Conductivities consistent with FACs in the AMPERE-driven TIEGCM

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Outline

• The AMPERE-driven TIEGCM
• Conductivities consistent with FACs
  - The diffuse aurora
  - The discrete aurora
• First results
• Summary and conclusions
The AMPERE-driven TIEGCM

Input:

- Default conductivities and wind-driven terms depending on $K_p$ and $F_{10.7}$.

\[ J_r^{AMP} \downarrow \Rightarrow \Phi \]

FACs flowing in (blue) and out (red) of the northern auroral ionosphere, used as input of the TIEGCM.
The AMPERE-driven TIEGCM

Output:

Electric potential (contours) and height-integrated ionospheric currents (arrows) over the Northern Hemisphere.

Ground magnetic signature essentially produced by the ionospheric current system (horizontal components represented by arrows; vertical comp. represented by contours).
The AMPERE-driven TIEGCM

Results:

Comparison between modeled (blue line) and observed (black line) magnetic components at Tromsø (TRO) and College (CMO) auroral observatories.

Conductivities consistent with FACs

Regions of enhanced upward (AMPERE) currents at the top of the ionosphere must be affected by increased ionization and conductivity.

Knight’s (1973) formulation:

\[ J_\parallel = e \left\{ N_S \frac{kT_S}{2\pi m_e} \left[ B_r - (B_r - 1)e^{-\frac{eV}{kT_S(B_r - 1)}} \right] \right. \]

\[ - N_I \frac{kT_I}{2\pi m_e} \left[ B_r - (B_r - 1)e^{-\frac{eV}{kT_I(B_r - 1)}} \right] e^{-\frac{eV}{kT_I}} \]

Zhang and Paxton (2008):

\[ K_p \Rightarrow Q, \bar{E} \text{ at each ionospheric point} \]
Conductivities consistent with FACs

Our approach: the diffuse aurora

\[ J_{\parallel}^{AMP} \leq \frac{eQ_{ZP}}{E_{ZP}} \Rightarrow \begin{cases} F_S = \frac{Q_{ZP}}{E_{ZP}} \\ \alpha = \frac{E_{ZP}}{2} \end{cases} \]

Characteristic energy
\( (= kT_s \text{ for a Maxwellian distribution in the source region}) \)

Downward and weak upward currents, i.e., below Zhang-Paxton’s threshold -> “diffuse” aurora

Electron flux from source region

Precipitating electrons

Downward current

Upward current

Aurora
Conductivities consistent with FACs

Our approach: the discrete aurora

Assuming a Maxwellian distribution in the source region, and since

\[ 2\alpha = \overline{E} = \int_{E_k=0}^{\infty} E_k dF_S(E_k) \]

we get:

\[ F_S = \frac{J_{\parallel}^{AMP}}{e} \]

Current carried by downward flux

Enhanced upward currents, i.e., above Zhang-Paxton’s threshold -> “discrete” aurora

\[ J_{\parallel}^{AMP} > \frac{eQ_{ZP}}{E_{ZP}} \implies \alpha = \frac{E_{ZP}}{2} \left[ 1 + \frac{B_r}{2} \left( 1 - \frac{F_0}{F_S} \right) \ln \left( \frac{B_r - 1}{B_r - \frac{F_S}{F_0}} \right) \right] \]

\[ B_r \equiv \frac{B_I}{B_S} \]

\[ F_0 \equiv \frac{Q_{ZP}}{E_{ZP}} \]
Conductivities consistent with FACs

Input AMPERE FACs

Output Hall conductivity for standard TIEGCM
Conductivities consistent with FACs

Input AMPERE FACs

Output Hall conductivity consistent with FACs
Conductivities consistent with FACs

AMPERE data
$J_r$ component of FACs (positive upward)

TIEGCM output - SIGMA_HAL (S/m) - NH projection

Input AMPERE FACs

Output Hall conductivity consistent with FACs
First results

Comparison between modeled (blue and red lines) and observed (black line) magnetic components at College (CMO) observatory.

Observed variation
Modeled using our first approach
Modeled with conductivities consistent with FACs

Our new approach can explain:

• 54 % of the X variation -> 1 % improvement
• 65 % of the Y variation -> 15 % improvement
• 7 % of the Z variation -> 10 % improvement
Summary and Conclusions

• We have made TIEGCM conductivities consistent with FACs measured by AMPERE.

• Our approach improves the “standard” TIEGCM substantially.

• Horizontal components of the geomagnetic field are better reproduced than vertical component. Typically 40 % to 60 % of the observed horizontal variation can be modeled, vs. 0 % to 10 % of the vertical variation.

• Preliminary results of our new approach show a moderate improvement with respect to our previous approach, typically below 10 %. We must investigate why.