Thermosphere Mass Density Enhancement via cusp electron precipitation

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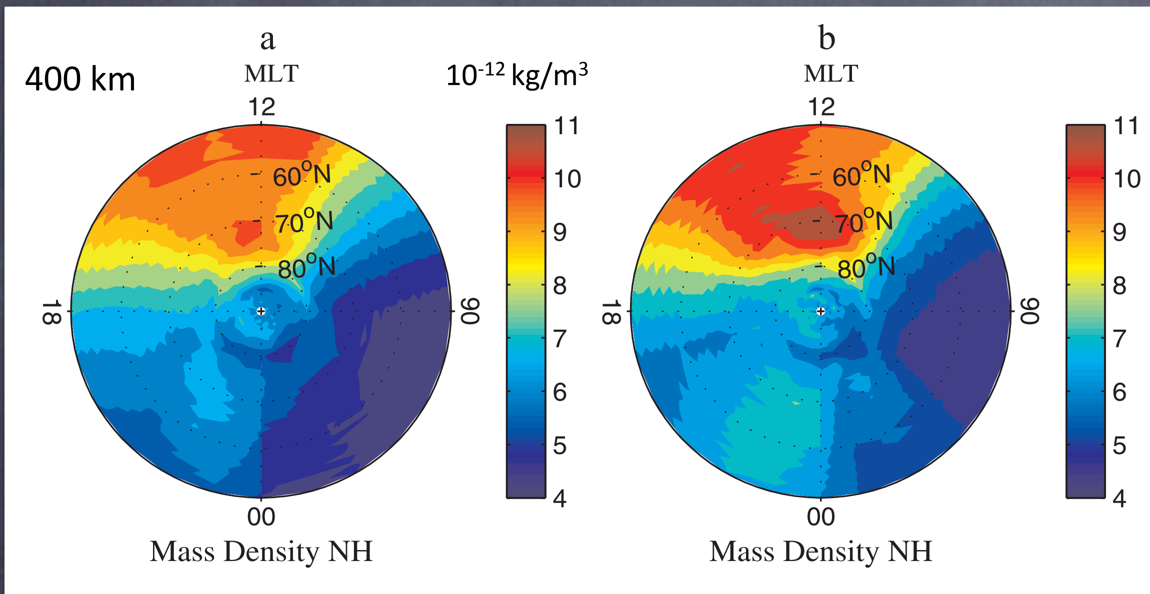
Observed Thermospheric Mass Density Enhancement

Northern Hemisphere

quite

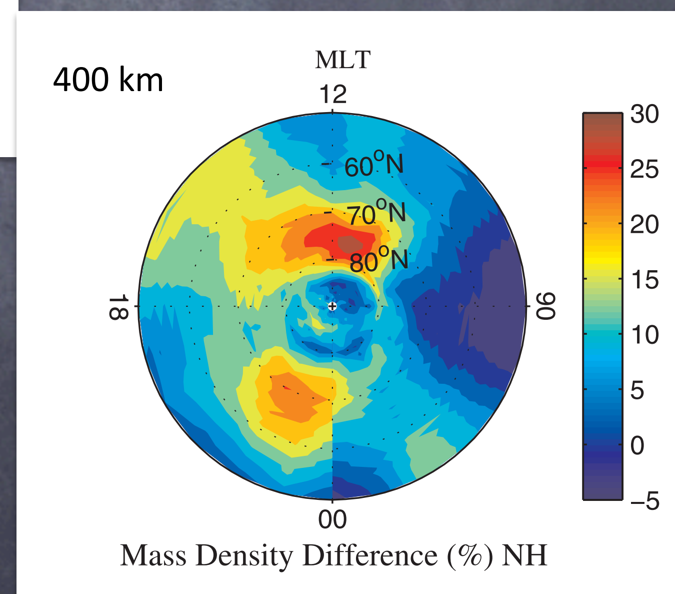
active



Compared with MSIS:

- Enhancement near noon and premidnight at auroral latitudes
- Dayside enhancement around 30%, nightside around 20%

CHAMP vs MSIS



At 400 km altitude:

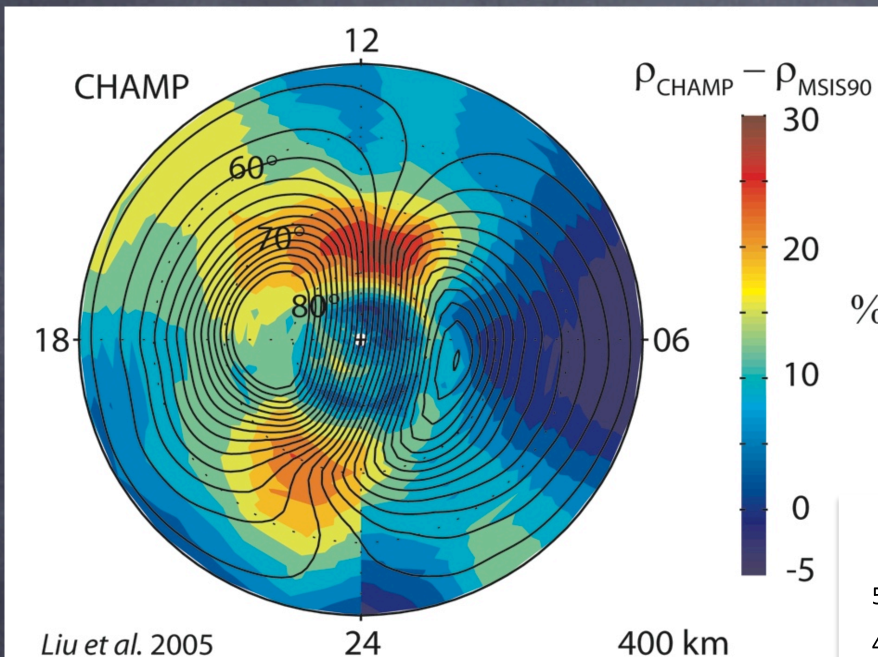
- Mass density peaks near 1400 MLT
- Dayside enhancement near 70-80 MLT
- Nightside enhancement in the premidnight sector

WHY?

Drivers for Thermospheric Mass Density

Possible large-scale Drivers at High-latitudes

CHAMP - MSIS



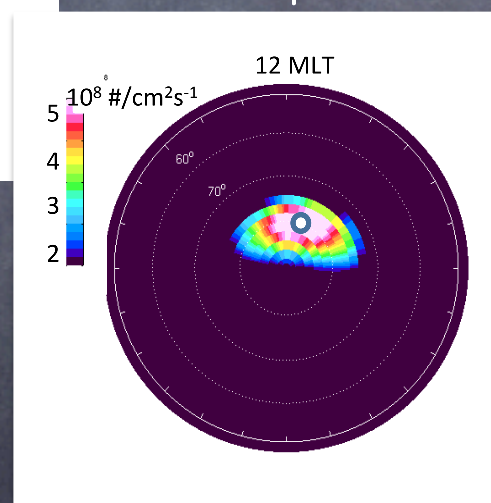
In the cusp region:

- Joule Heating (Crowley et al. 2010)
- Soft Electrons (Zhang et al. 2012)

In the Pre-midnight region:

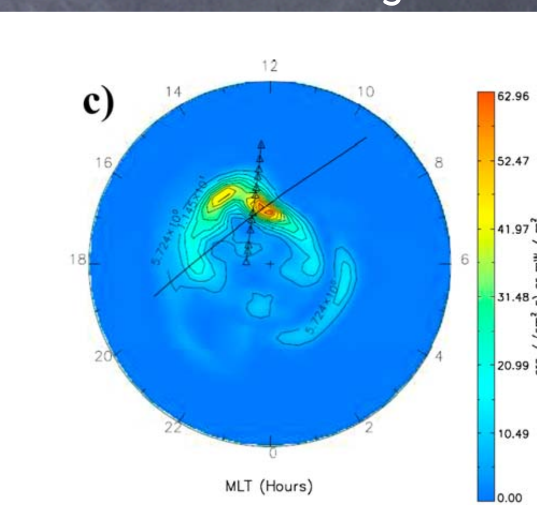
- Small scale processes?
- Soft Electron Precipitation?

Soft Precipitation



Zhang et al. [2012]

Joule Heating



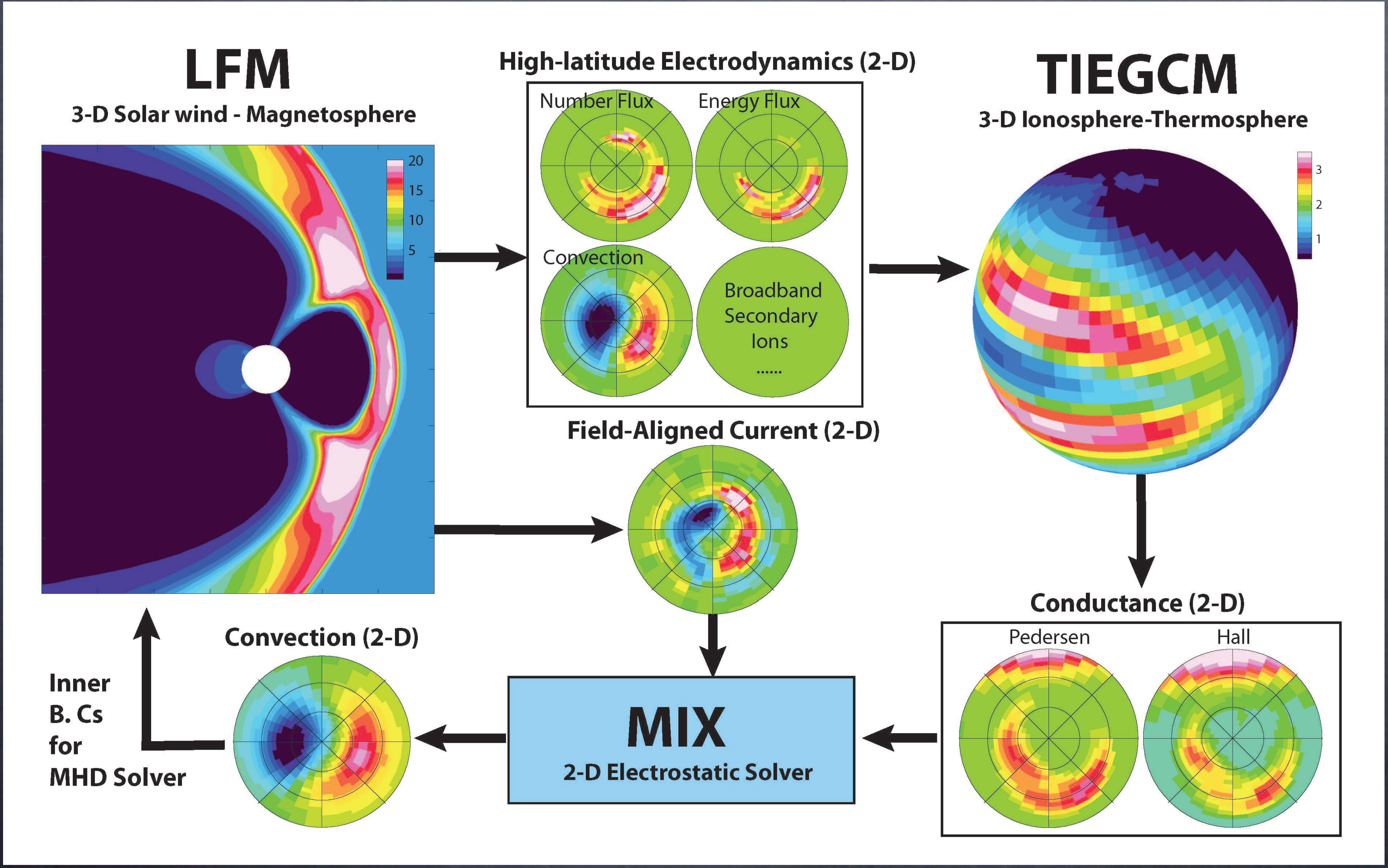
Crowley et al. [2010]

CHAMP found large deviations of mass density at auroral latitudes both on the dayside and in the premidnight sector

Mechanism for thermospheric mass density enhancement? – the coupled M-I-T (CMIT)

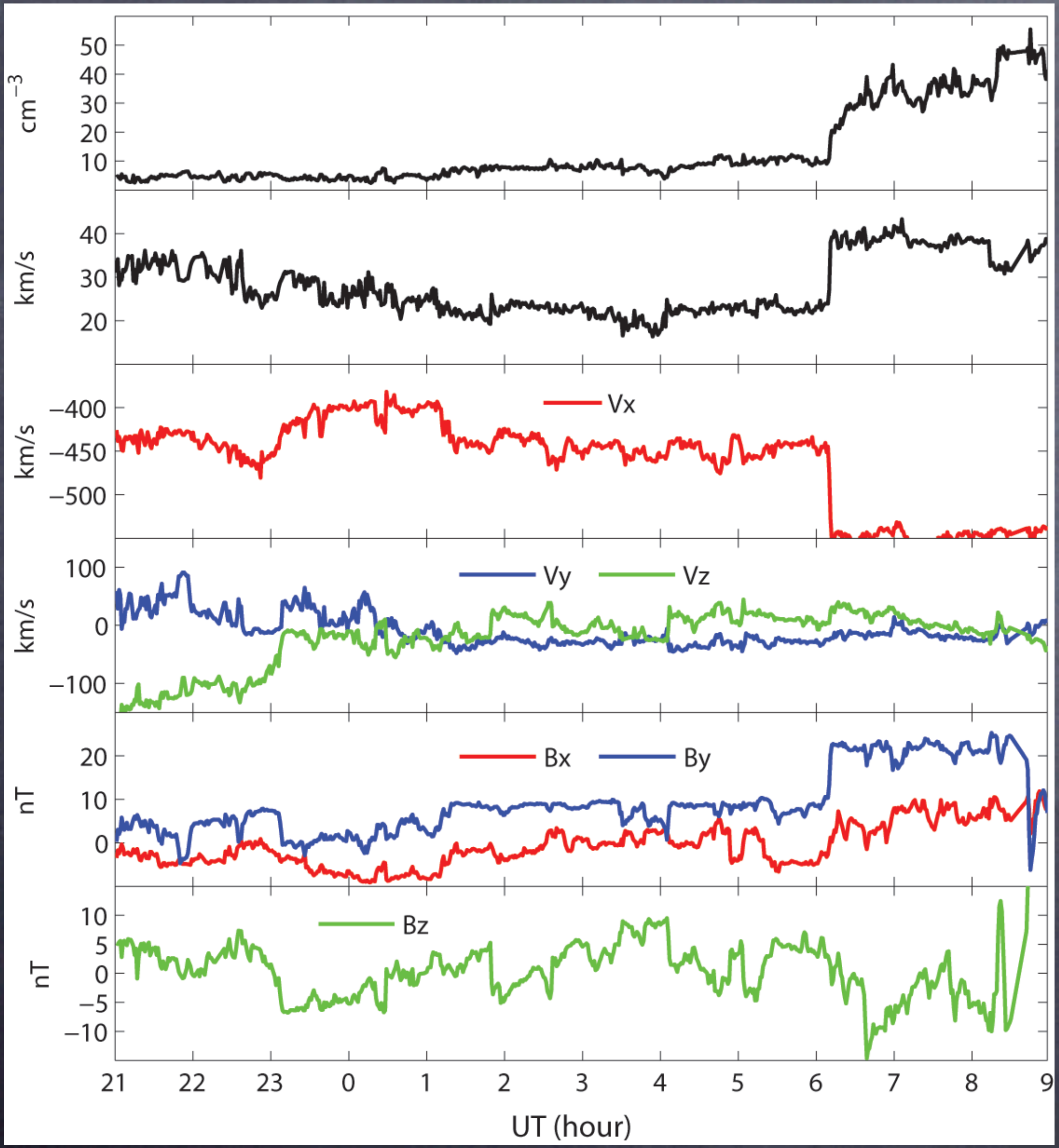
The Coupled M-I-T (CMIT) Model

LFM – Magnetosphere model; TIEGCM – Ionosphere-Thermosphere model

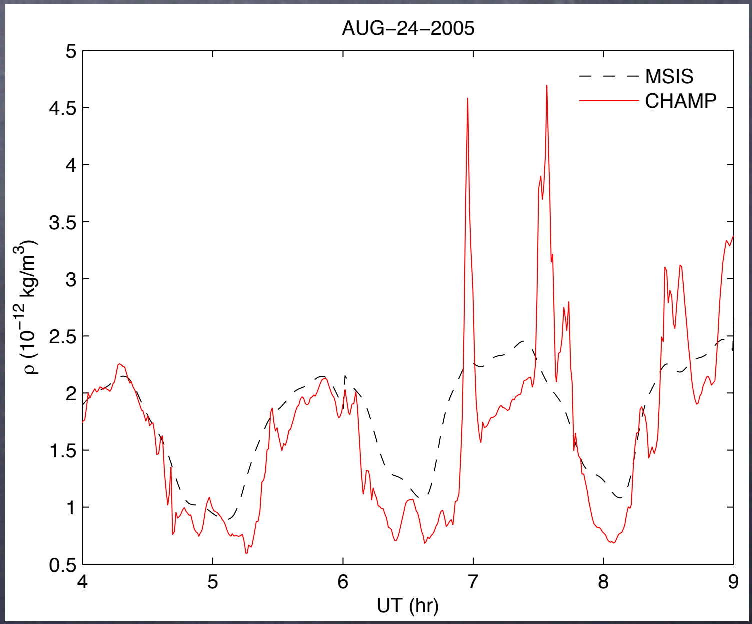


The Aug 23-24, 2005 Storm Simulation

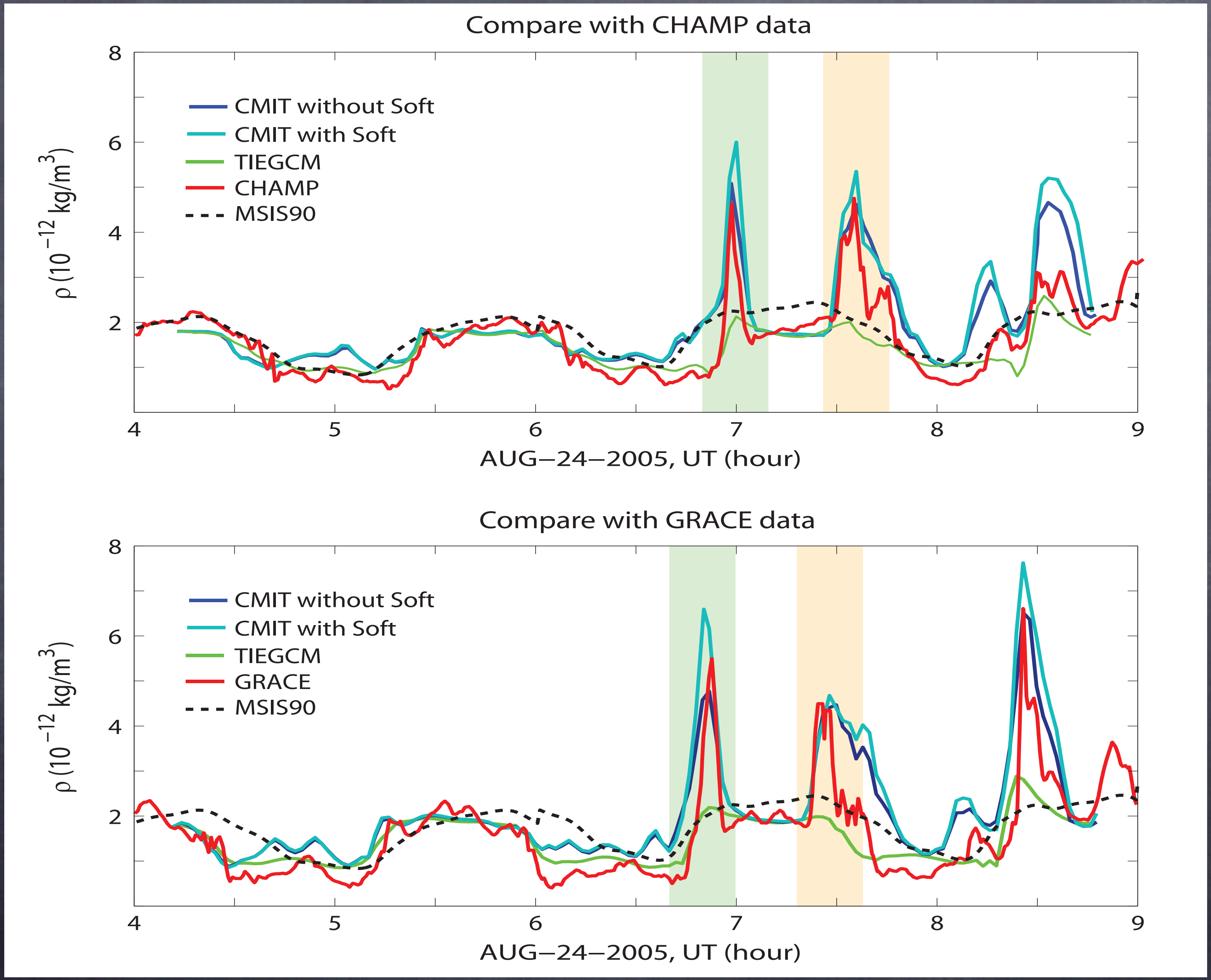
SW / IMF Conditions



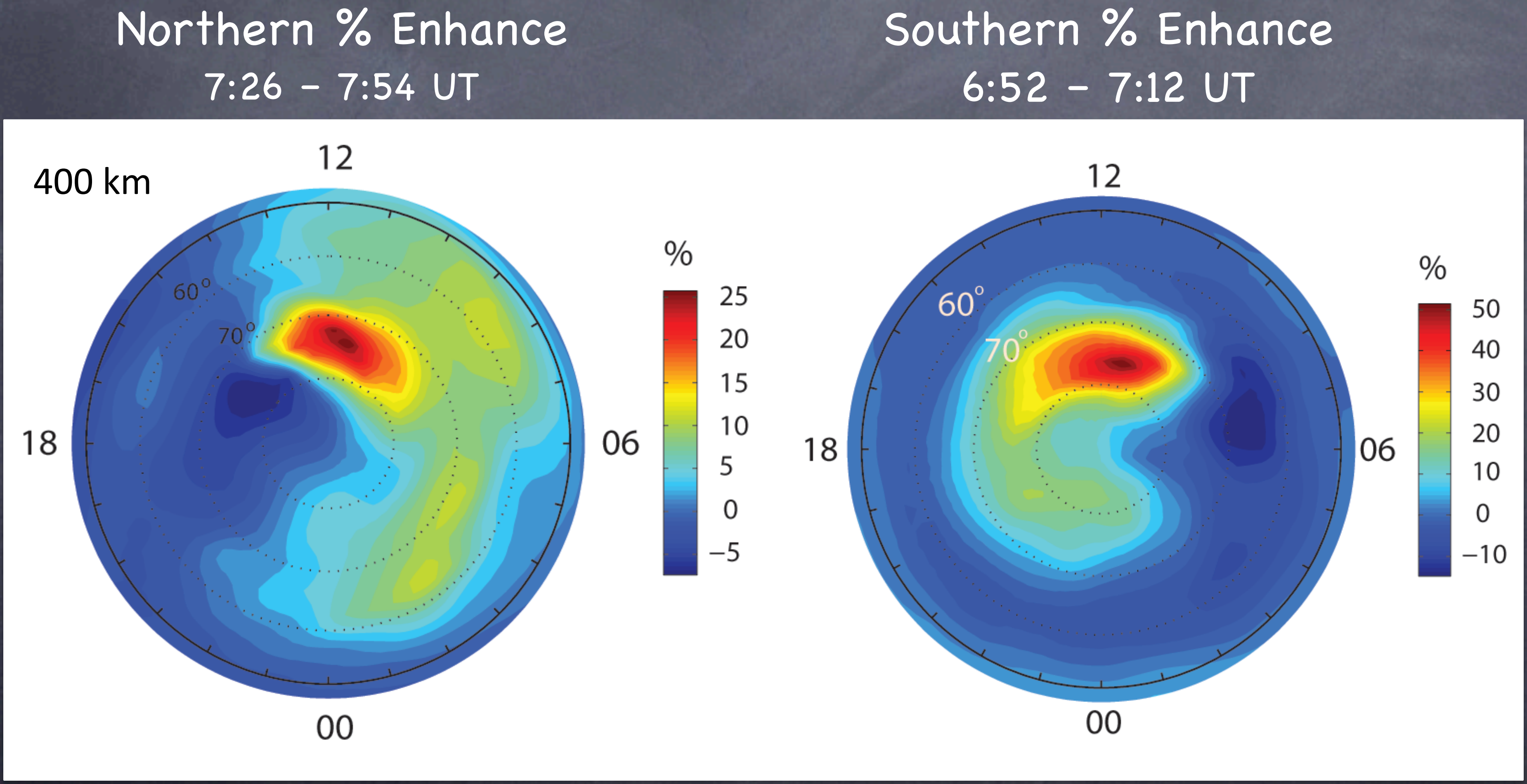
- large IMF By component between 06:00-09:00 UT
- large amount of Joule heating was observed in the cusp region
- thermospheric mass density enhancement (400 km) in the cusp region was also observed by CHAMP



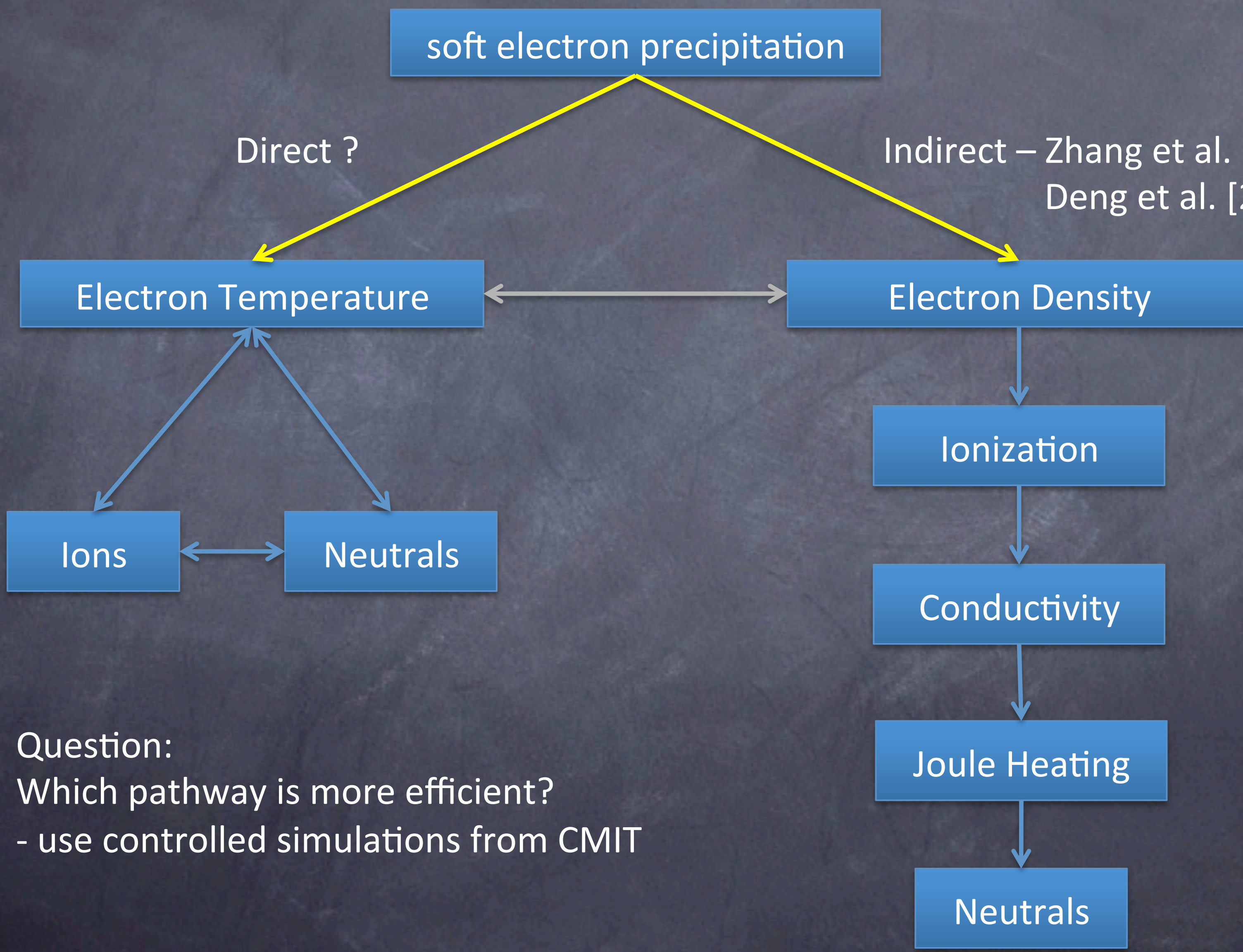
Data-Model Comparison (CMIT vs CHAMP/GRACE)



Enhancement of Mass Density by Soft Electrons

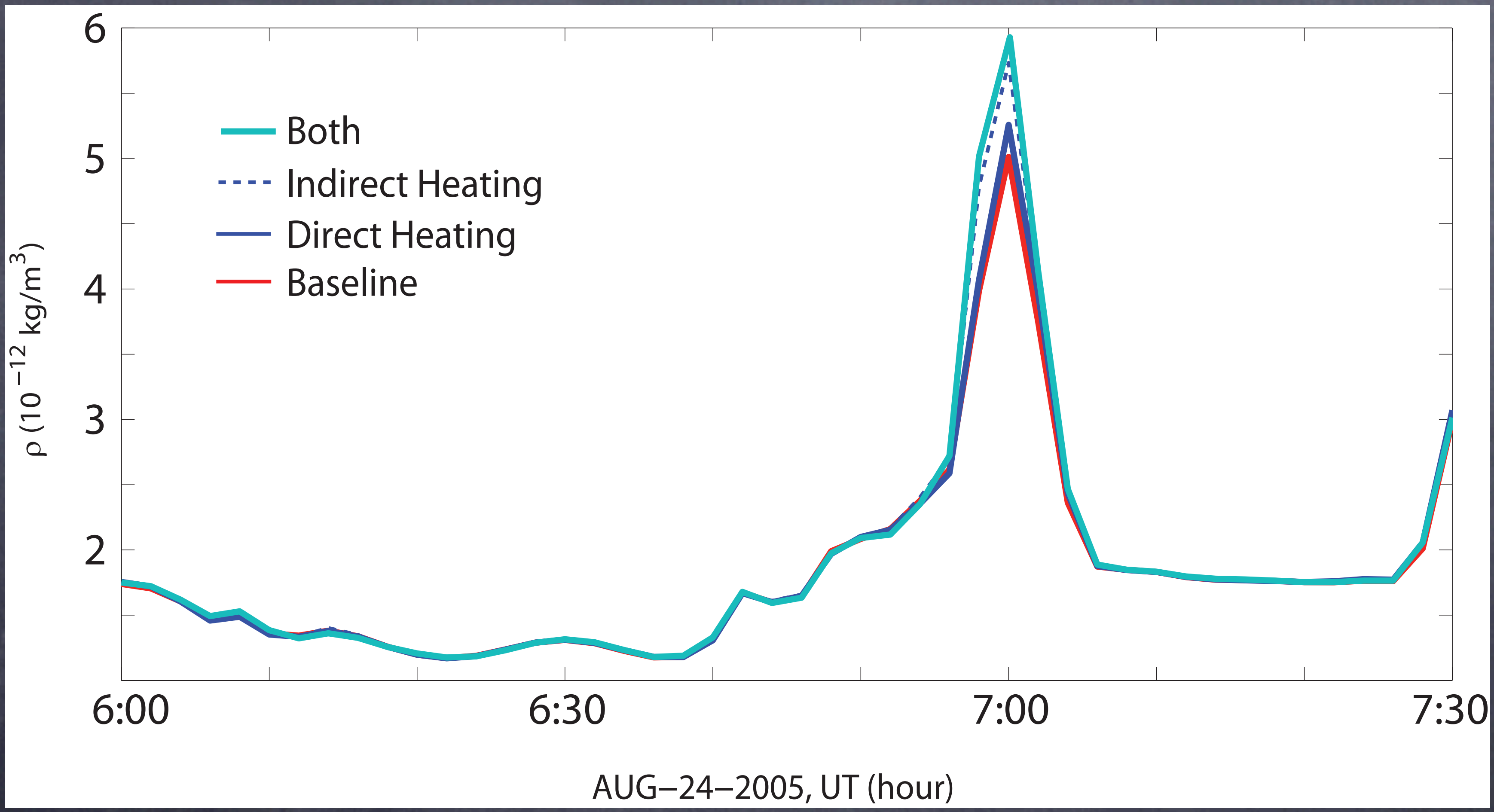


Pathways of Thermospheric Heating via S.E.P



Question:
Which pathway is more efficient?
- use controlled simulations from CMIT

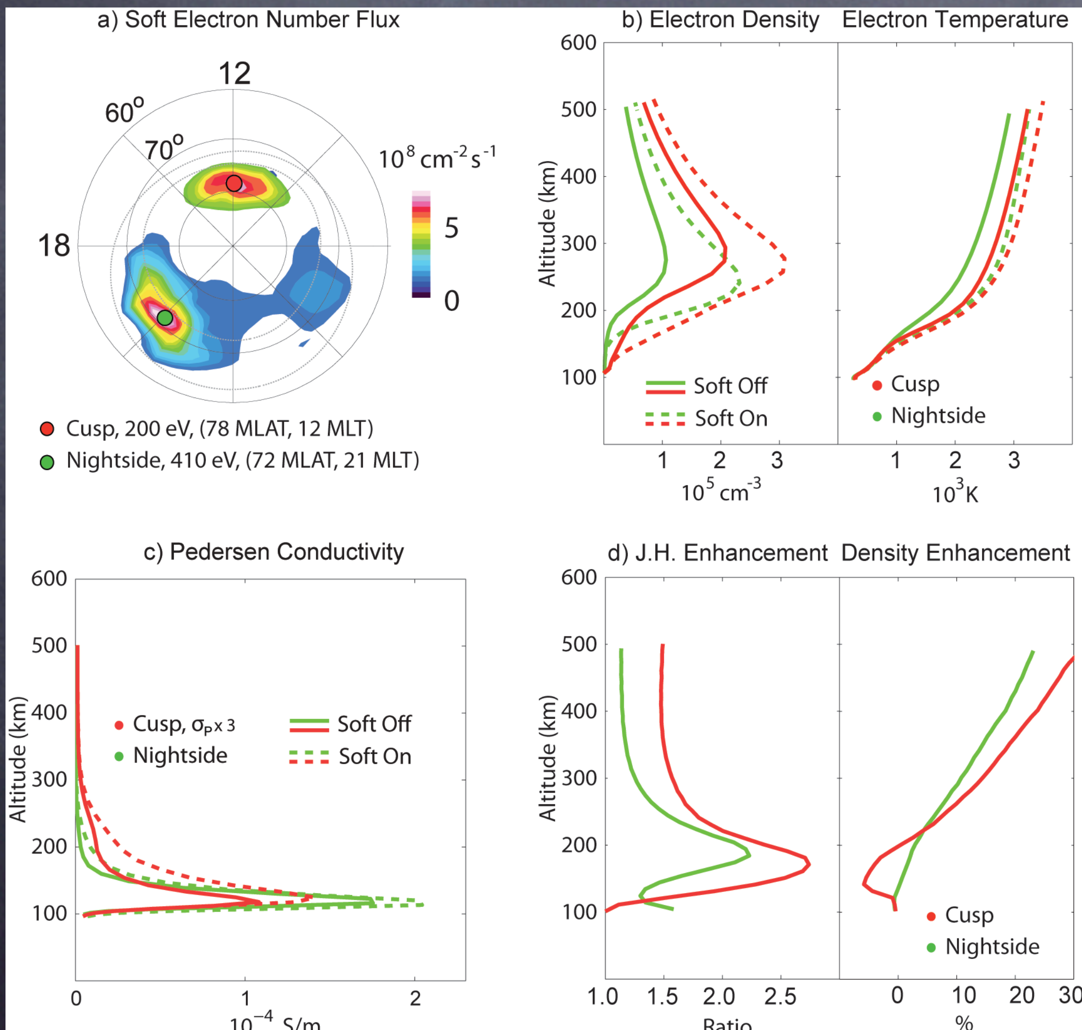
Pathways of Thermospheric Heating via S.E.P

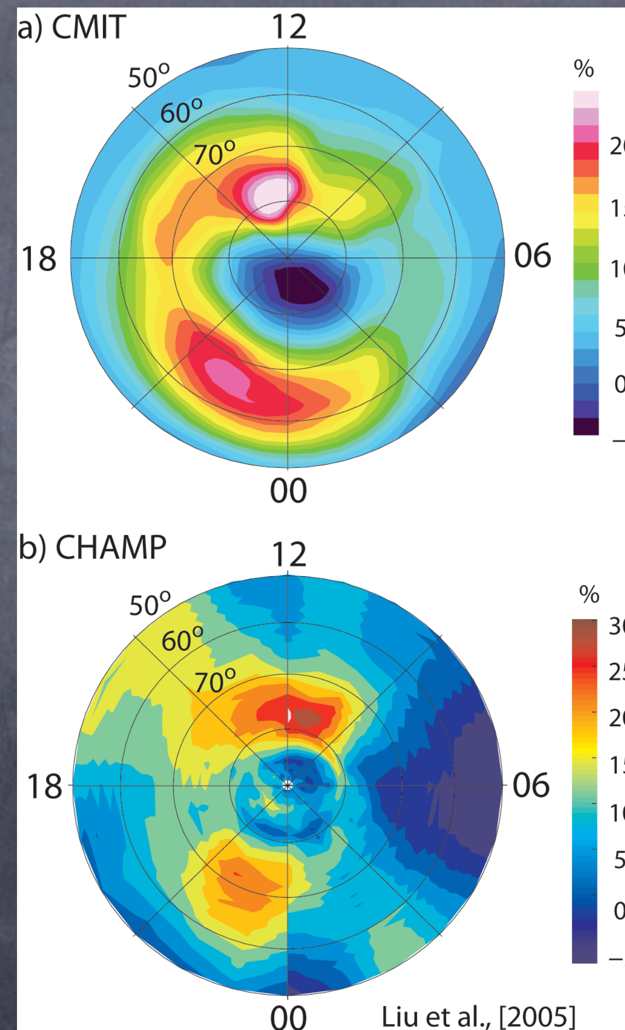


The Role of Soft Electron Precipitation

Ideal CMIT simulations with steady SW/IMF Driving conditions

Vx = 400 km/s, Vy=Vz=0; N = 5/cc, T = 10 eV, Bx = By = 0, Bz = -5 nT





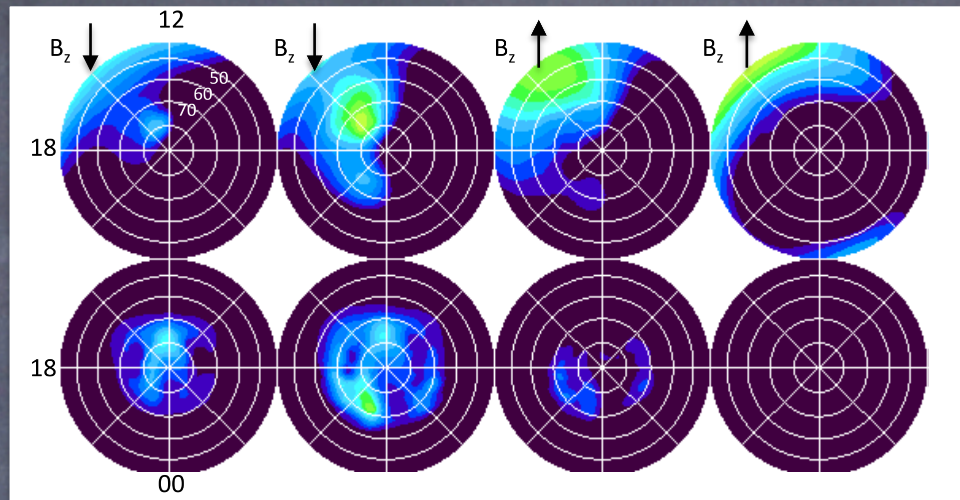
Effects of soft electrons: Thermospheric Neutral Density

CMIT without soft precipitation - hourly average

04:00-05:00 05:00-06:00 06:00-07:00 07:00-08:00

ρ@400km

Joule Heating



CMIT with soft precipitation - hourly average

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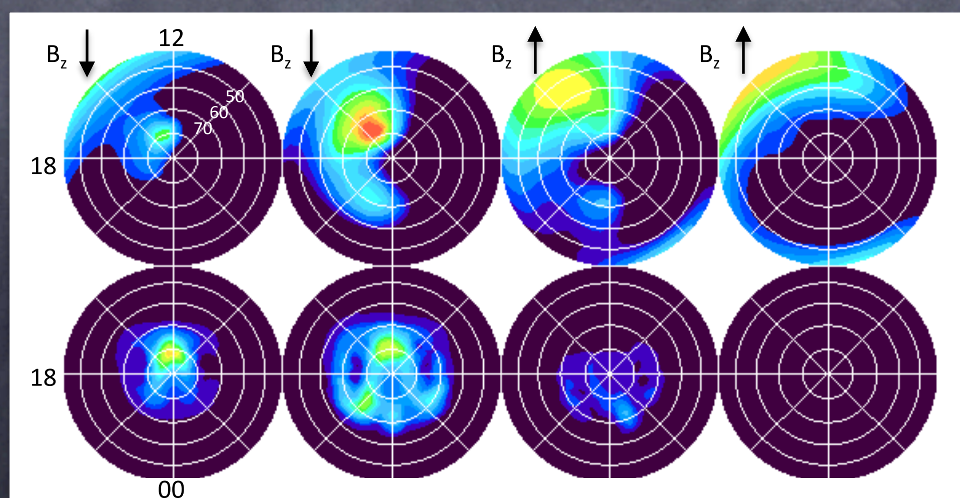
Joule Heating

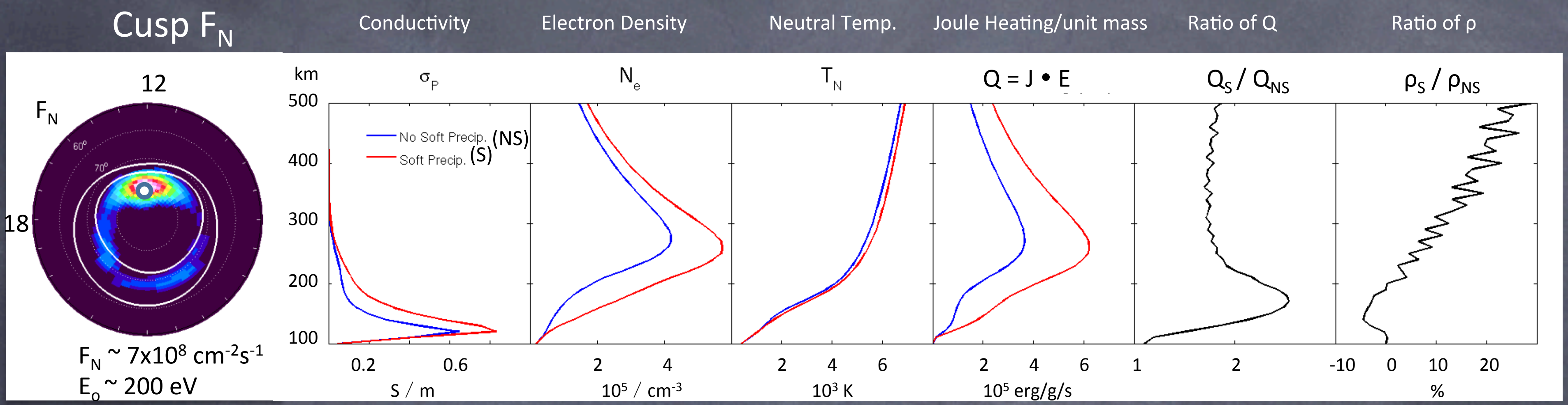


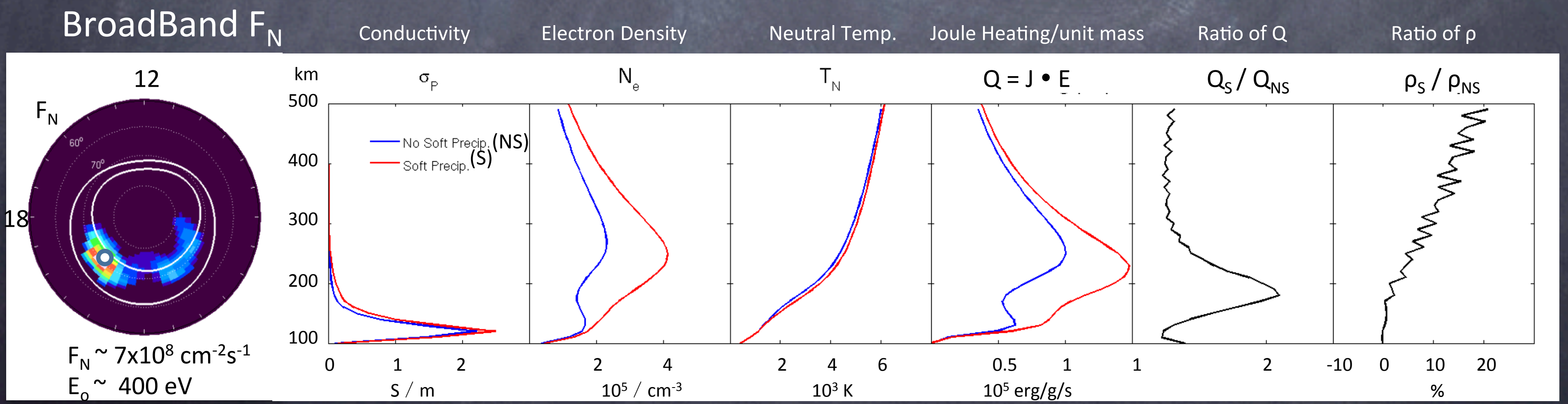
B_z ↓ : Southward IMF

B_z ↑ : Northward IMF

Effects of soft electrons: Height Profiles

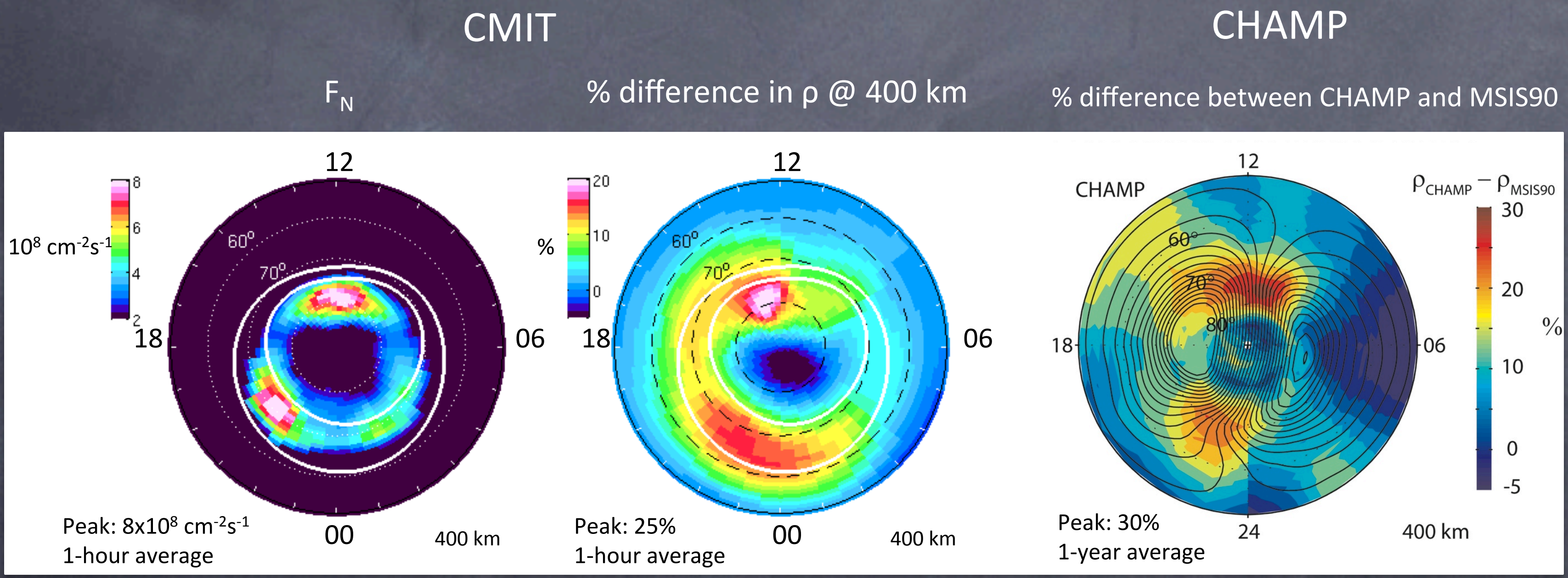
One hour average from the test CMIT simulation (05:00-06:00)





Effects of soft electrons: Neutral Density@400km

One hour average difference calculated from the CMIT simulation with and without soft electron precipitation



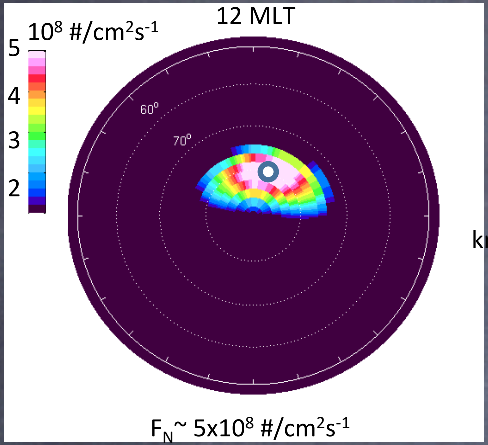
CMIT simulation, Bz=-5nT

Liu et al., 2005

When soft electron precipitation was included neutral density at 400 km is enhanced in the dayside cusp region and premidnight sector where intense soft electron precipitation occurs. The maximum enhancement in the dayside cusp region is ~ 20% and ~ 16% on the nightside

Effects of soft electrons: Energy Dependence

Soft precipitation distribution



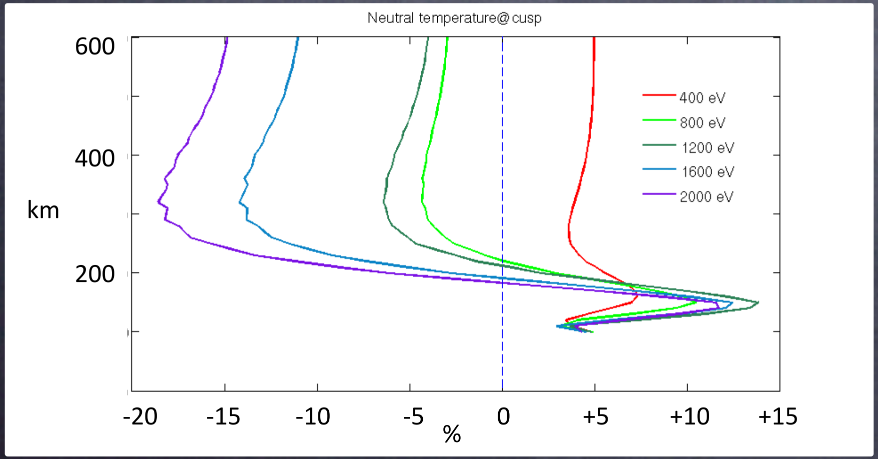
Altitudinal distribution of Joule Heating

km

0 1 2 3 4 5

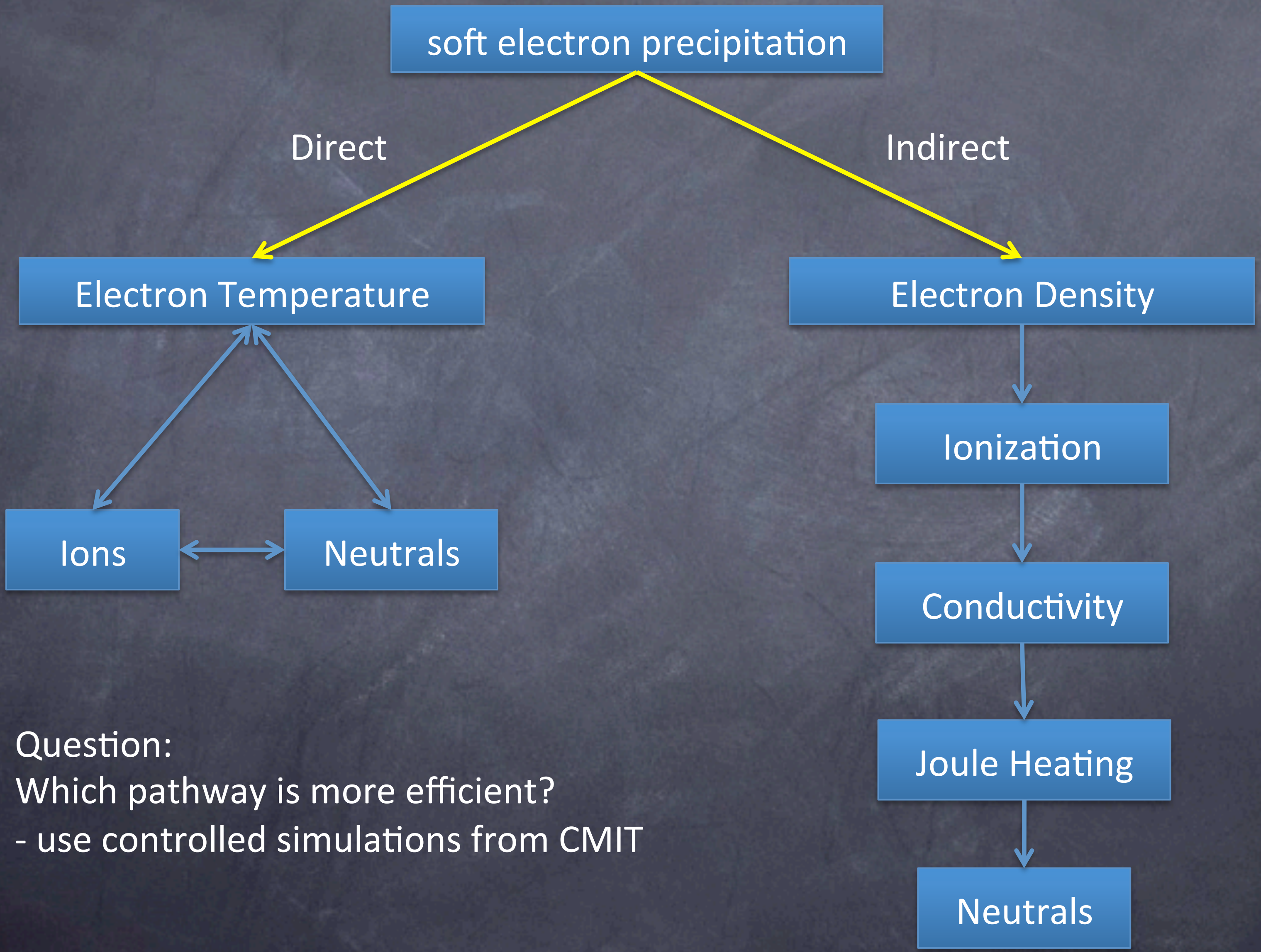
Eo(EV)	CPCP(kV)	%Δρ	Σp(S)
-	151	-	3.2
400	150	+20	3.8
800	144	-2	5.4
1200	139	-3	7.0
1600	132	-5	8.5
2000	125	-10	9.7

% Increase of Neutral temperature



- Soft electrons change the altitude distribution of Joule heating, Joule heating above 200 km has significant influence on neutral density
- As the average energy of soft electrons increases, the effect on the neutral density at 400 km decreases
- The magnetospheric response increases as average energy increases

How does soft electrons "heat" the thermosphere?



Question:
Which pathway is more efficient?
- use controlled simulations from CMIT

Test Simulations Setup

To test the efficiency of the two pathways of thermospheric heating through soft electrons, Four test simulations are used:

- Baseline : No soft electron precipitation

RUNS	Soft Electrons	Change Te	Change Ne	Physical
BASELINE	NO	-	-	Yes
HEATING ONLY	YES	YES	NO	No
IONIZATION ONLY	YES	NO	YES	No
HEATING & IONIZATION	YES	YES	YES	Yes

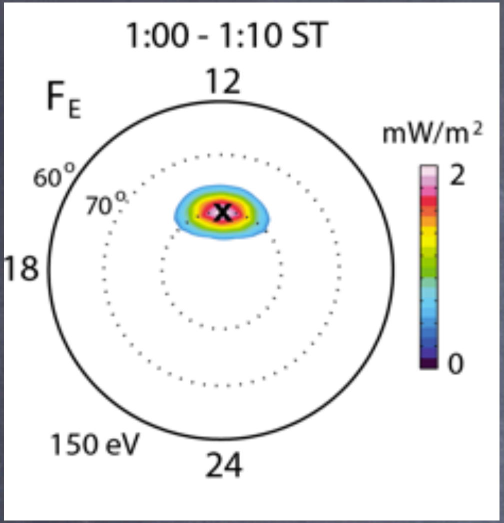
SW/IMF driving conditions

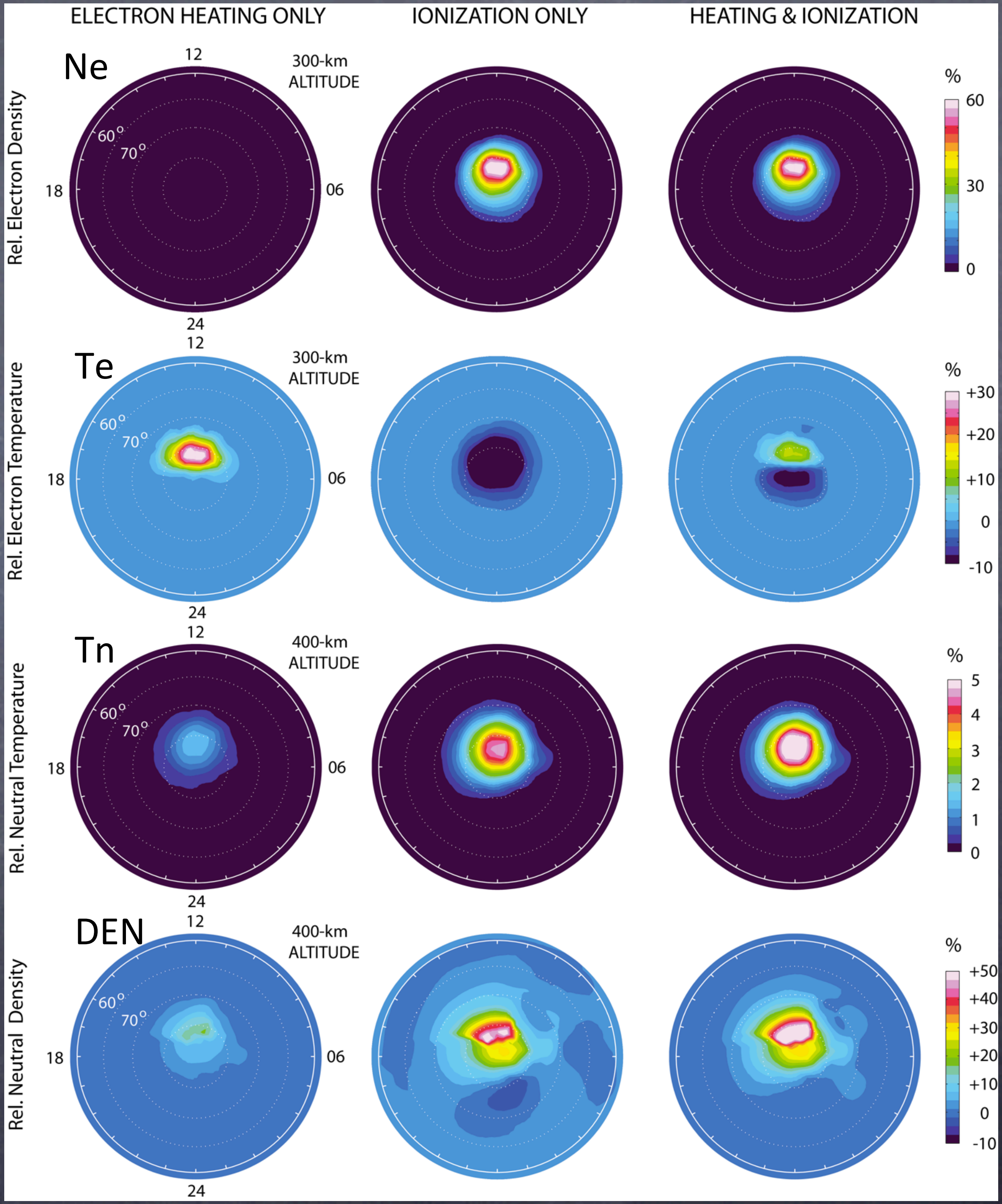
N(cc)	Vx(km/s)	Vy(km/s)	Vz(km/s)	Bx(nT)	By(nT)	Bz(nT)	Cs(km/s)	Tilt(°)
5	400	0	0	0	0	-5	40	0

Cusp precipitating electron flux: Fe ~ 2 mW/m^2, Eo ~ 150 eV

Results

Cusp Electron Flux



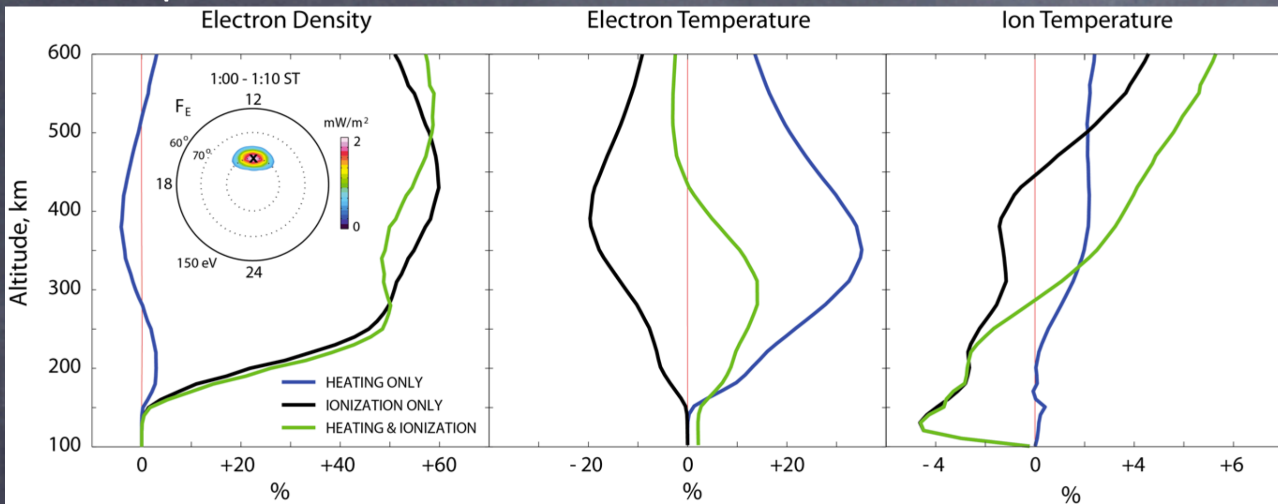


At 400 km altitude

- HEATING ONLY RUN causes ~ 10% mass density enhancement
- IONIZATION ONLY RUN causes > 40% mass density enhancement

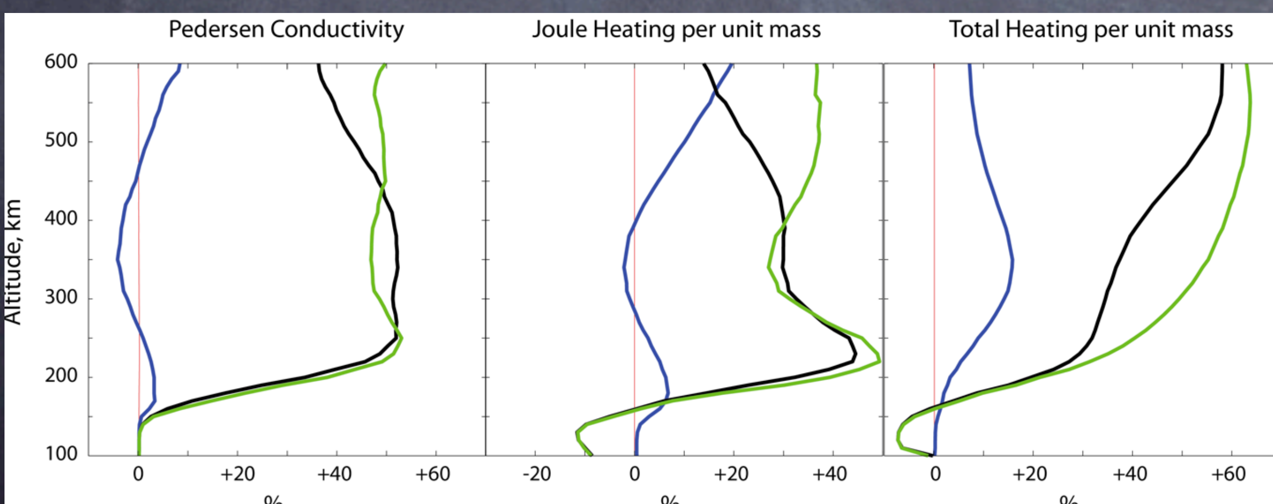
Results

Plasma profiles



The INDIRECT pathway is more efficient than the DIRECT pathway of thermospheric heating

Heating profiles



Neutral Temperature