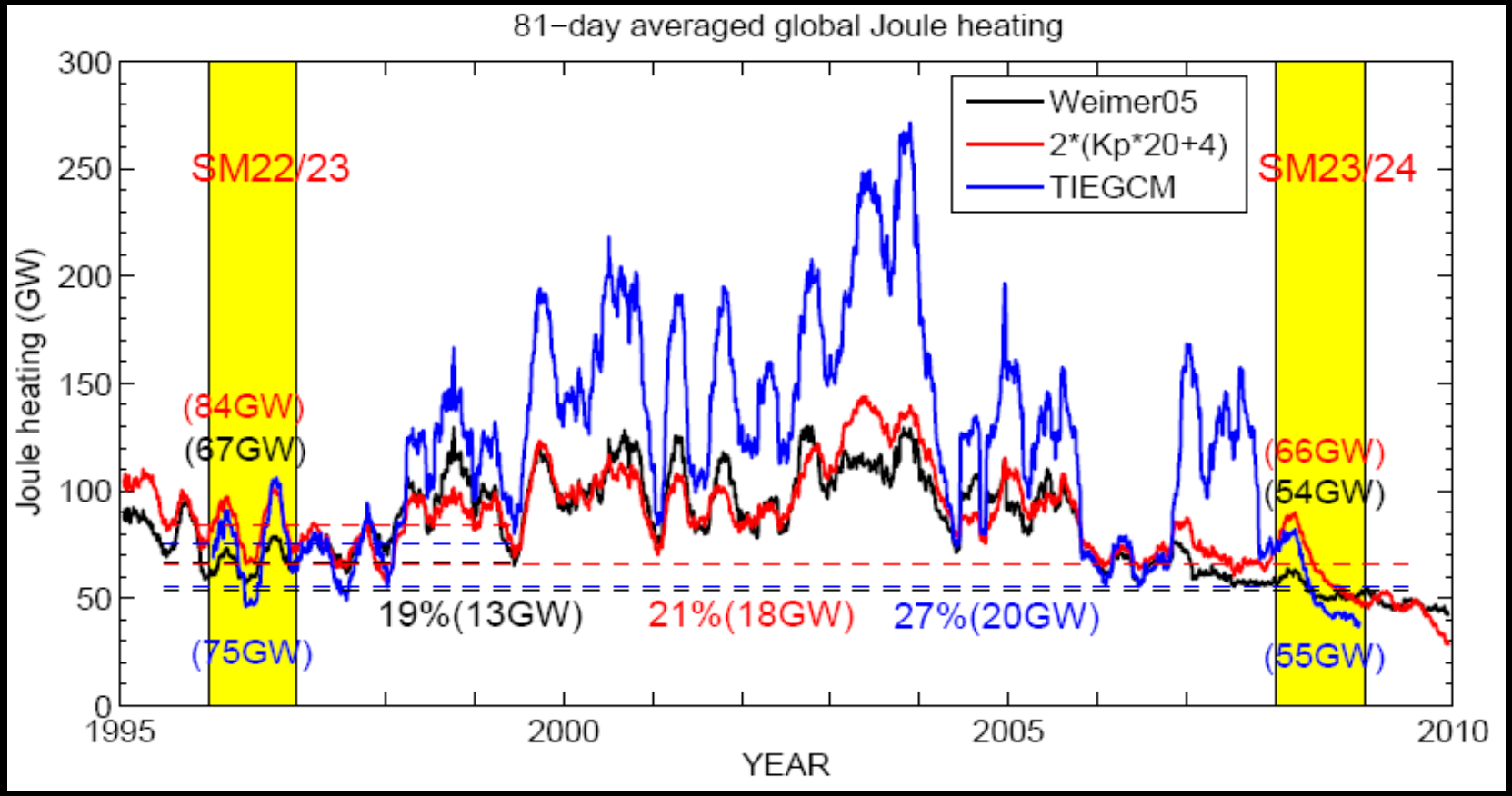
Different solar EUV estimations



Solar EUV decease:

- EUVAC($F_{10.7}$): 13GW
- EUVAC($M_{10.7}$): 33GW

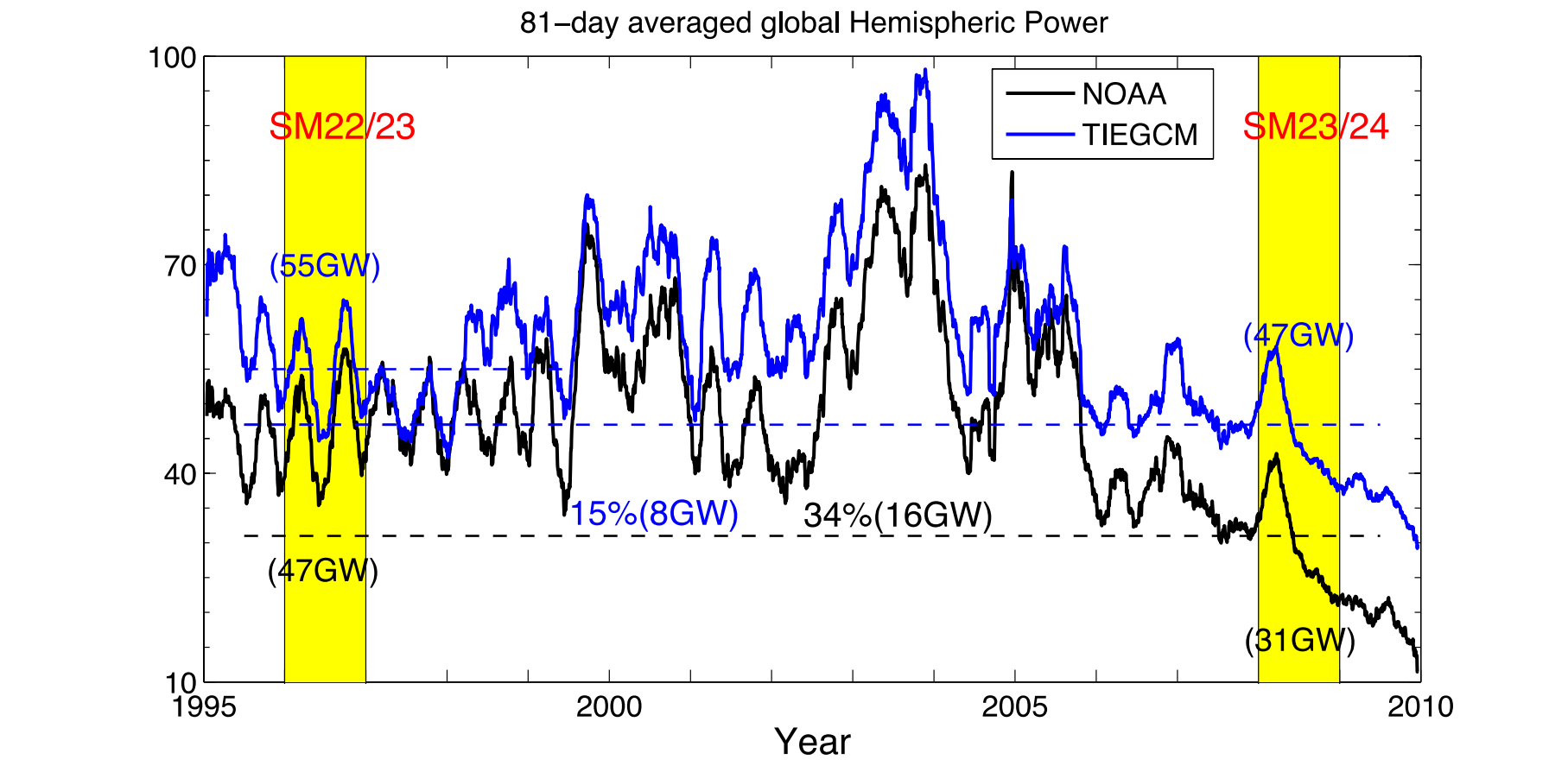
Different Joule heating estimations



Joule heating decrease:

- Weimer05: 13GW
- Empirical formula: 18GW
- TIEGCM (Factor 1.5): 20GW

Different HP estimations



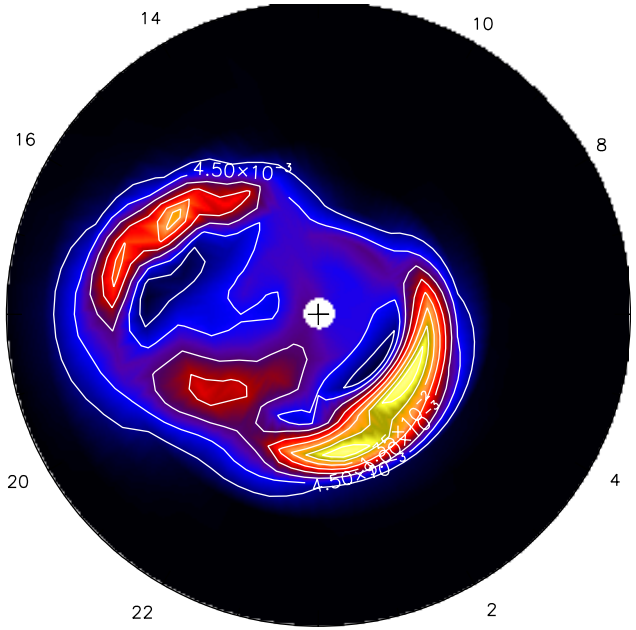
HP decrease:

- NOAA: 16GW
- TIEGCM: 8GW

2. Distribution (2-D)

(A) Northern (Summer) hemisphere

Simple Joule heating (207 GW)



Poynting flux (288 GW)

[*Deng et. al.*, 2007]

Simulation conditions

$$B_y = 0, B_z = -10nT, F_{10.7} = 150, HP = 16GW, DOY = 180$$

$$S_{down} = \int q_J dh$$

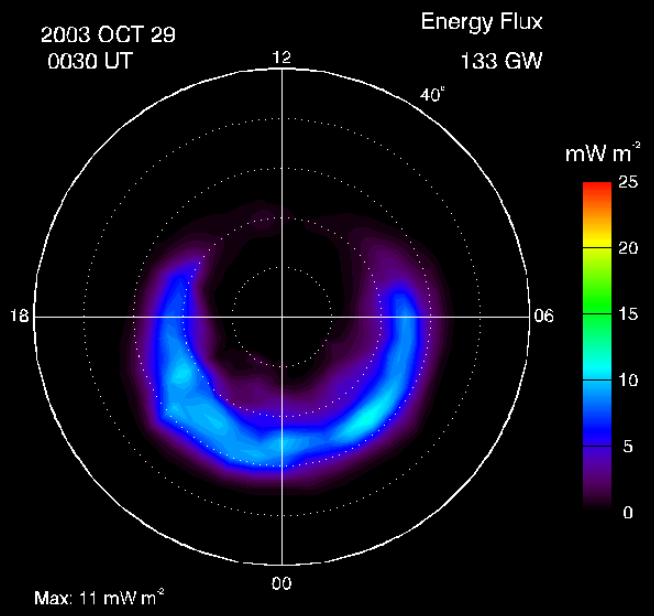
Residual E-field

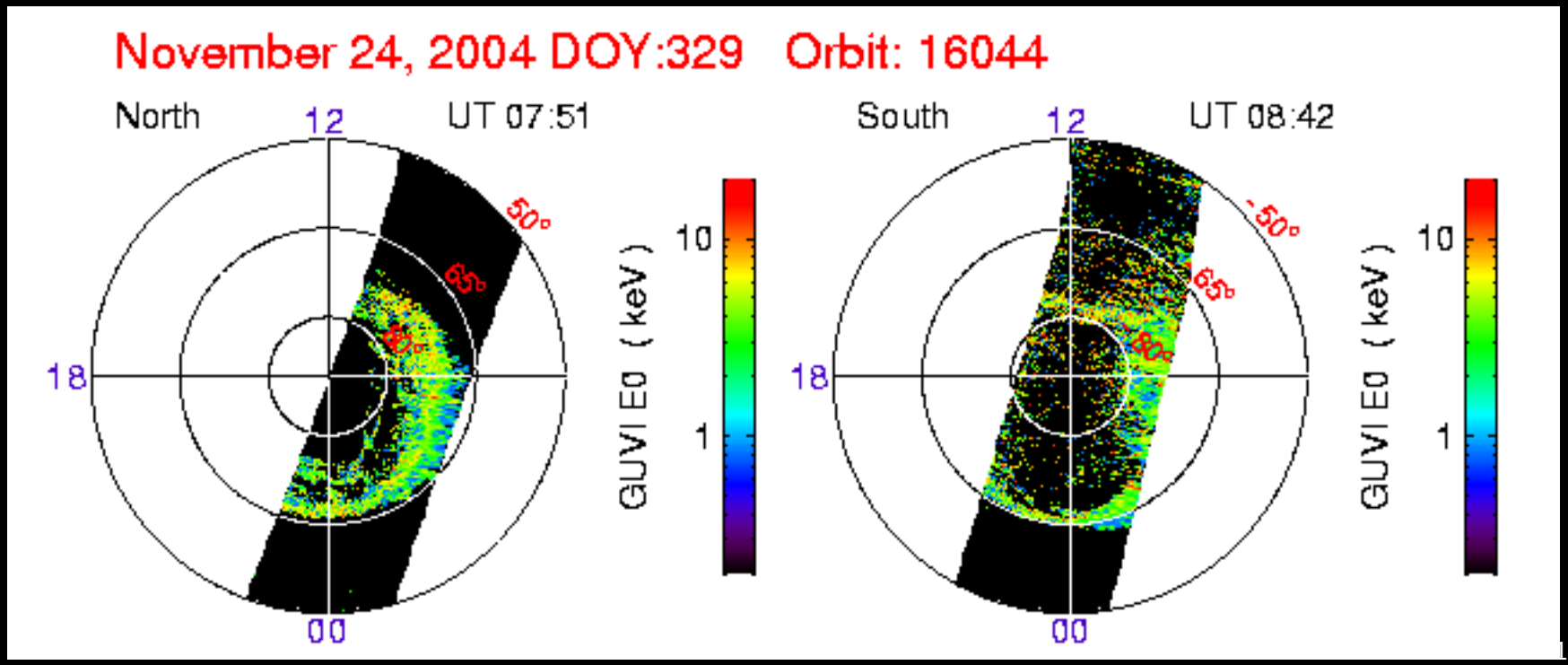
$$q_J = \sigma_p \left(\langle E \rangle + E' + u_n \times B \right)^2$$

$$q_J = \sigma_p \left(\langle E \rangle + u_n \times B \right)^2 + 2\sigma_p E' \cdot \left(\langle E \rangle + u_n \times B \right) + \sigma_p E'^2$$

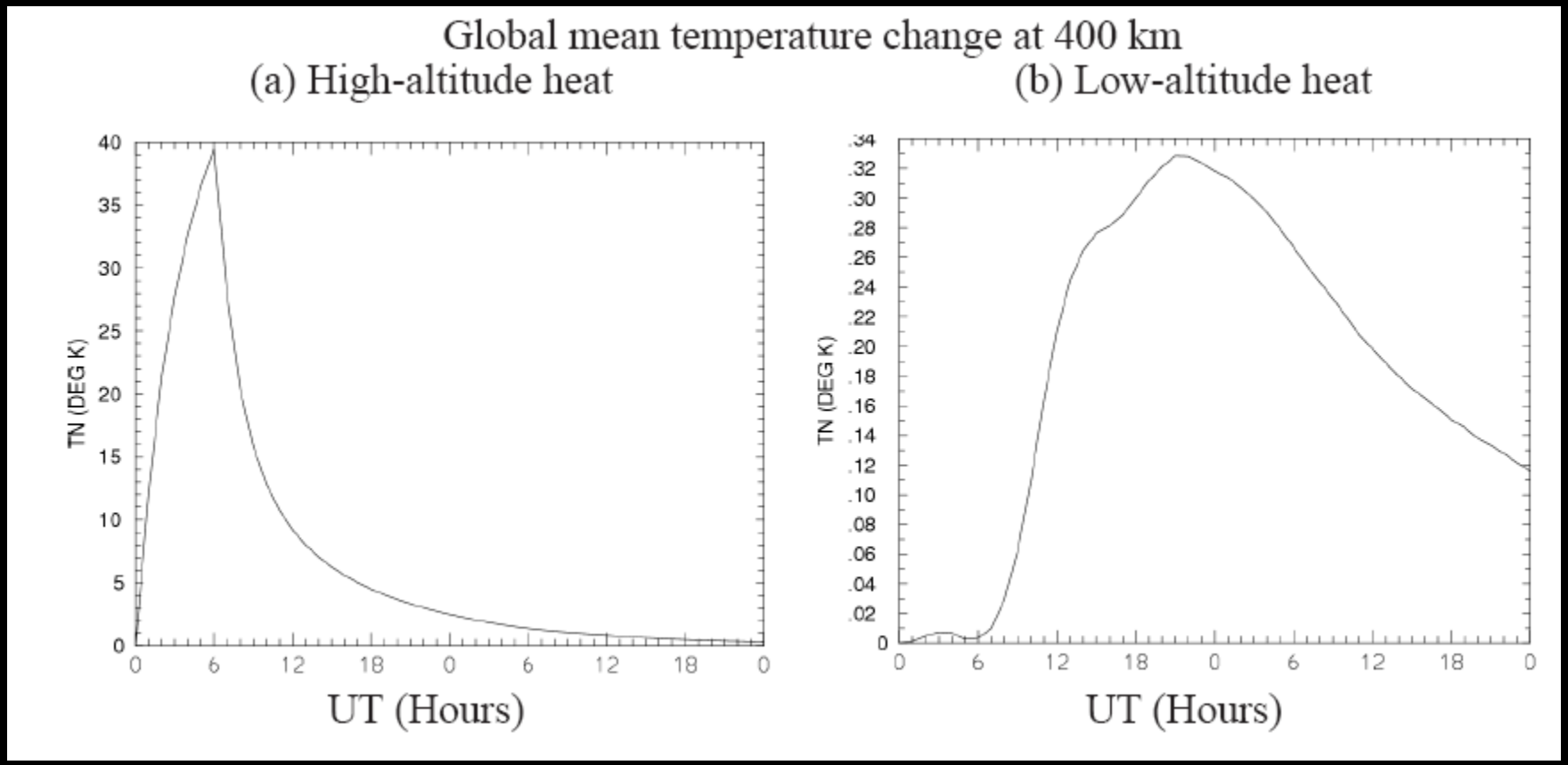
Case	Simple JH	Poynting-Joule	Poynting-Pedersen	Poynting-Diff
Energy input	simple JH	Poynting	Poynting	Poynting
Alt-distribute	NA	simple JH	Pedersen conductivity	difference according Pedersen

$$q_e = \frac{q_s}{\int q_s dh} S_{down} \qquad \frac{\sigma_p}{\int \sigma_p dh} S_{down} \qquad q_s + \frac{\sigma_p}{\int \sigma_p dh} \left(S_{down} - \int q_s dh \right)$$


2003 OCT 29
0030 UT
Energy Flux
133 GW
12
40°
18
06
00
mW m⁻²
25
20
15
10
5
0
Max: 11 mW m⁻²


November 24, 2004 DOY:329 Orbit: 16044
North
UT 07:51
12
18
00
50°
65°
80°
GUVI E0 (keV)
10
1
South
UT 08:42
12
18
00
-50°
65°
80°
GUVI E0 (keV)
10
1

2. Distribution (Altitudinal)



Courtesy of Arthur Richmond.

Global-mean temperature change at 400 km altitude for two TIE-GCM runs with identical total Joule heating between 0 and 6 UT.
(a) heating input at heights 225-325 km; (b) 108-138 km.

- Joule heating

$$q_J = \sigma_P (E - U_n \times B)^2$$

$$Q_J = \int q_J dz = \sum_P E^2, \text{ when } E \gg U_n \times B$$

- The Ratio

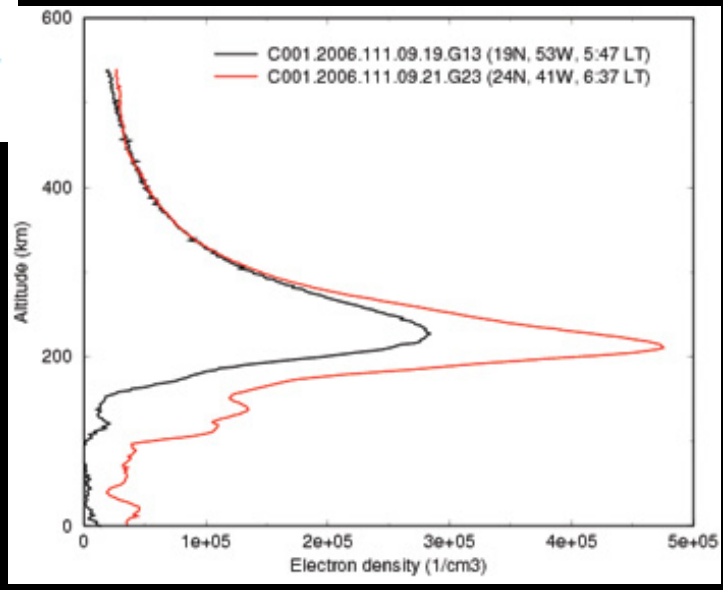
$$\gamma_{JH} = Q_E / Q_F = \gamma_P = \sum_{PE} / \sum_{PF}$$

- Pedersen conductivity

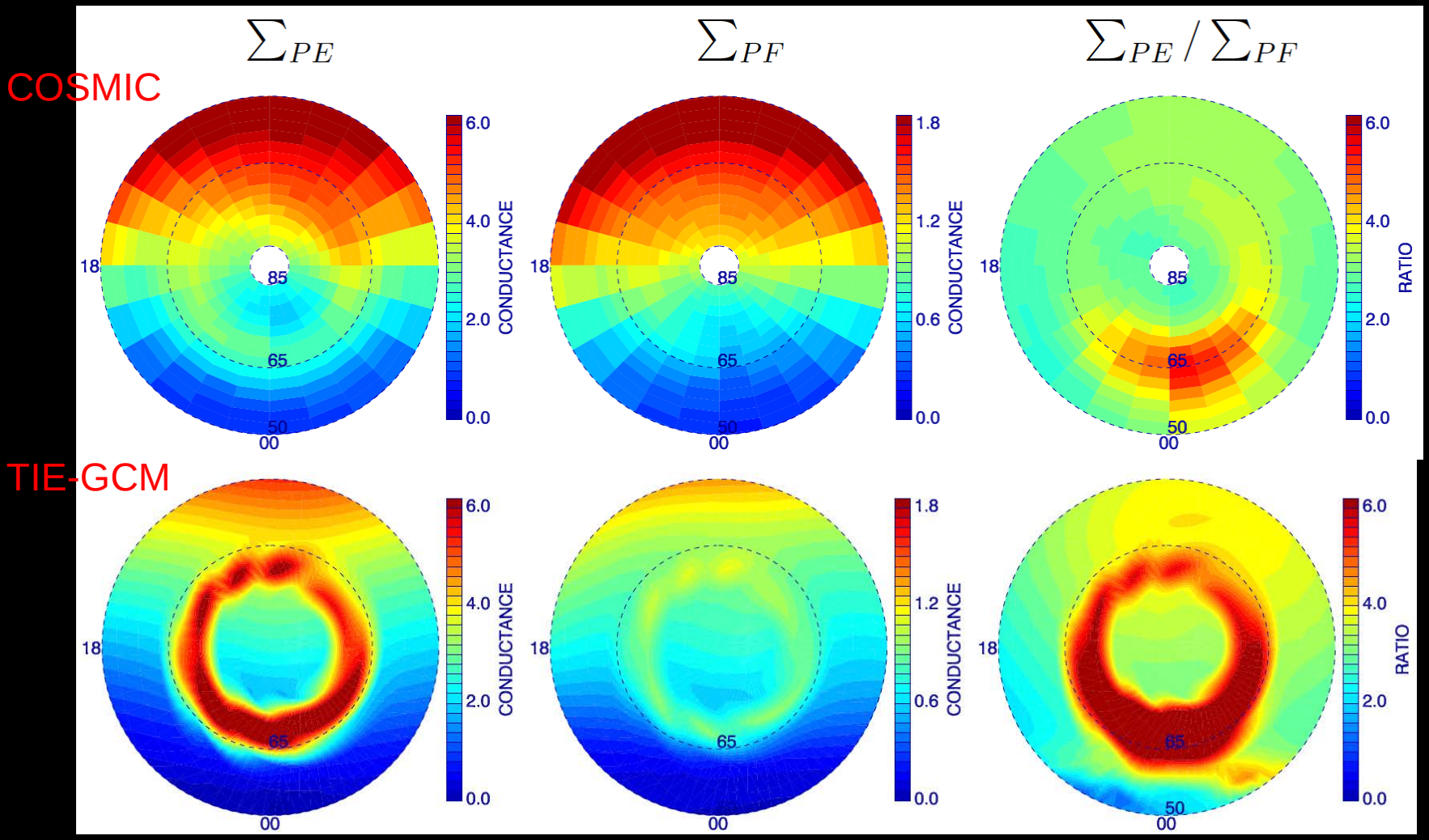
$$\sigma_P = \frac{e n_e}{B} \left\{ \sum_i C_i \left[\frac{\nu_{in}/\omega_i}{1+(\nu_{in}^2/\omega_i^2)} \right] + \frac{\nu_e/\omega_e}{1+(\nu_e^2/\omega_e^2)} \right\}$$

- Magnetic Field : IGRF Model
- Neutral Species : MSIS Model
- Electron Density : COSMIC
- Period : 2008-2011

Electron density profiles from COSMIC



Results: Comparison with TIE-GCM Model

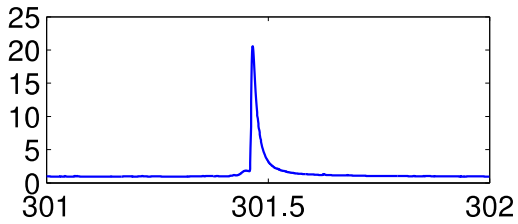


[*Cheng et. al.*, 2014]

- The maximum value of the ratio in the northern summer hemisphere is 5.5, which is smaller than the result from TIE-GCM simulation (9).

Spectral dependence

XUV EUV



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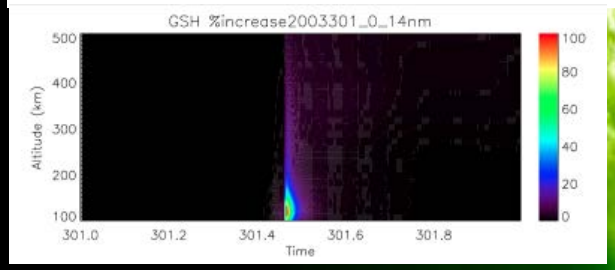


- 0-14nm: largest energy deposition
- 25-105nm: largest influence on I-T
- Altitudinal distribution of energy is different

[*Huang et. al.*, 2013]

2003/10/24 16:00

3. Correlation: Poynting flux Vs. particle precipitation

- Poynting flux → neutral density → ionization caused by particle precipitation

- Particle precipitation → distribution of conductance → Joule heating

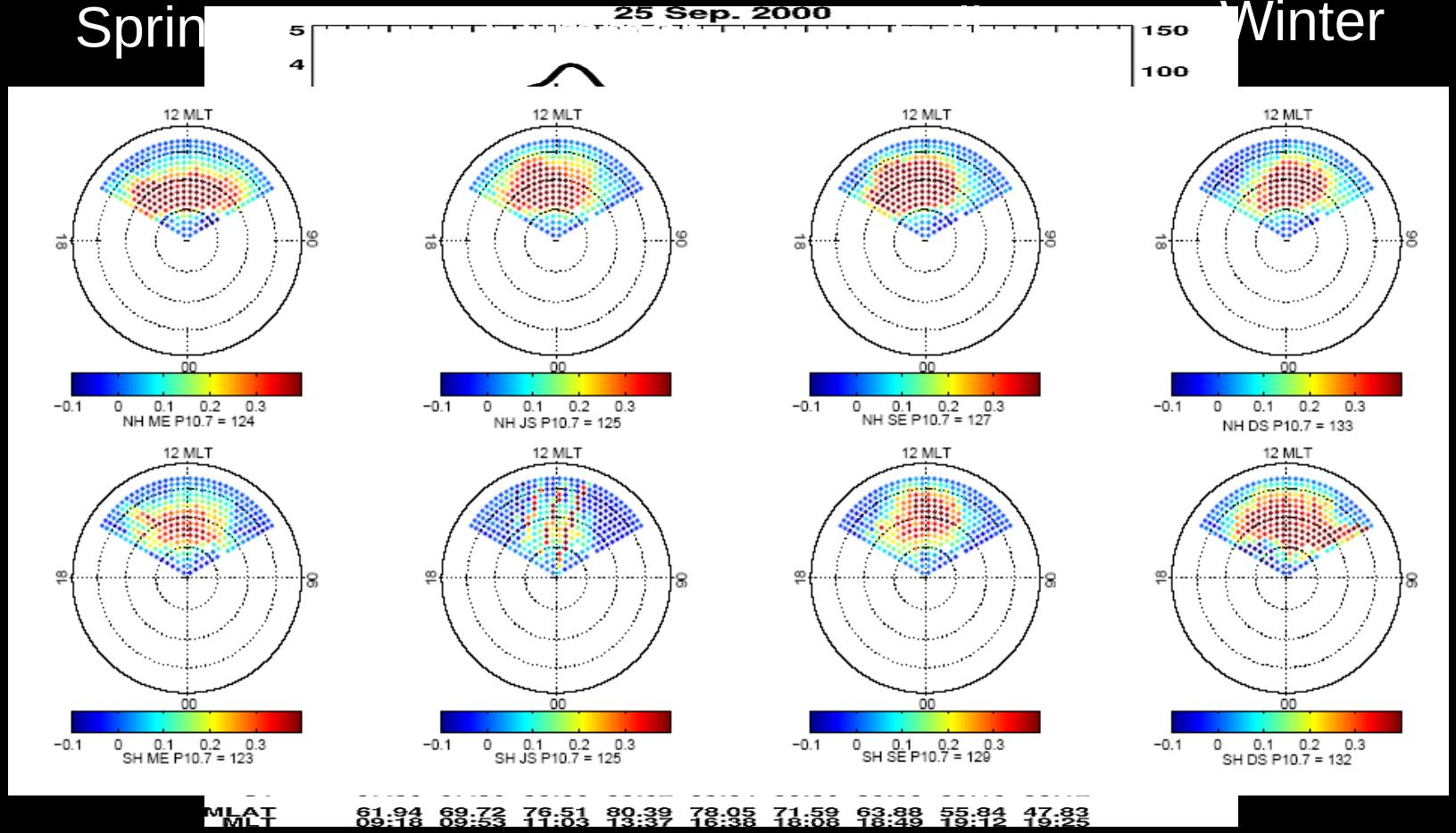
$$q_J = \sigma_P (E - U_n \times B)^2$$

Enhancement of Neutral Density

Sprin Winter

NH

SH

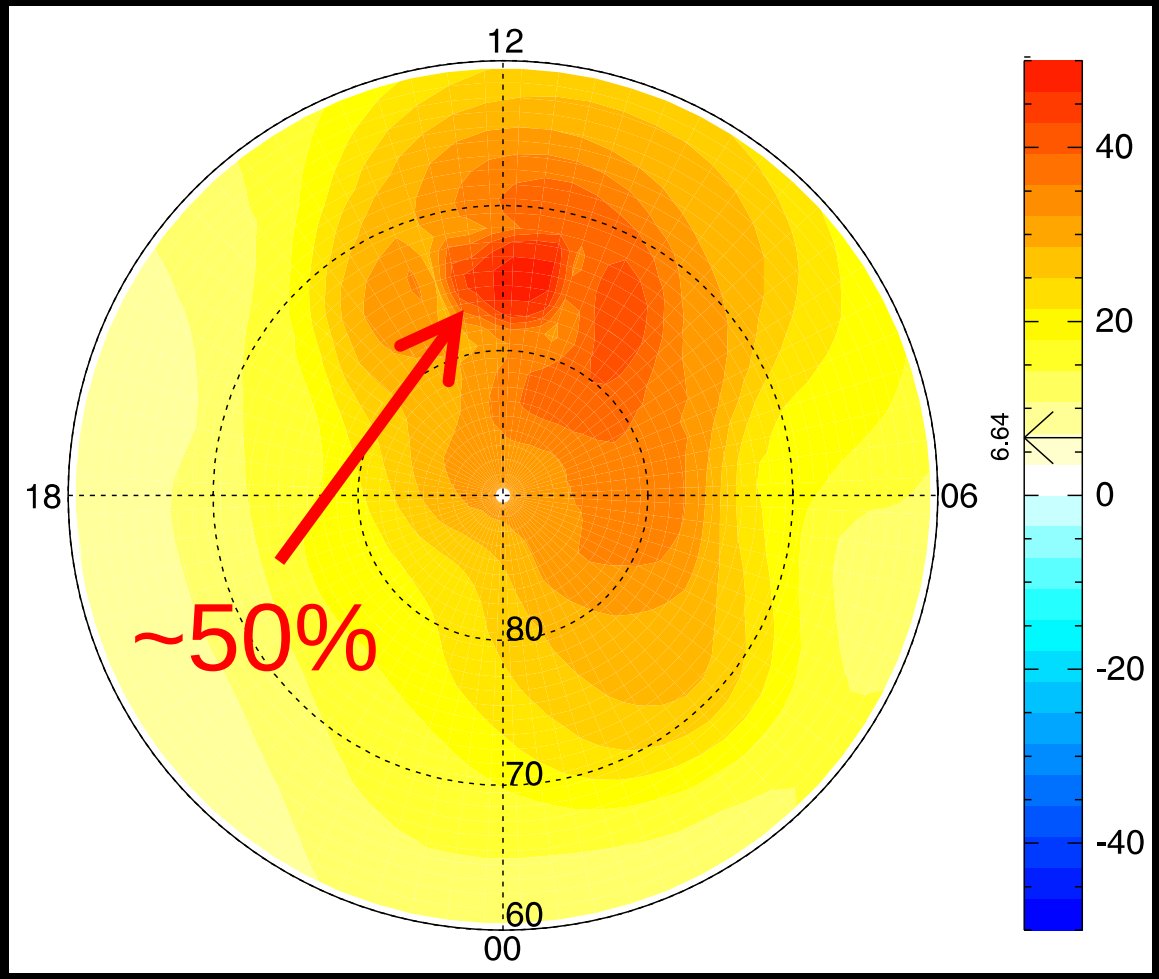


Luhr et al. GRL 2004.

Reatz & Luhr, 2008

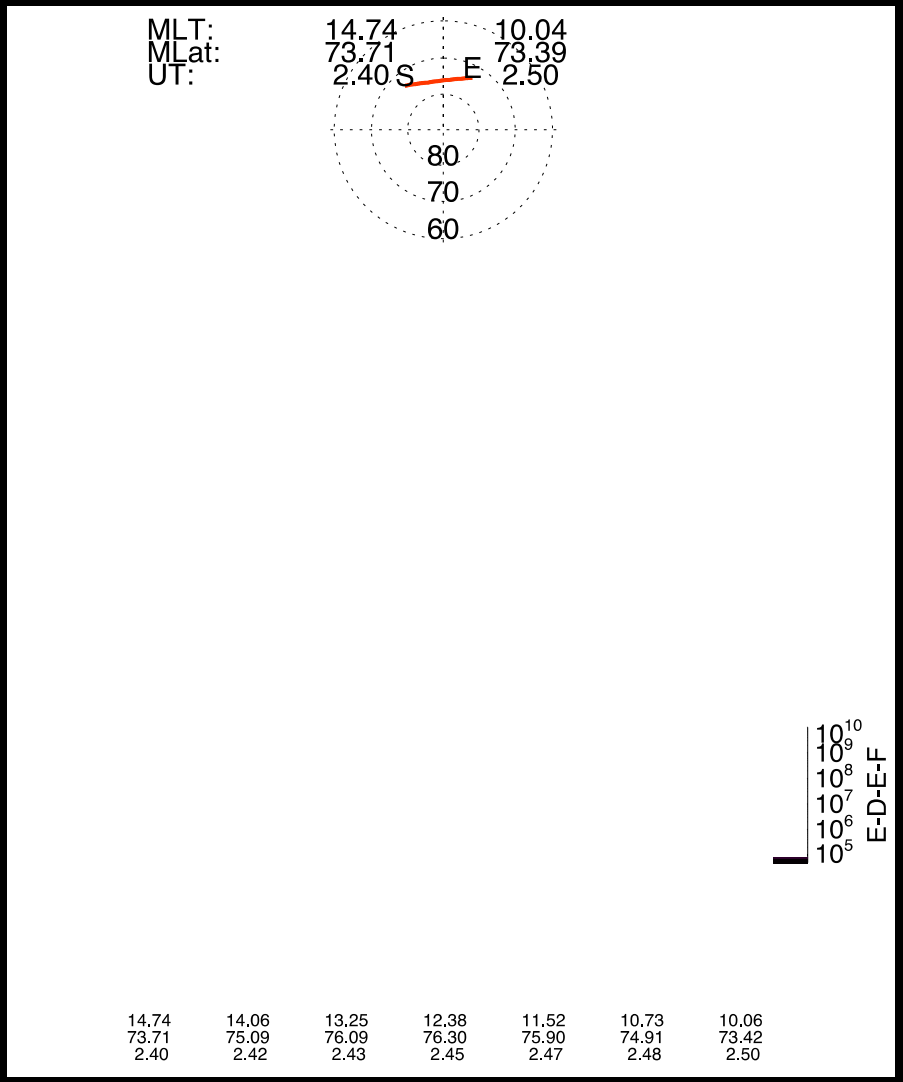
Neutral density enhancements in the cusp region from CHAMP satellite measurements.

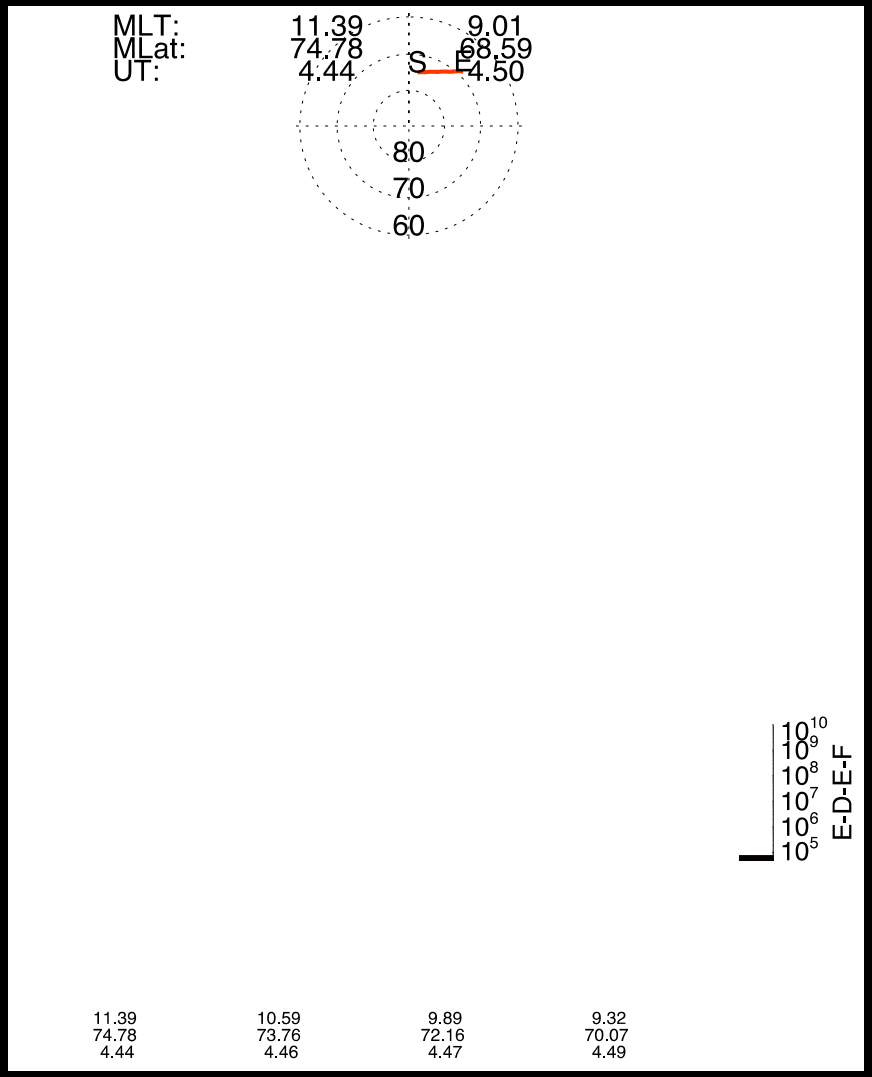
Total % change of Rho
(Poynting flux + soft particle precipitation)



- Total % difference with both Poynting and soft particles
- Rho (400km) → 50%
- 50% is consistent with CHAMP observations.

Poynting flux vs. Soft particles: (DMSP)





Match

$$q_J = \sigma_P (E - U_n \times B)^2$$

Not Match

Summary:

1. Total amount: ~100%
2. Distribution
   1) 2-D distribution: Small-scale variability
   2) Altitudinal distribution: too much energy goes to lower thermospere
3. Correlation between particle precipitation & Poynting flux: Match & non-match