Anomalous Electron Heating Effects on the *E* region Ionosphere in TIEGCM

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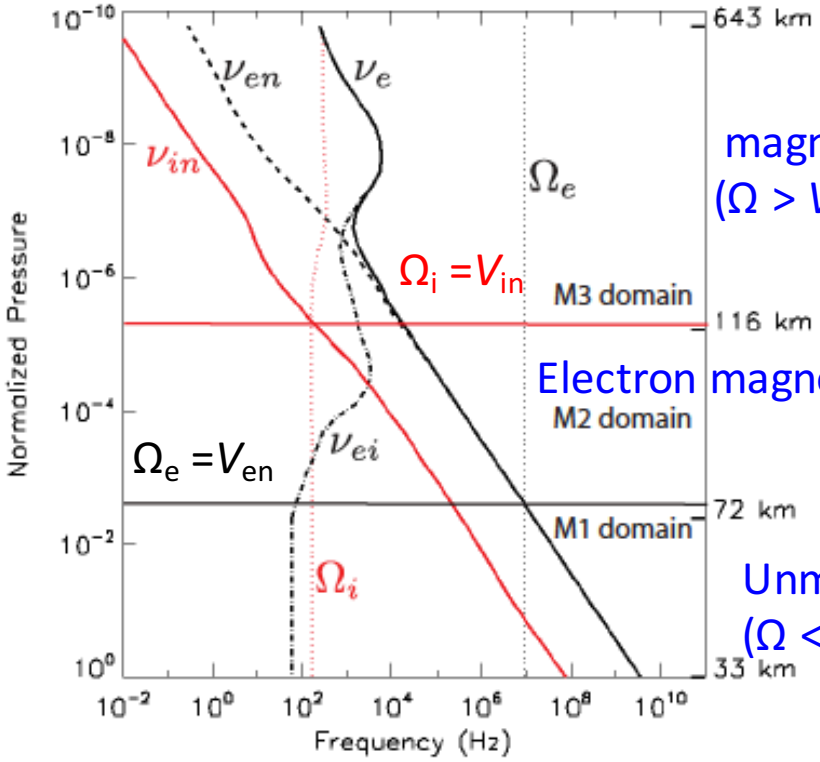
Leake et al., 2014, Space Sci. Rev.



- E-region ionosphere (90-130km):
- dominant collisions with neutrals

magnetized ($\Omega > V$)

- *Magnetized electrons:* ***(E x B** drift)*
- *Unmagnetized ions:* *(Attached to neutrals)*

Electron magnetized ($\Omega_e >> V_{en}$)

Unmagnetized ($\Omega < V$)

Ω gyrofrequency

V collision frequency

Farley-Buneman (two-stream) instability

Difference in drifts of electron and ion exceeding the ion acoustic speed.

Dimant and Milikh, JGR, VOL. 108, NO. A9, 1350, doi:10.1029/2002JA009524

$$\delta Q_e \approx \frac{m_e \nu_e n_0 E^2}{B^2}$$

Regular Electron Ohmic Heating

$$+ \frac{\alpha_1 m_i \nu_i \kappa_i^2 \left(E - E_1\right)^2 n_0}{\left(1 + \kappa_i^2\right) B^2} \left(\frac{E}{E_1} \left(1 + \psi_\perp\right) - 1 \right)$$

Anomalous Electron Heating

$$\psi_\perp = \frac{\nu_e \nu_i}{\Omega_e \Omega_i} = \frac{m_e m_i \nu_e \nu_i}{e^2 B^2}$$

$$E_1 = \left(1 + \psi_\perp\right) \sqrt{\frac{1 + \kappa_i^2}{1 - \kappa_i^2} \left(\frac{T_e + T_i}{m_i} \right)} B$$

Threshold: E > E1 (~ 30 mv/m) ,

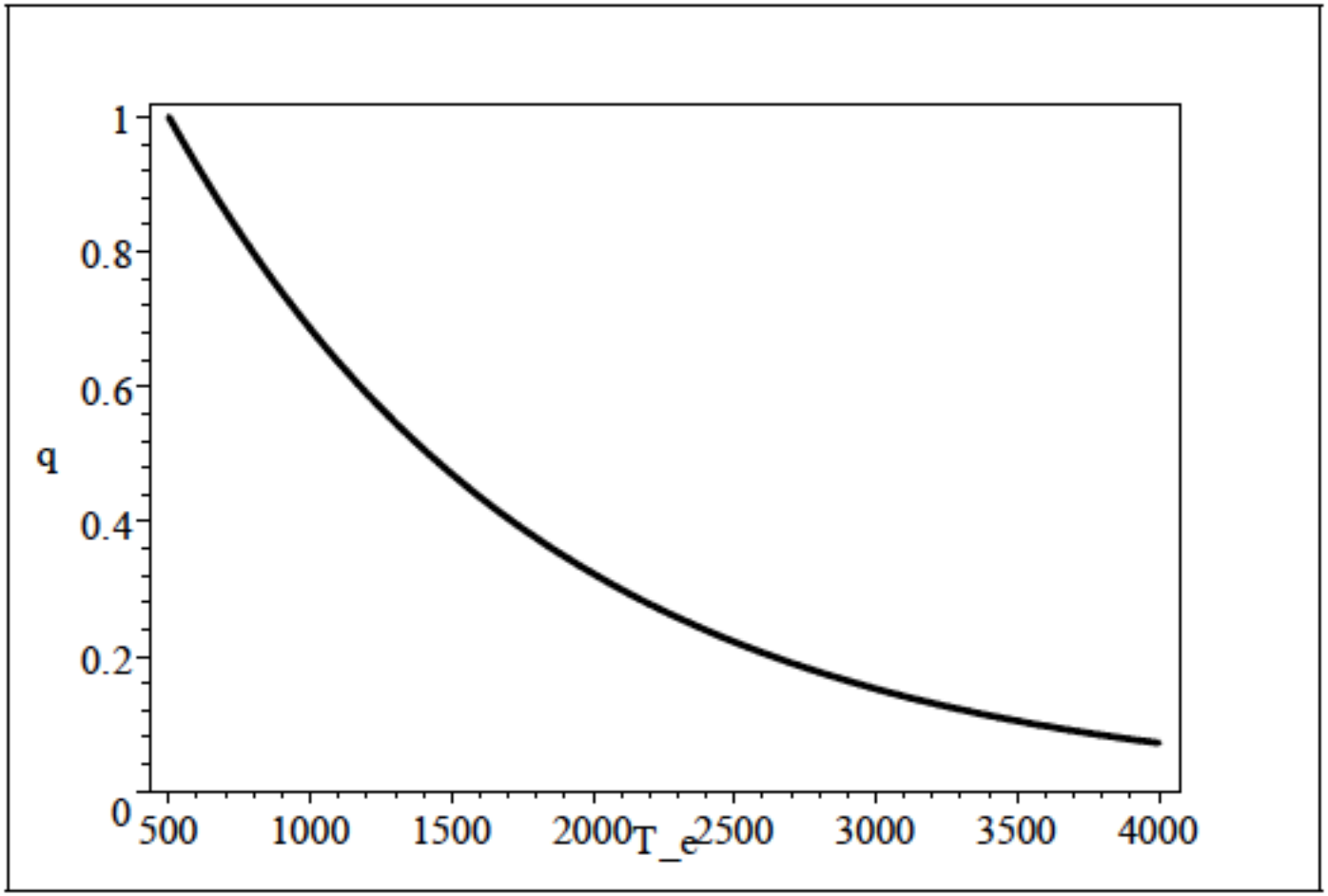
h < H_{mb},

$$\nu_i = \Omega_i$$

This is the temperature-dependent multipler for the TIEGCM cooling rate:

$$q(T_e) = \begin{cases} e^{-7.54\times10^{-4}(T_e-500)} & \text{if} \quad T_e \geq 500 \\ 1 & \text{if} \quad T_e < 500 \end{cases} \tag{1}$$

where T_e is in Kelvin.

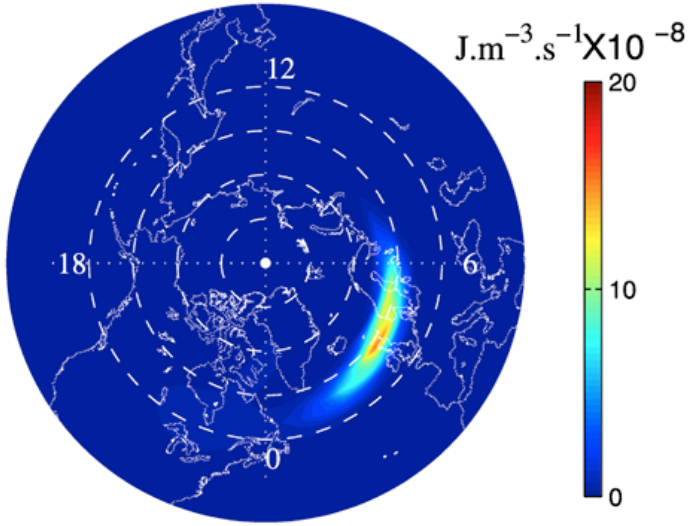


NCAR-TIEGCM (2.5° x ¼ scale height) Weimer-05

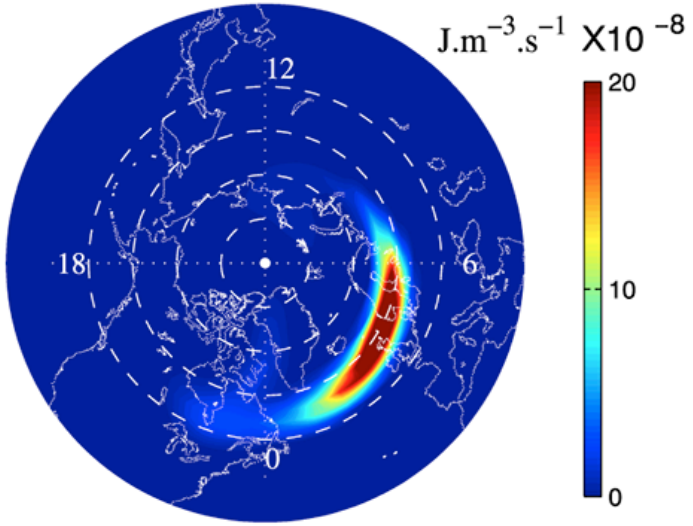
Pressure Level -5.625 (~102 km)

Sep. Eqinox
F10.7=120
IMF Bz=-20 nT

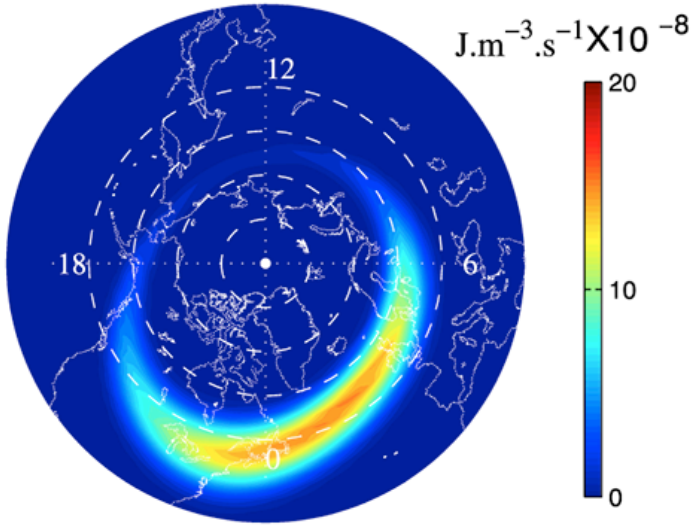
(a) Regular Electron Ohmic Energy Deposition



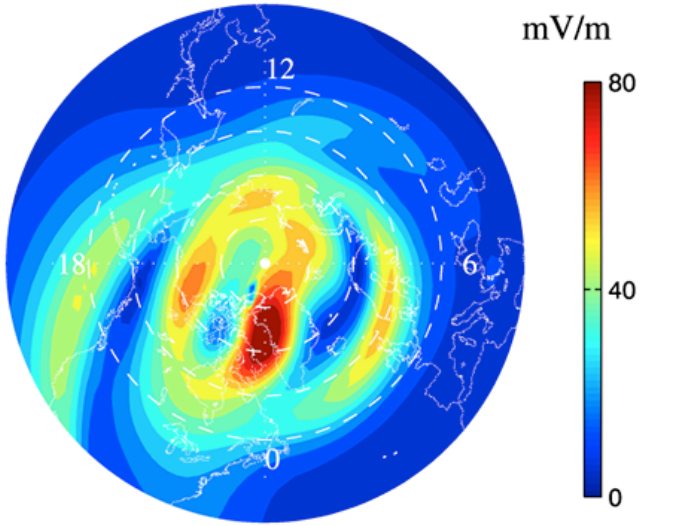
(b) Anomalous Electron Energy Deposition

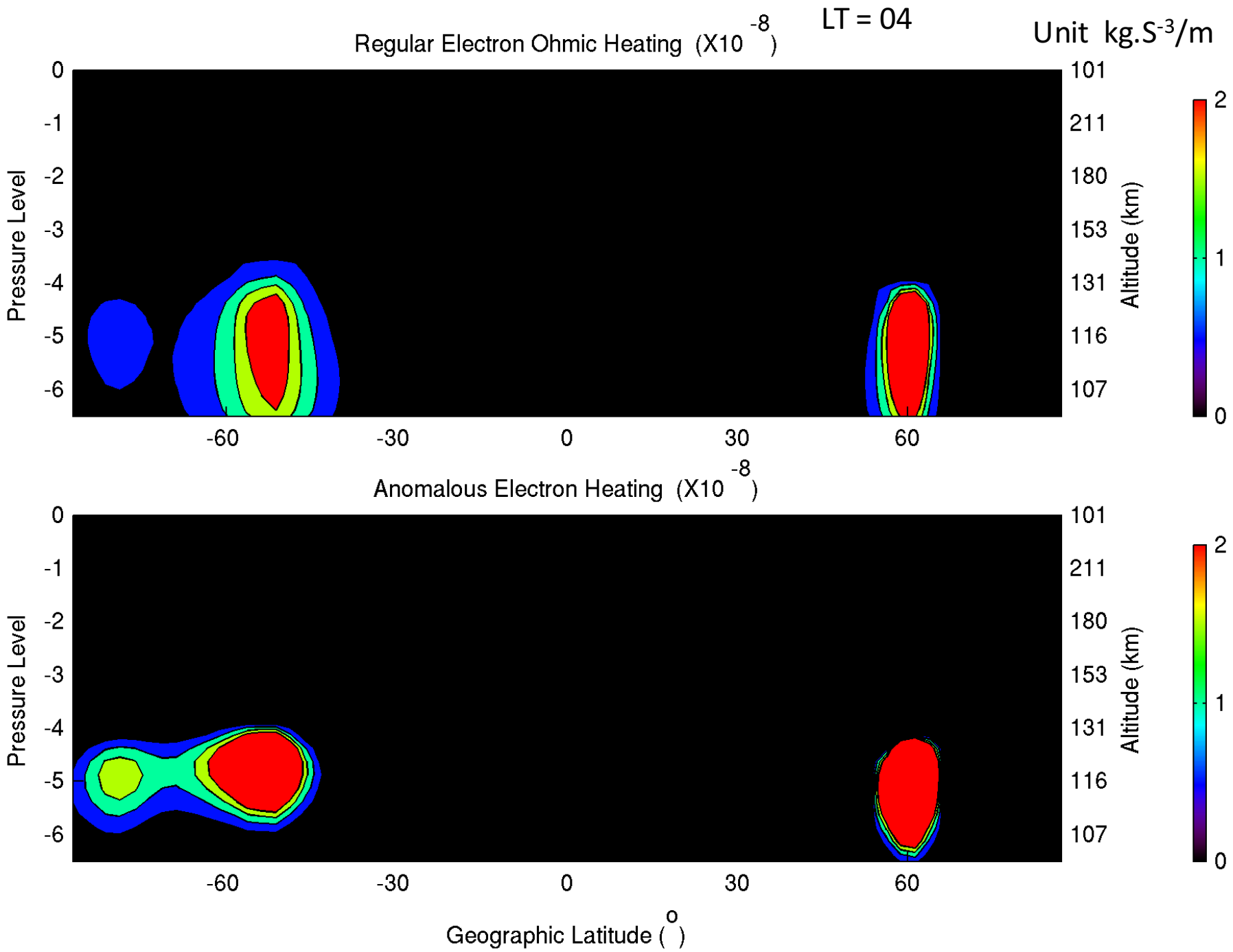


(c) TIEGCM Auroral Energy Deposition

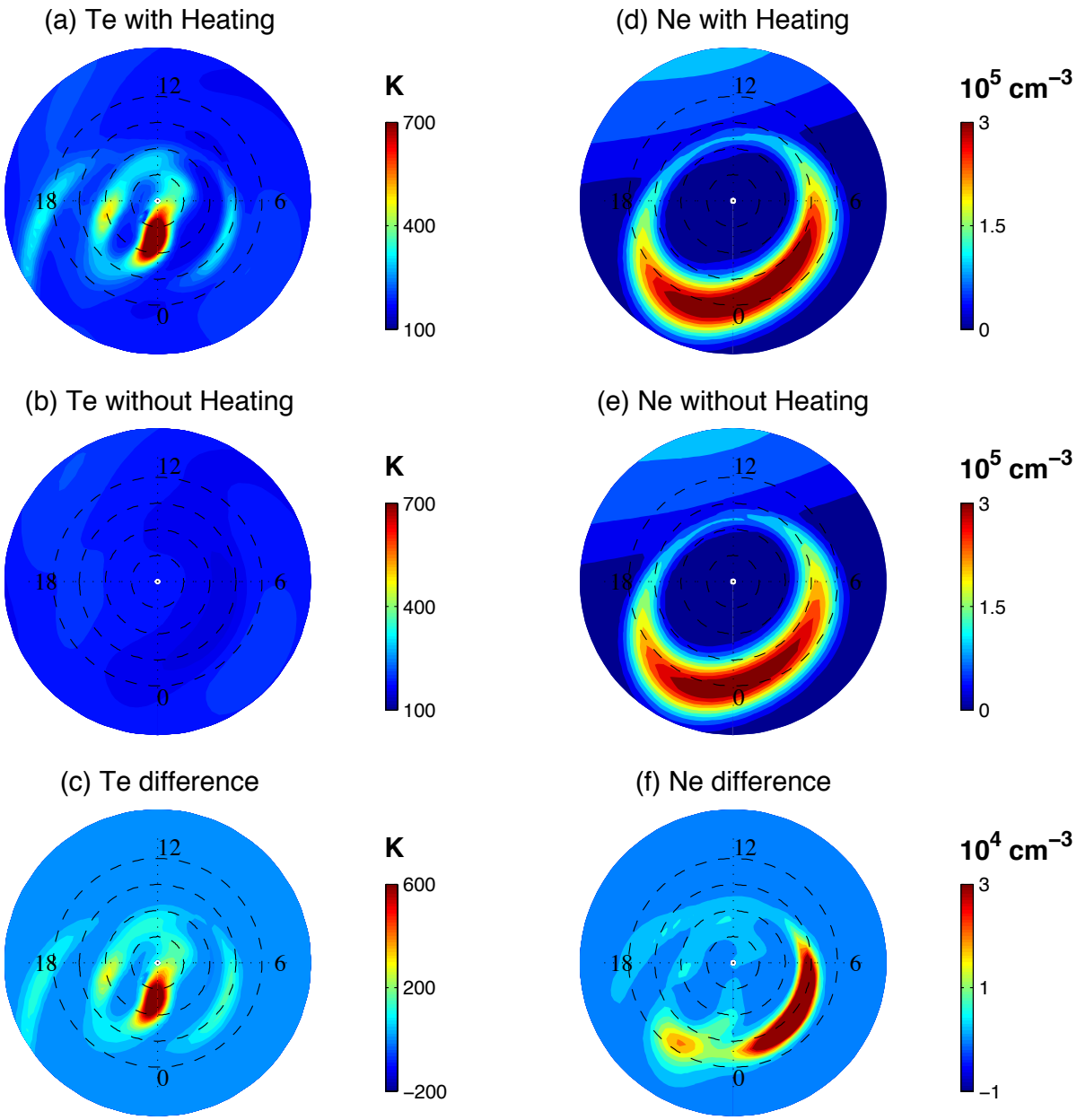


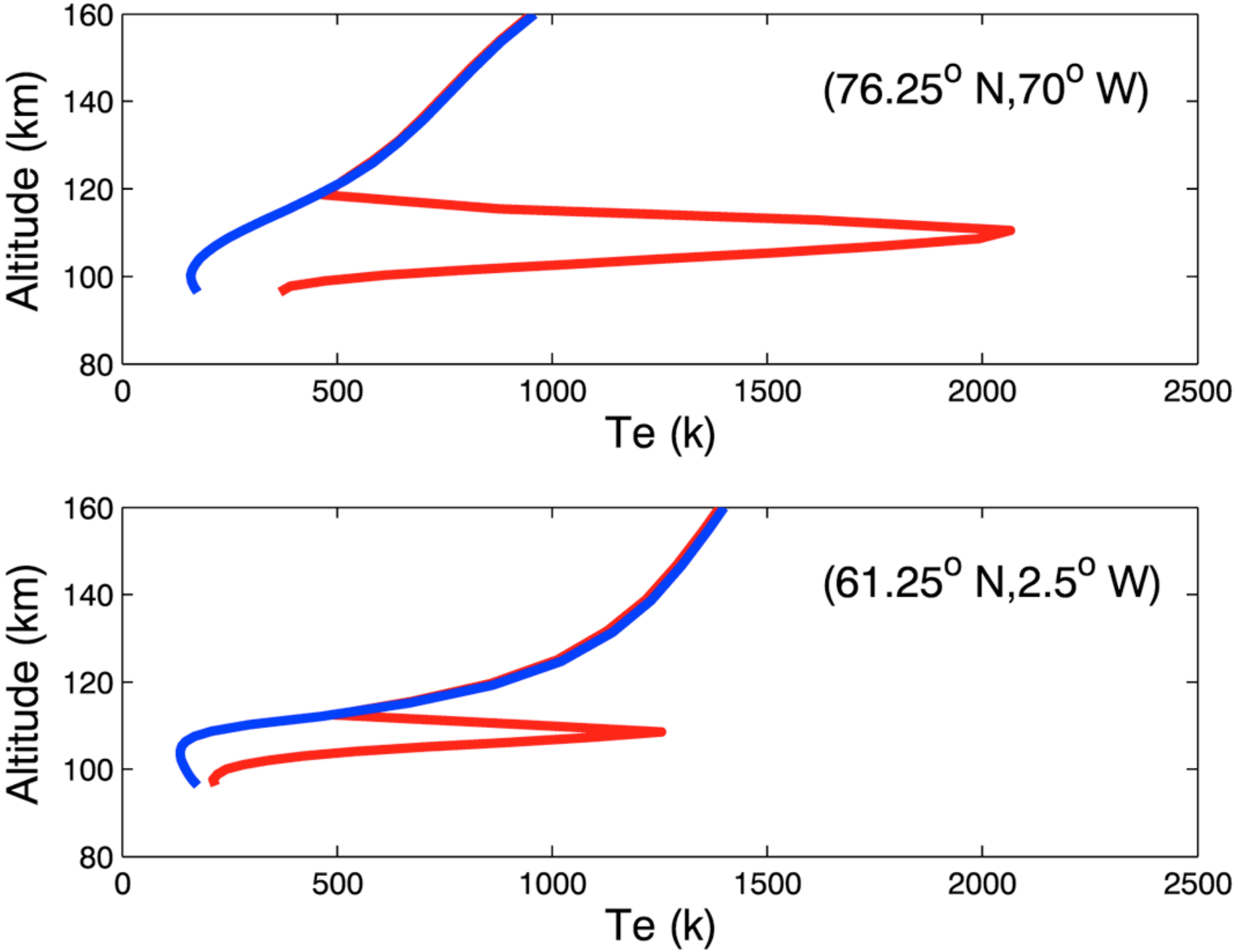
(d) Electric Field




LT = 04
Unit kg.S-3/m
Regular Electron Ohmic Heating (X10-8)
Anomalous Electron Heating (X10-8)
Pressure Level
Altitude (km)
0
-1
-2
-3
-4
-5
-6
101
211
180
153
131
116
107
2
1
0
-60
-30
0
30
60
Geographic Latitude (o)

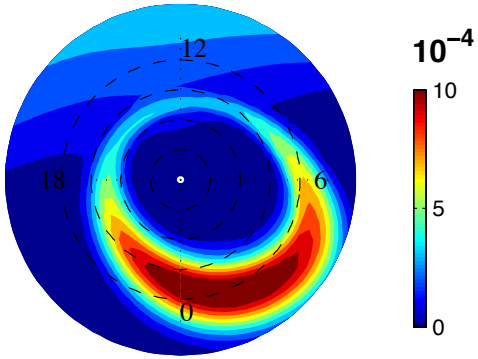
Pressure Level -5.625 (~102 km)



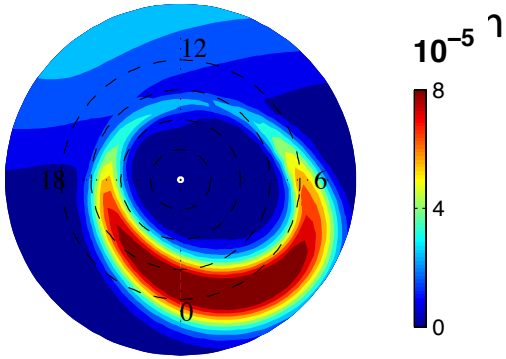

(76.25° N,70° W)
Altitude (km)
160
140
120
100
80
0
500
1000
1500
2000
2500
Te (k)
(61.25° N,2.5° W)
Altitude (km)
160
140
120
100
80
0
500
1000
1500
2000
2500
Te (k)

Pressure Level -5.625 (~102 km)

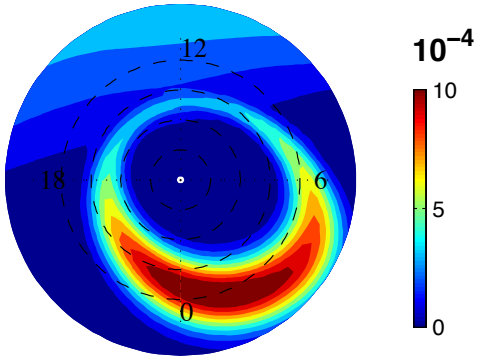
(a) Hall Conductivity with Heating



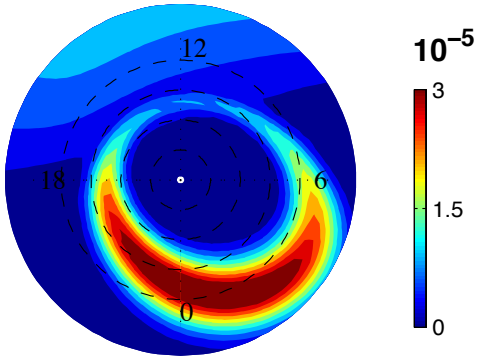
(d) Pedersen Conductivity with Heating



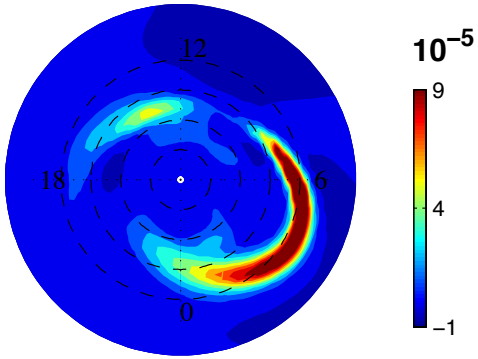
(b) Hall Conductivity without Heating



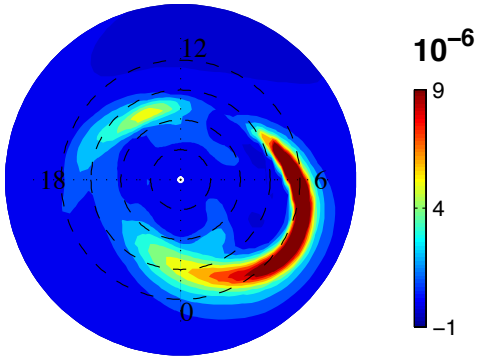
(e) Pedersen Conductivity without Heating



(c) Hall Conductivity difference



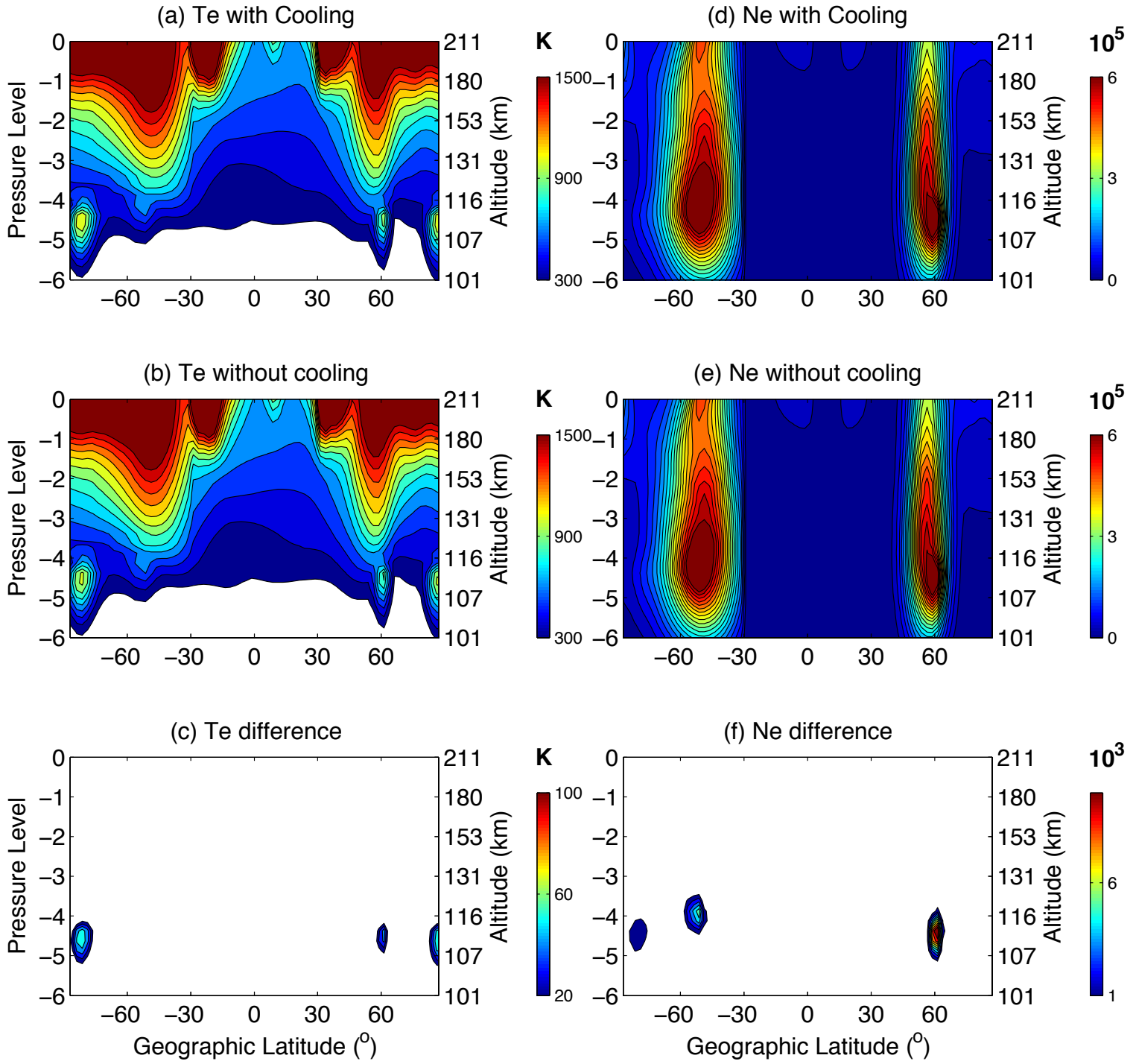
(f) Pedersen Conductivity difference



Summary

- For the first time, anomalous electron heating has been implemented in a physics based, coupled ionosphere-thermosphere model.
- Added heating source terms are comparable or larger than heating by auroral precipitation in the E region .
- There are significant changes in ionospheric electron density, electron temperature, and conductivity in the E region when anomalous electron heating is included in the TIEGCM.

Liu, J.,W.Wang, M. Oppenheim, Y. Dimant, M. Wiltberger, and S. Merkin (2016), Anomalous electron heating effects on the E region ionosphere in TIEGCM, Geophys. Res. Lett., 43, 2351–2358, doi:10.1002/2016GL068010.


(a) Te with Cooling
(b) Te without cooling
(c) Te difference
(d) Ne with Cooling
(e) Ne without cooling
(f) Ne difference
Pressure Level
Altitude (km)
Geographic Latitude (°)
K
10^5
10^3
0
−1
−2
−3
−4
−5
−6
211
180
153
131
116
107
101
−60
−30
0
30
60
1500
900
300
6
3
100
60
20
1