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

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

Farley-Buneman (two-stream) instability

Difference in drifts of electron and ion exceeding the ion acoustic speed.
\[
\delta Q_e \approx \frac{m_e \nu_e n_0 E^2}{B^2} \\
+ \frac{\alpha_1 m_i \nu_i \kappa_i^2 (E - E_1)^2 n_0}{(1 + \kappa_i^2) B^2} \left( \frac{E}{E_1} (1 + \psi_\perp) - 1 \right)
\]

### Anomalous Electron Heating

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

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

**Threshold:** \( E > E_1 (\sim 30 \text{ mv/m}) \),

\( h < H_{mb} \),

\( \nu_i = \Omega_i \)
This is the temperature-dependent multiplier for the TIEGCM cooling rate:

\[
q(T_e) = \begin{cases} 
  e^{-7.54 \times 10^{-4}(T_e - 500)} & \text{if } T_e \geq 500 \\
  1 & \text{if } T_e < 500 
\end{cases}
\]  
(1)

where $T_e$ is in Kelvin.
Heating source at press level - 5.75 (~100 km)

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

Pressure Level -5.625 (~102 km)

(a) Regular Electron Ohmic Energy Deposition

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

(b) Anomalous Electron Energy Deposition

(c) TIEGCM Auroral Energy Deposition

(d) Electric Field

mV/m

J.m⁻³.s⁻¹ X 10⁻⁸

J.m⁻³.s⁻¹ X 10⁻⁸

J.m⁻³.s⁻¹ X 10⁻⁸

J.m⁻³.s⁻¹ X 10⁻⁸
Pressure Level -5.625 (~102 km)

(a) Te with Heating

(b) Te without Heating

(c) Te difference

(d) Ne with Heating

(e) Ne without Heating

(f) Ne difference
Pressure Level -5.625 (~102 km)

(a) Hall Conductivity with Heating

(b) Hall Conductivity without Heating

(c) Hall Conductivity difference

(d) Pedersen Conductivity with Heating

(e) Pedersen Conductivity without Heating

(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.
