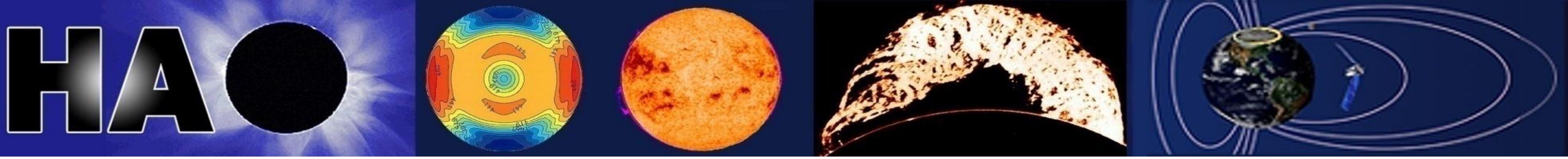

Modeling the high latitude energy transfer for GCMs

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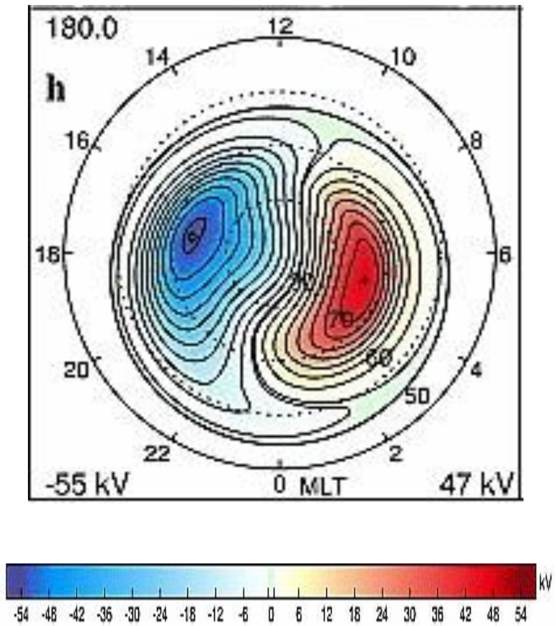
Outline

- Magnetosphere-ionosphere coupling options in GCMs
- AMPERE field-aligned current
- Processing the field-aligned current for TIEGCM
- Results
- What needs improvement?

Standard coupling: Reference potential

Weimer 2005



B_y = 0 nT, dipole tilt = 0°,
v_{sw}= 450 km/s, N_{sw}= 4 /cc

Ionospheric steady-state electrodynamo equation

$$\nabla \cdot \left(\tilde{\Sigma} \nabla \Phi \right) = \underbrace{\frac{1}{R}\left[\frac{\partial}{\partial \phi_m} K^D_{m\phi} + \frac{\partial}{\partial \lambda_m} \left(\cos\lambda_m \, K^D_{m\lambda} \right) \right]}_{\text{wind driven forcing}} \underbrace{+ \cos\lambda_m \, J_{Mr}}_{\text{magnetospheric forcing}}$$

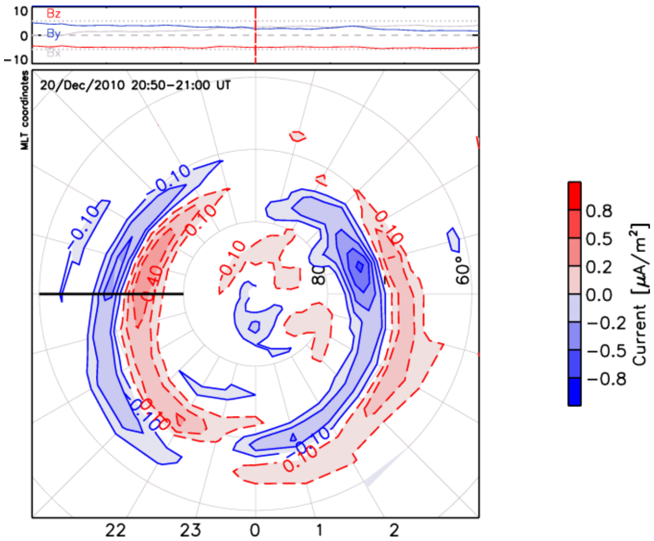
Predefined reference potential Φ^R

$$J_{Mr} = \frac{(1-p)\sigma^R}{pR} (\Phi - \Phi^R)$$

Based on empirical models, e.g. Heelis [1982] or Weimer [2005], or assimilative models, e.g., AMIE, or physics based models.

- Predefined high latitude region
- Artificial transition zone between predefined high latitude (where p=0) and mid-latitude wind driven potential (where p=1).
- Predefined high latitude potential might not be realistic- equivalent to climatology.

Reference field-aligned current



AMPERE map during southward IMF

Ionospheric steady-state electrodynamo equation

$$\nabla \cdot \left(\tilde{\Sigma} \nabla \Phi \right) = \frac{1}{R} \left[\frac{\partial}{\partial \phi_m} K_{m\phi}^{D} + \frac{\partial}{\partial \lambda_m} \left(\cos \lambda_m \, K_{m\lambda}^{D} \right) \right] + \cos \lambda_m \, J_{Mr}$$

Reference field-aligned currents (FAC) J_{Mr}^{R}

$$J_{Mr} = J_{Mr}^{R}$$

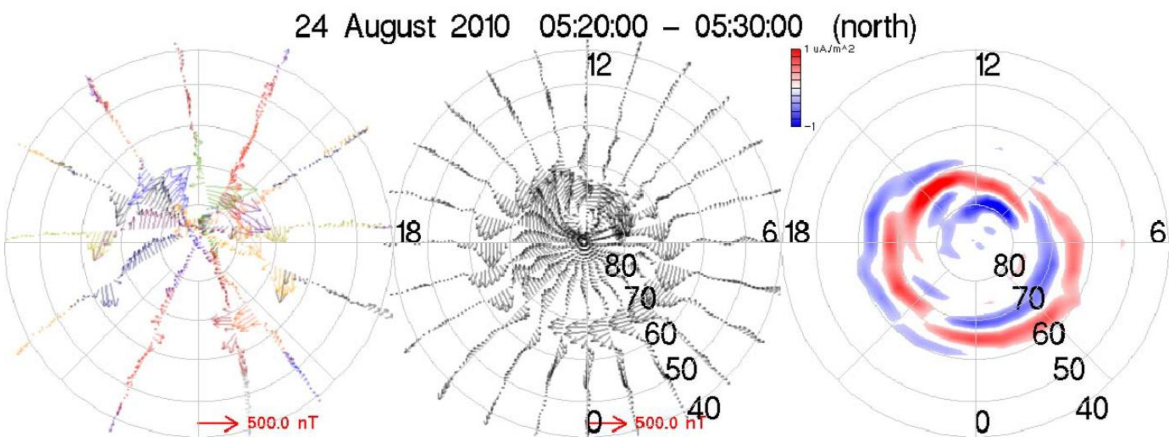
Based on empirical model e.g. Weimer [2005], or magnetospheric models, e.g.,RCM, LFM, OpenGGCM, or observations, e.g. AMPERE.

- J_{mr}^{R} over the globe has to vanish to satisfy current continuity. Therefore, J_{mr}^{R} has to be adjusted.
- Defined cut-off latitude since J_{mr}^{R} might not realistic anymore.
- Wind-driven dynamo is taken into account.

AMPERE field-aligned current

Iridium constellation

- Iridium constellation consists of 66 satellites.
- Satellites are in 6 circular polar orbits at 780 km altitude.
- AMPERE measures the magnetic perturbations and from the curl of the perturbations gets the radial FAC.
- FAC is given with a 2 min time resolution, 1 deg. latitudinal resolution and 1 hr in magnetic local time.



Raw data

Spherical harmonics

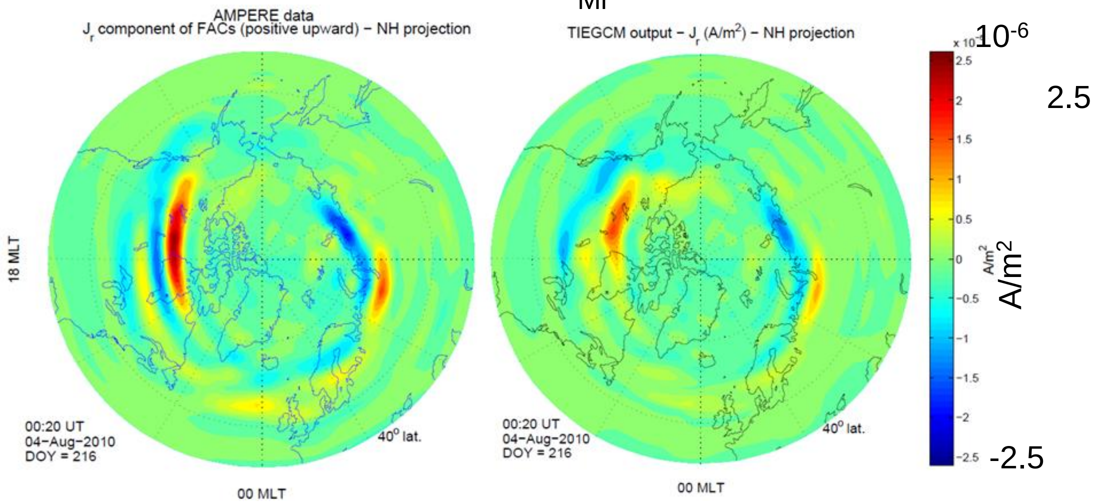
FAC

[Anderson et al. in preparation Space Science Review]

AMPERE reference FAC

For August 4, 2010 (Ap = 49)

AMPERE data | J_{Mr} from TIEGCM



- AMPERE current is updated every 10 min in TIEGCM.
- To avoid unrealistic potentials at point i $J_{mr,i}=0$ if $\Sigma_{P,i} < 2S$

- The FAC correction for each hemisphere to ensure integrated FAC vanishes is

$$J^{cor}_{mr,i} = J_{mr,i} - \frac{\int J_{mr} d\Omega}{\int \Sigma_P \left| J_{mr} \right| d\Omega} \Sigma_{P,i} \left| J_{mr,i} \right|$$

- In electrodynamo equation we use the current sum of conjugate points J_{mr}

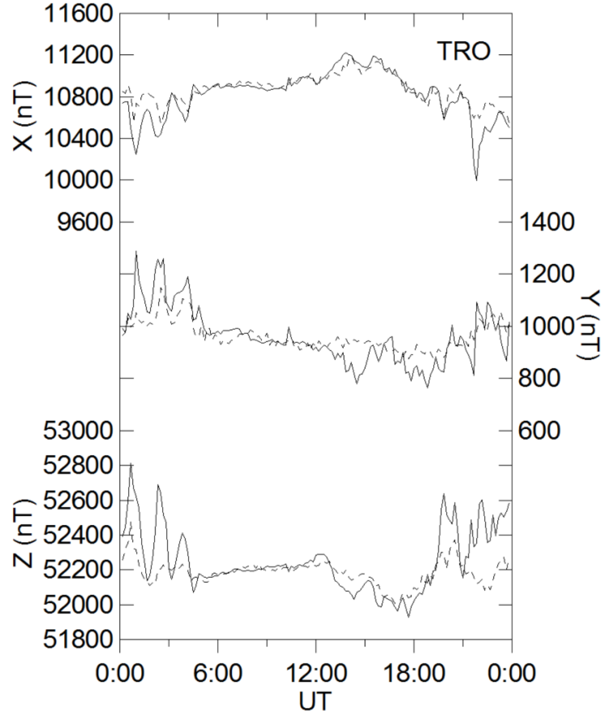
[Marsal et al. 2012]

Simulated ground magnetic field

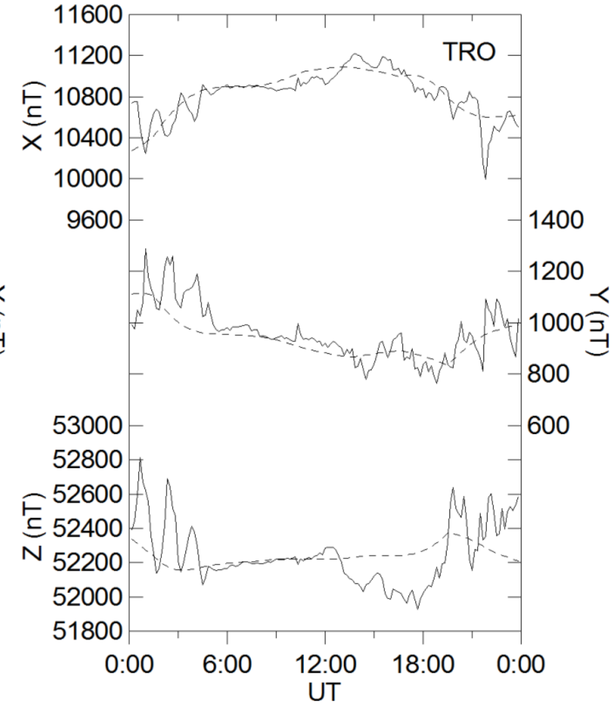
Tromsø
(66.5º mag.lat)
For August 4,
2010 (Ap = 49)

- Used AMPERE data from northern hemisphere
- Increased mean energy of auroral precipitating electrons by a factor of 3

TIEGCM driven by AMPERE data



Standard TIEGCM with Heelis convection



- Standard TIEGCM can reproduce slow time variation but not time variations shorter than approximately 6 hours. The standard version is driven by 3hourly Kp and daily F10.7 solar flux.
- TIEGCM driven by AMPERE data can reproduce variations down to 30 min.

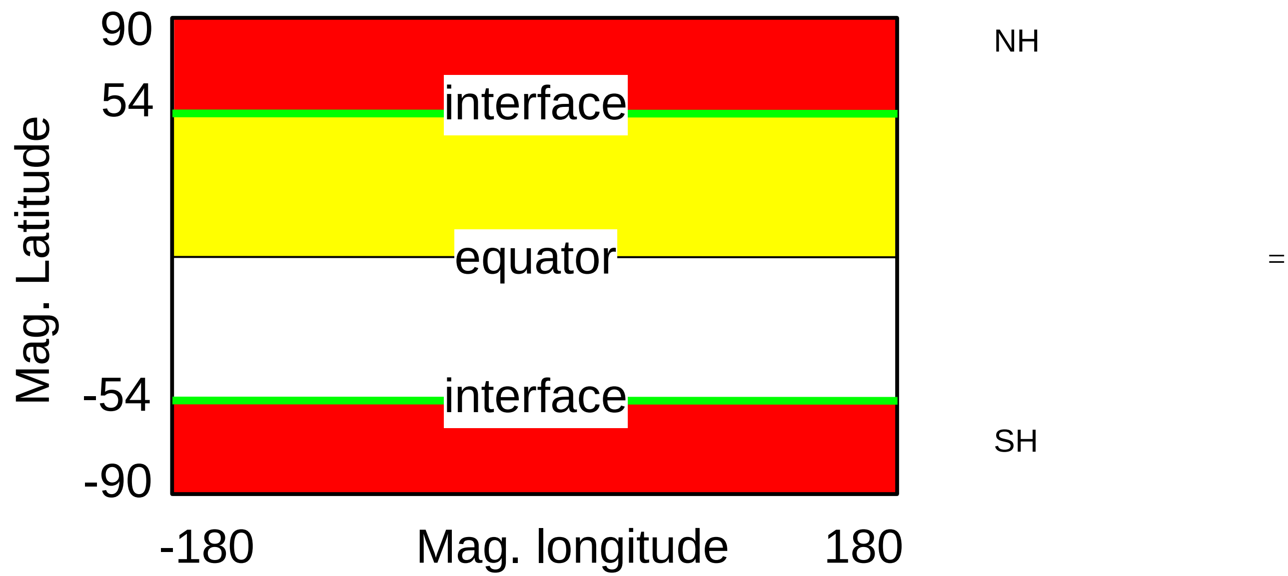
Need for improvement!

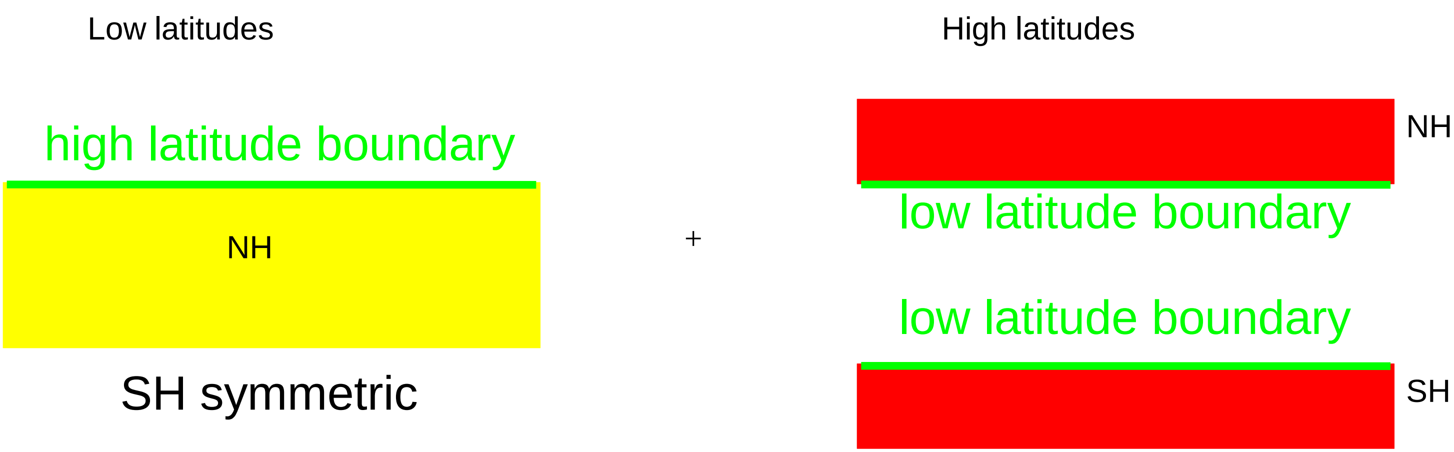
•Overall using AMPERE FAC leads to better model-observation agreement at high latitude and high disturbance levels than at mid-latitude and quiet periods. Probably, the AMPERE current as a driver is more important at high latitude and for disturbed periods.

•One probable cause of model-data difference is that the AMPERE FAC has a high spatial and temporal resolution but this is not reflected in the high latitude conductivity distribution which is driven by auroral particle precipitation. In TIEGCM an empirical model of the auroral particle precipitation is used driven by 3-hourly Kp.

•For some stations the data-model agreement was better forcing the model with the northern or southern or the sum of both FAC patterns. This inconsistency points to the importance of a hemispherically asymmetric potential solver.

An “old” attempt





Questions?