Conductivities consistent with FACs in the AMPERE-driven TIEGCM

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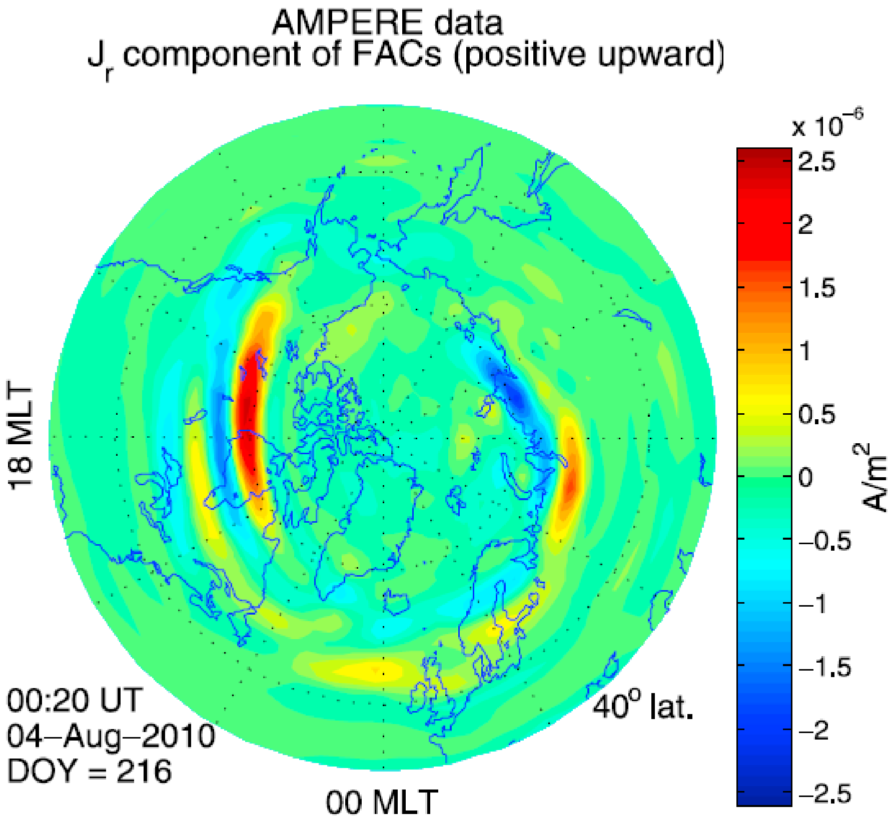
Outline

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

The AMPERE-driven TIEGCM

Input:



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

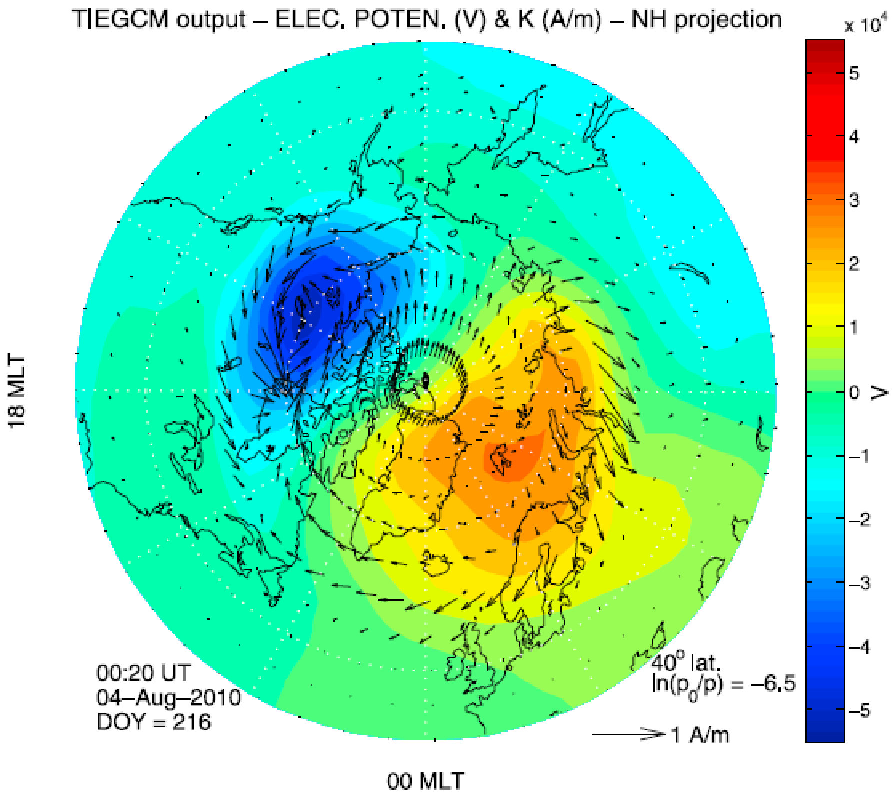
Electrodynamo equation

- $J_r^{AMP} \Rightarrow \Phi$

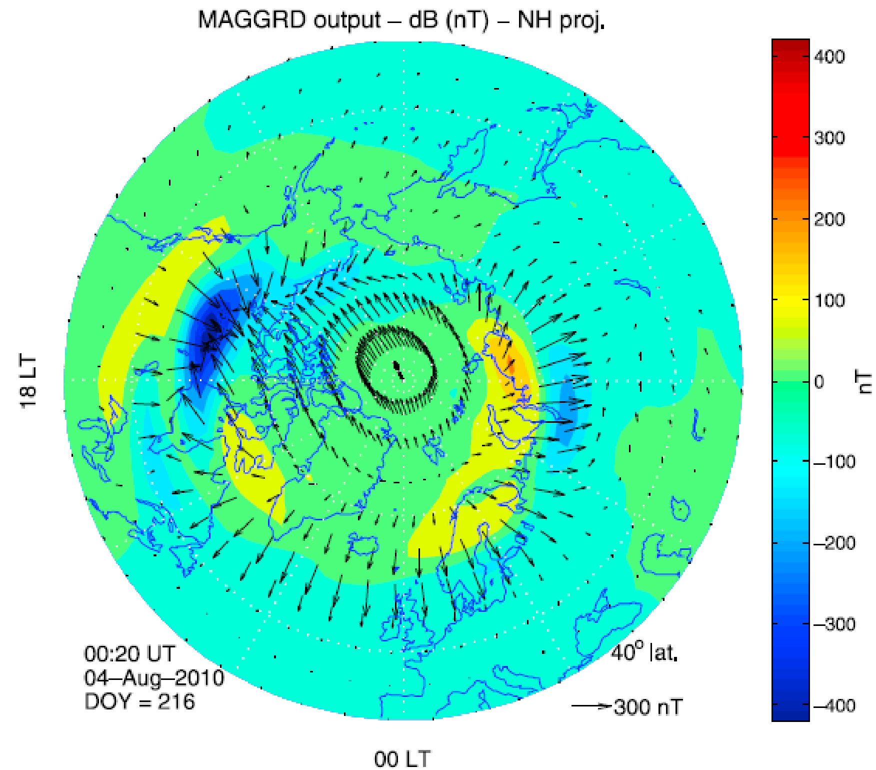
- Default conductivities and wind-driven terms depending on K_p and F10.7.

The AMPERE-driven TIEGCM

Output:



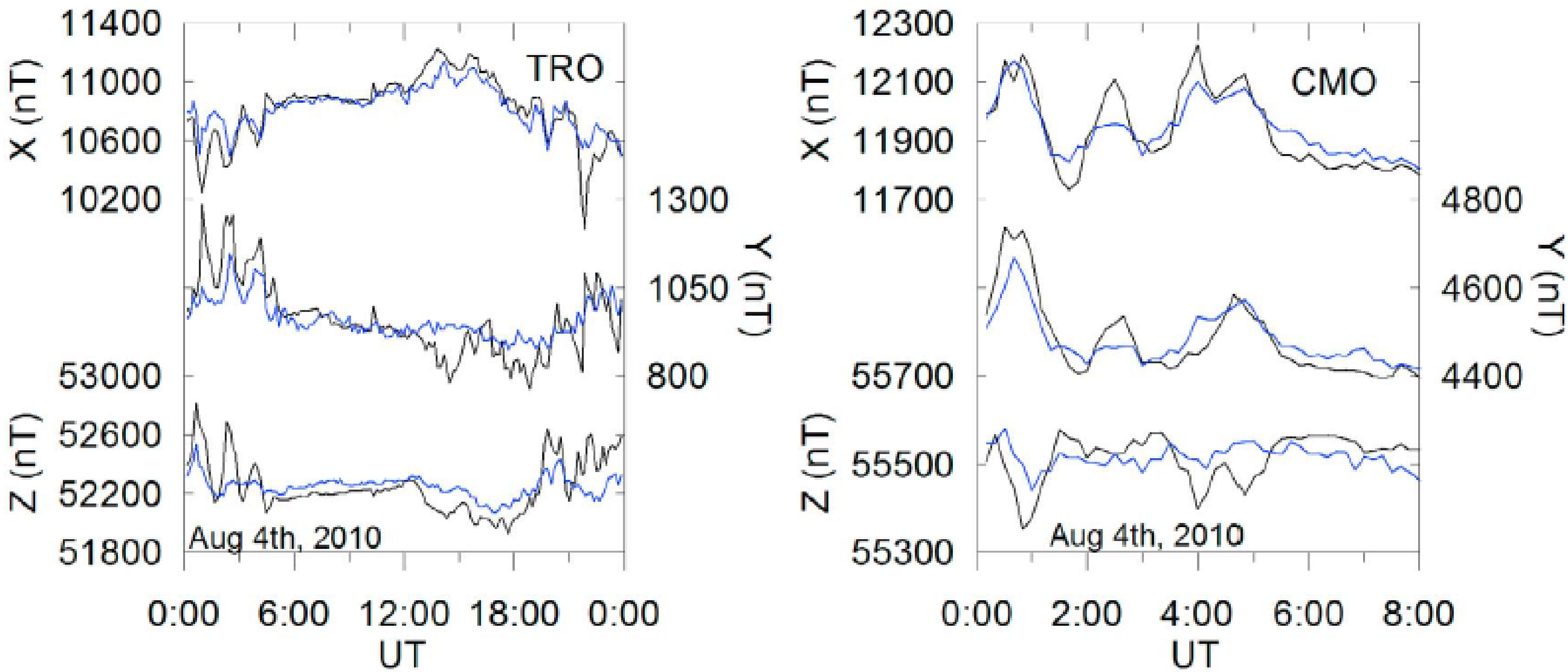
Electric potential (contours) and height-integrated ionospheric currents (arrows) over the Northern Hemisphere.



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

The AMPERE-driven TIEGCM

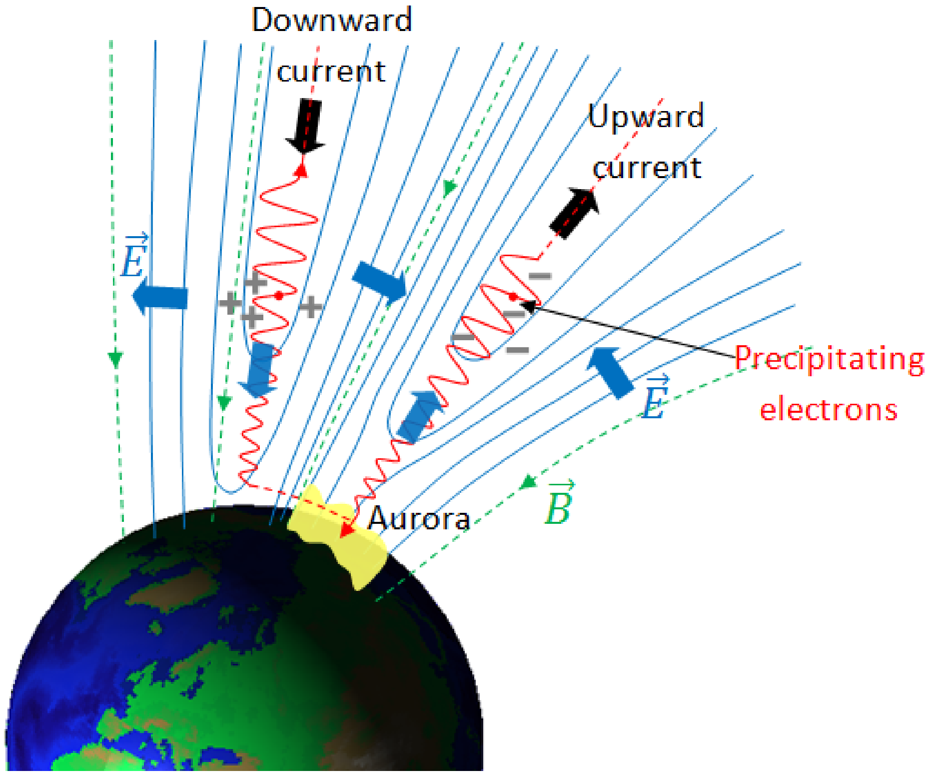
Results:



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

Marsal, S., A. D. Richmond, A. Maute, and B. J. Anderson (2012), Forcing the TIEGCM model with Birkeland currents from the Active Magnetosphere and Planetary Electrodynamics Response Experiment, J. Geophys. Res., 117, A06308, doi:10.1029/2011JA017416.

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:

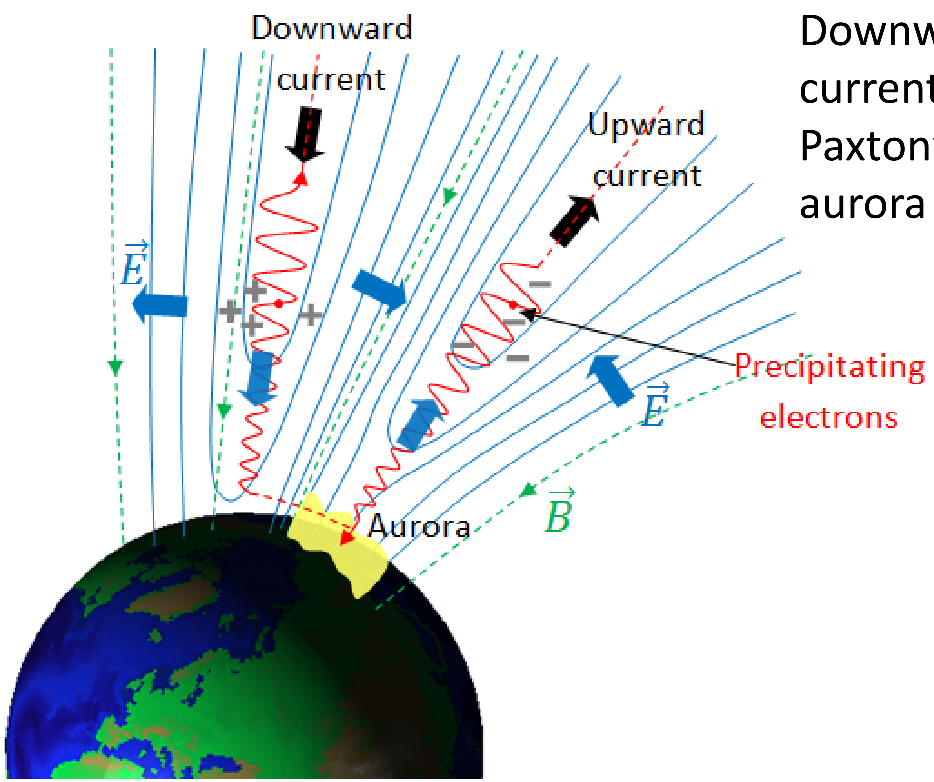
$$J_{\parallel} = e\left\{N_S\sqrt{\frac{kT_S}{2\pi m_e}}\left[B_r - (B_r - 1)e^{-\frac{eV}{kT_S(B_r-1)}}\right] - N_I\sqrt{\frac{kT_I}{2\pi m_e}}\left[B_r - (B_r - 1)e^{-\frac{eV}{kT_I(B_r-1)}}\right]e^{-\frac{eV}{kT_I}}\right\}$$

Zhang and Paxton (2008):

$$\mathrm{K_p} \Longrightarrow Q, \bar{E} \text{ at each ionospheric point}$$

Conductivities consistent with FACs

Our approach: the diffuse aurora



Downward and weak upward currents, i.e., below Zhang-Paxton's threshold -> "diffuse" aurora

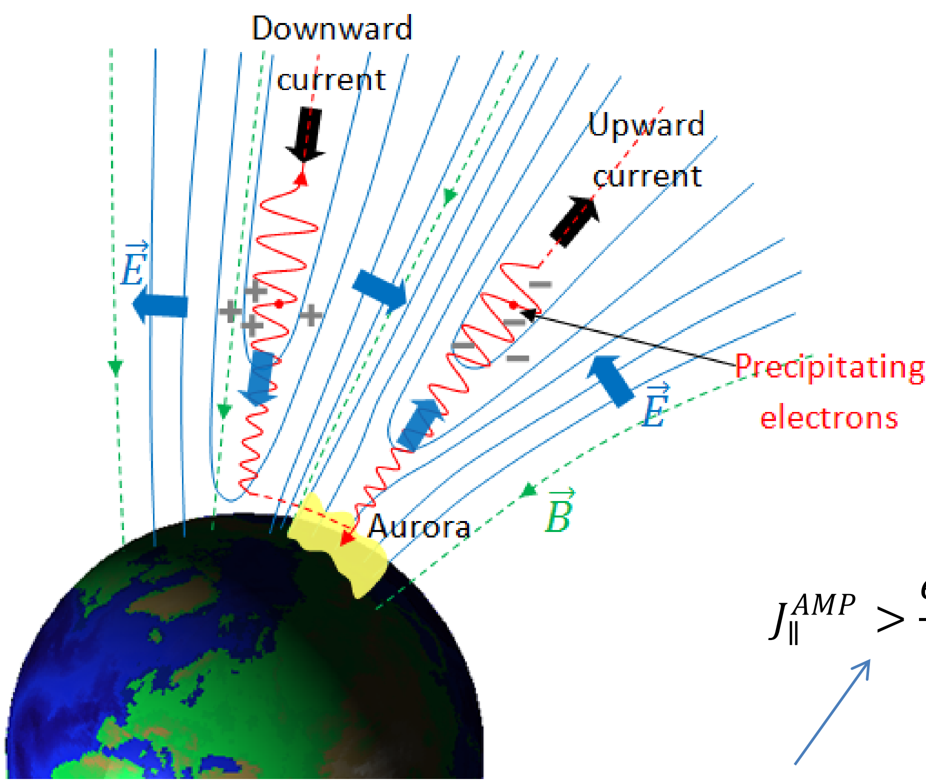
Electron flux from source region

$$J_{\parallel}^{AMP} \leq \frac{eQ_{ZP}}{\bar{E}_{ZP}} \Longrightarrow \begin{cases} F_S = \dfrac{Q_{ZP}}{\bar{E}_{ZP}} \\ \alpha = \dfrac{\bar{E}_{ZP}}{2} \end{cases}$$

Characteristic energy (= kT_s for a Maxwellian distribution in the source region)

Conductivities consistent with FACs

Our approach: the discrete aurora



Assuming a Maxwellian distribution in the source region, and since

$$2\alpha = \bar{E} = \frac{\int_{E_k=0}^{\infty} E_k \, dF_S(E_k)}{F_S}$$

we get:

Current carried by downward flux

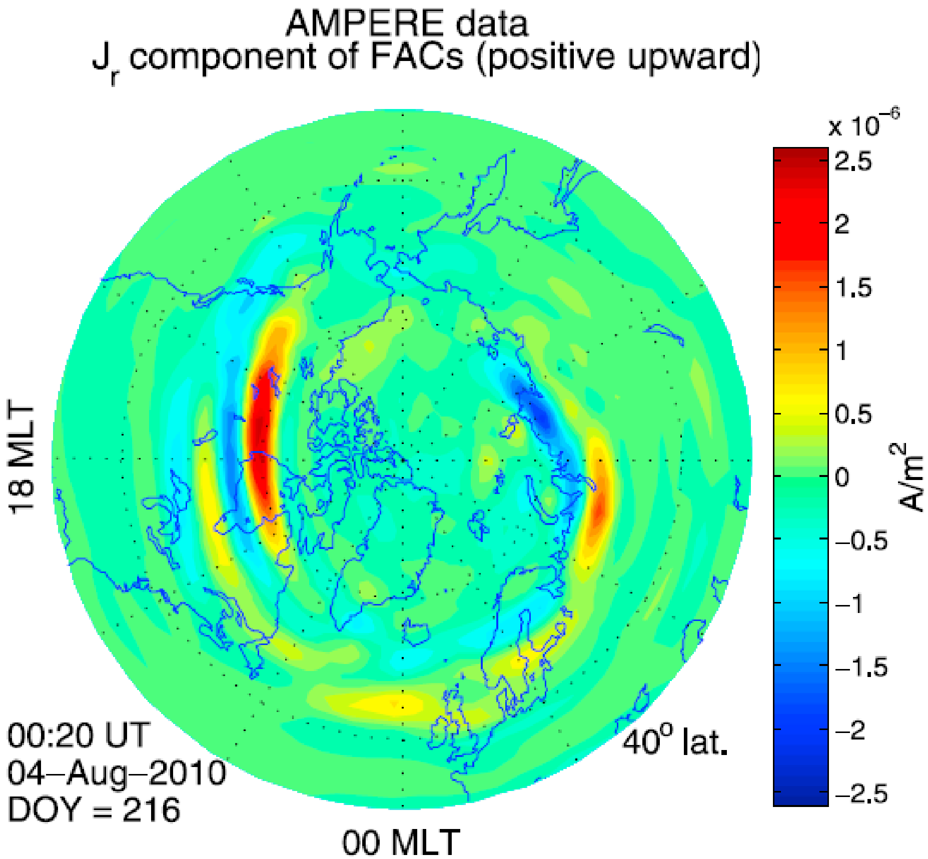
$$J_{\parallel}^{AMP} > \frac{eQ_{ZP}}{\bar{E}_{ZP}} \Longrightarrow \begin{cases} F_S = \dfrac{J_{\parallel}^{AMP}}{e} \\ \alpha = \dfrac{\bar{E}_{ZP}}{2}\left[1 + \dfrac{B_r}{2}\left(1 - \dfrac{F_0}{F_S}\right)\ln\left(\dfrac{B_r - 1}{B_r - \dfrac{F_S}{F_0}}\right)\right] \end{cases}$$

Enhanced upward currents, i.e., above Zhang-Paxton's threshold -> "discrete" aurora

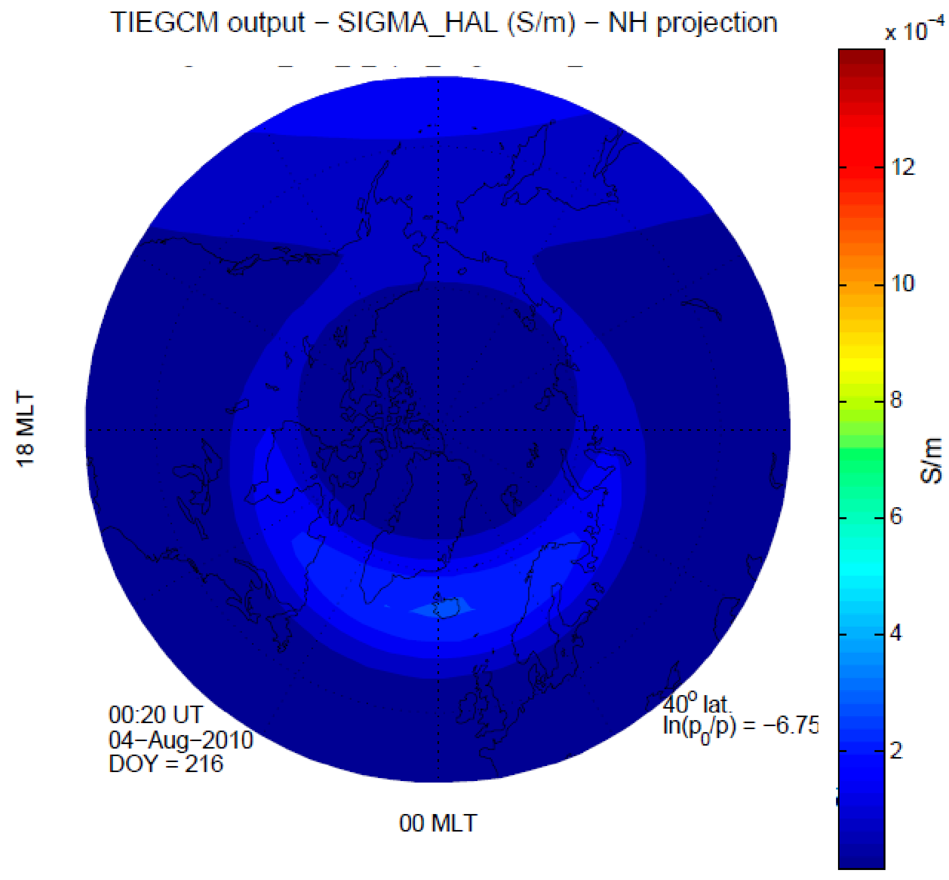
$$B_r \equiv \frac{B_I}{B_S}$$

$$F_0 \equiv \frac{Q_{ZP}}{\bar{E}_{ZP}}$$

Conductivities consistent with FACs

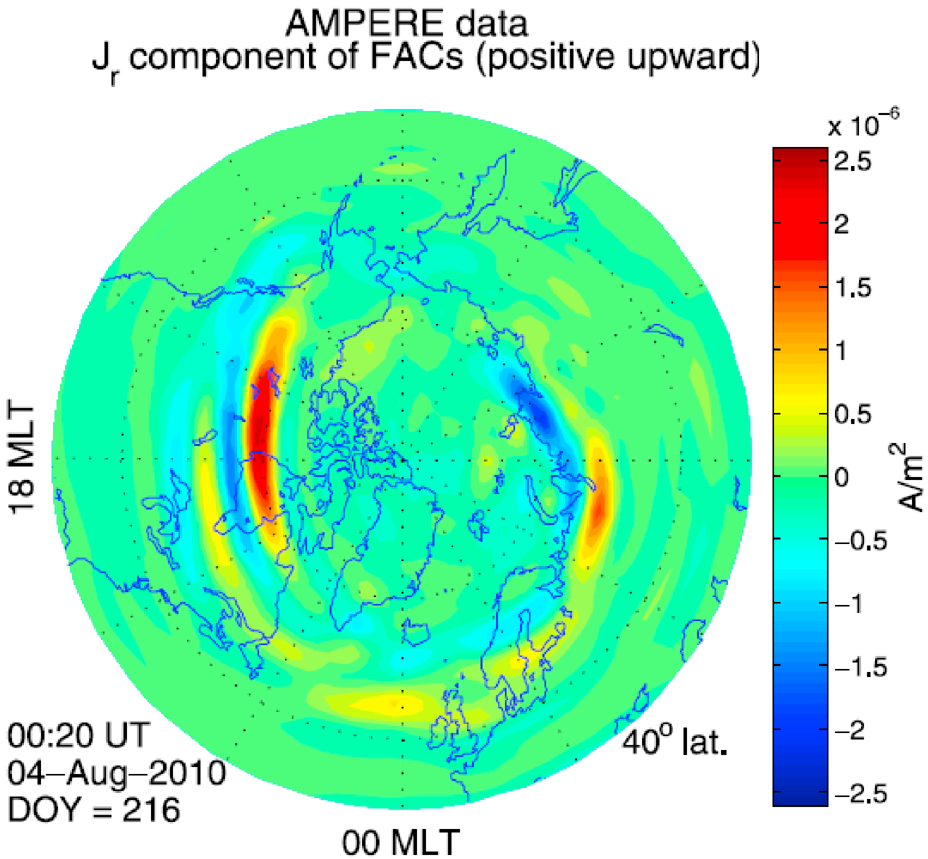


Input AMPERE FACs

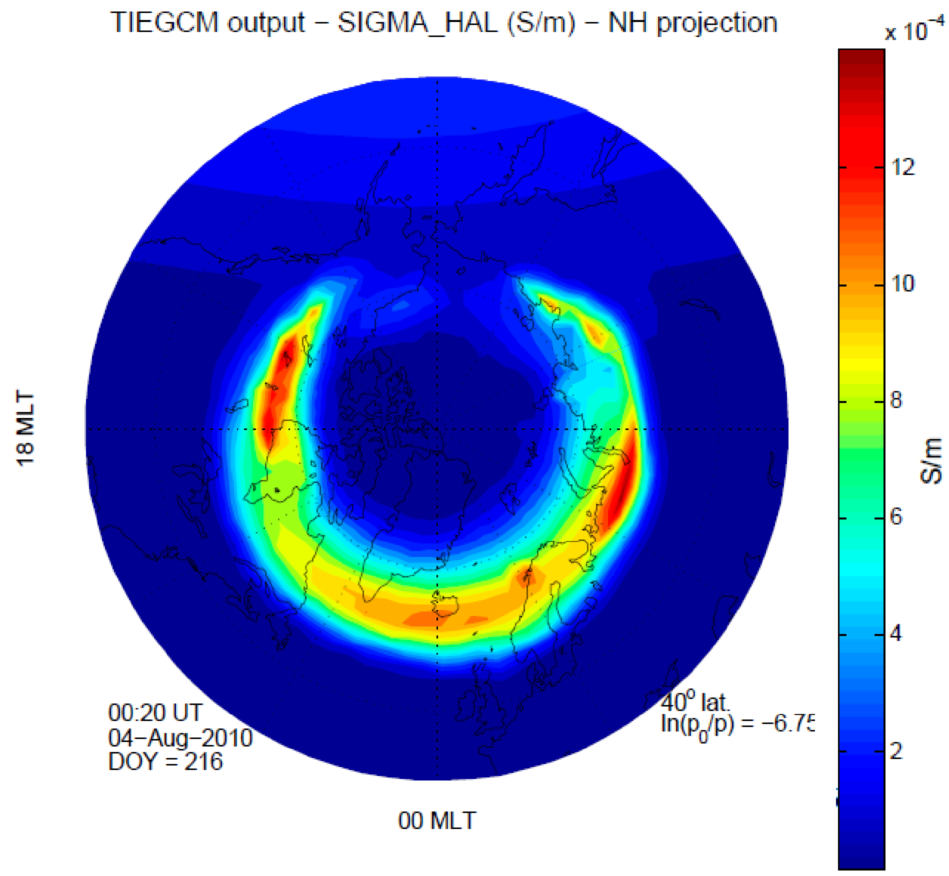


Output Hall conductivity for standard TIEGCM

Conductivities consistent with FACs

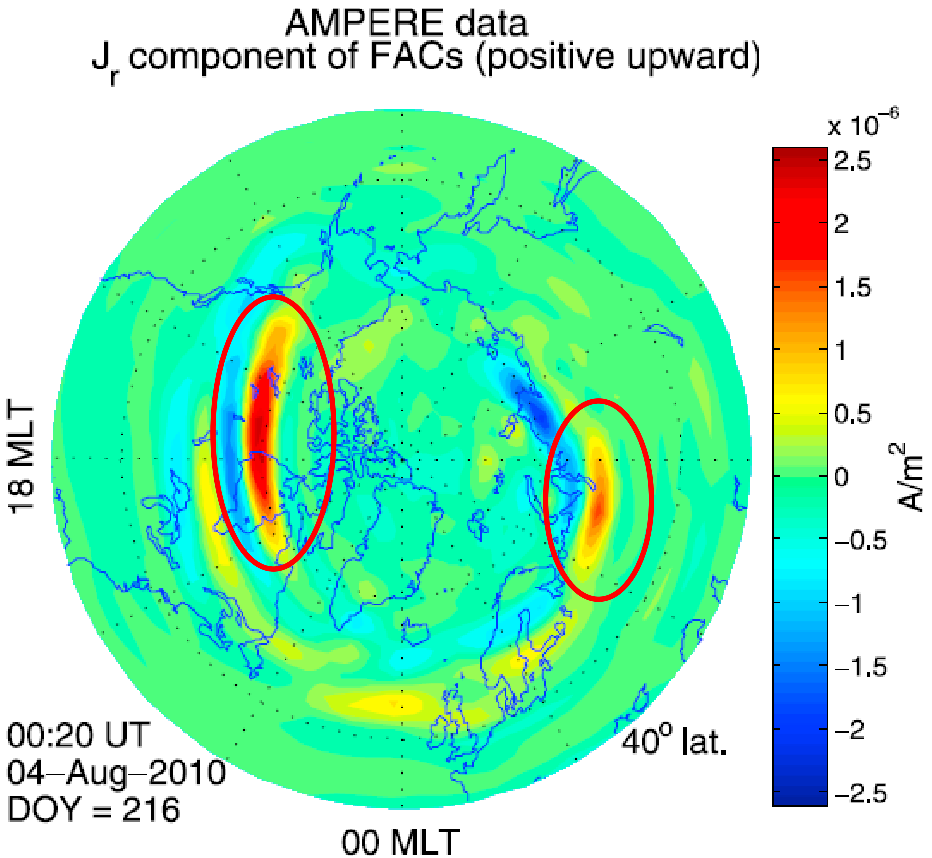


Input AMPERE FACs

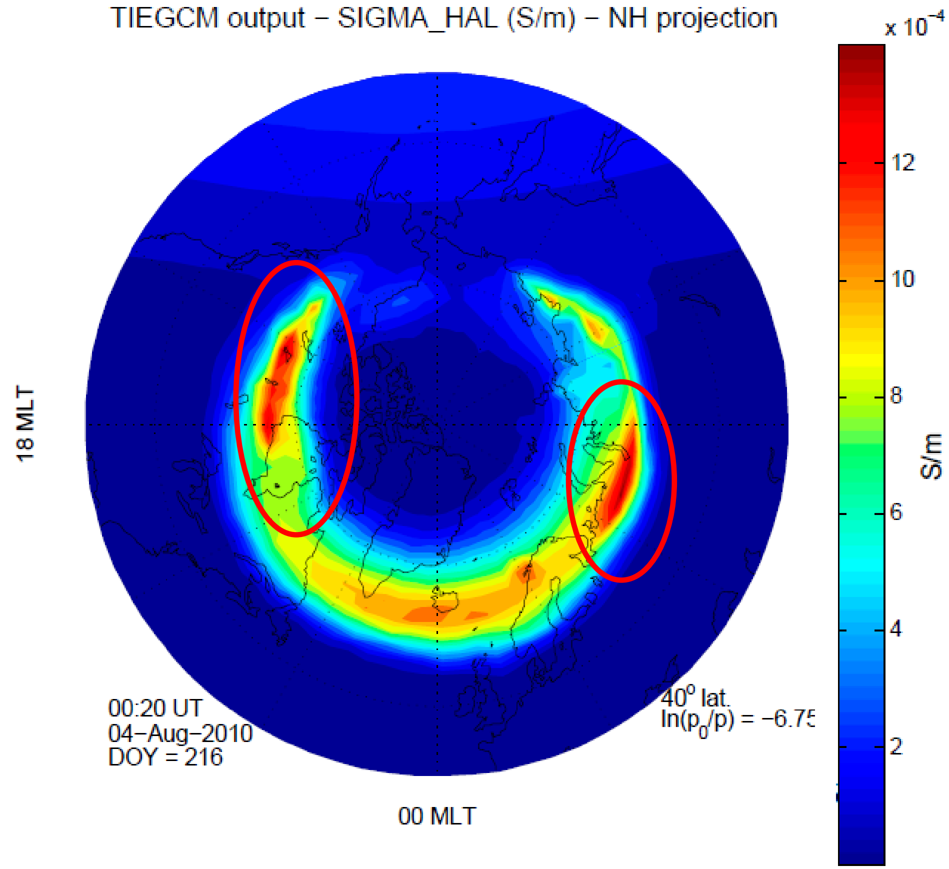


Output Hall conductivity consistent with FACs

Conductivities consistent with FACs

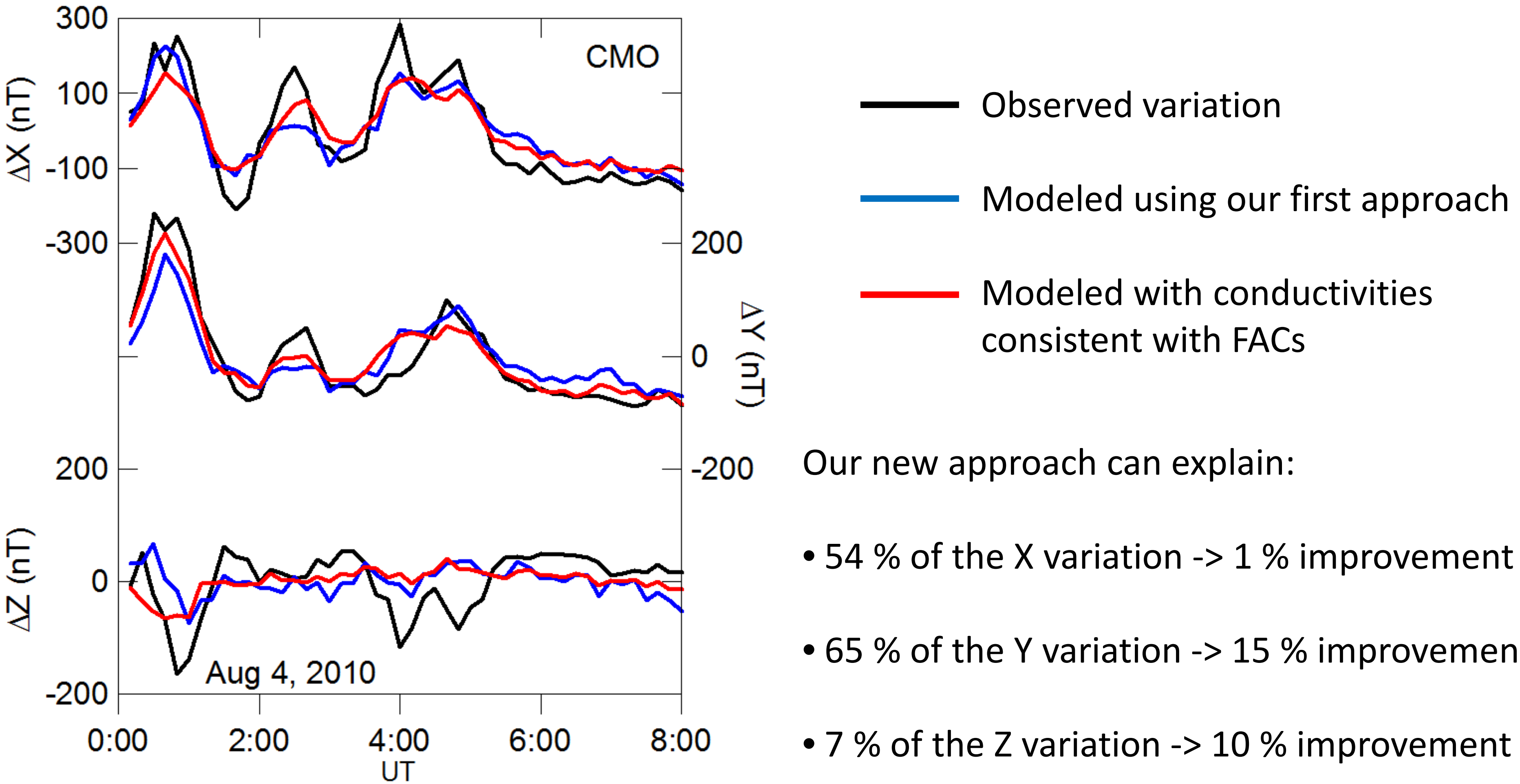


Input AMPERE FACs



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.

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.