A Global Electric Circuit Model within WACCM

WACCM Meeting February 9th

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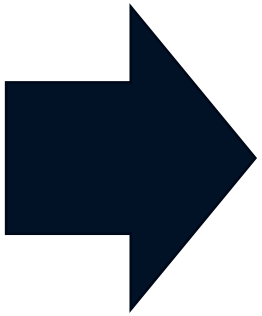
Outline

- Overview of the Global Electric Circuit (GEC)

- Conductivity
- Sources
- Magnetosphere

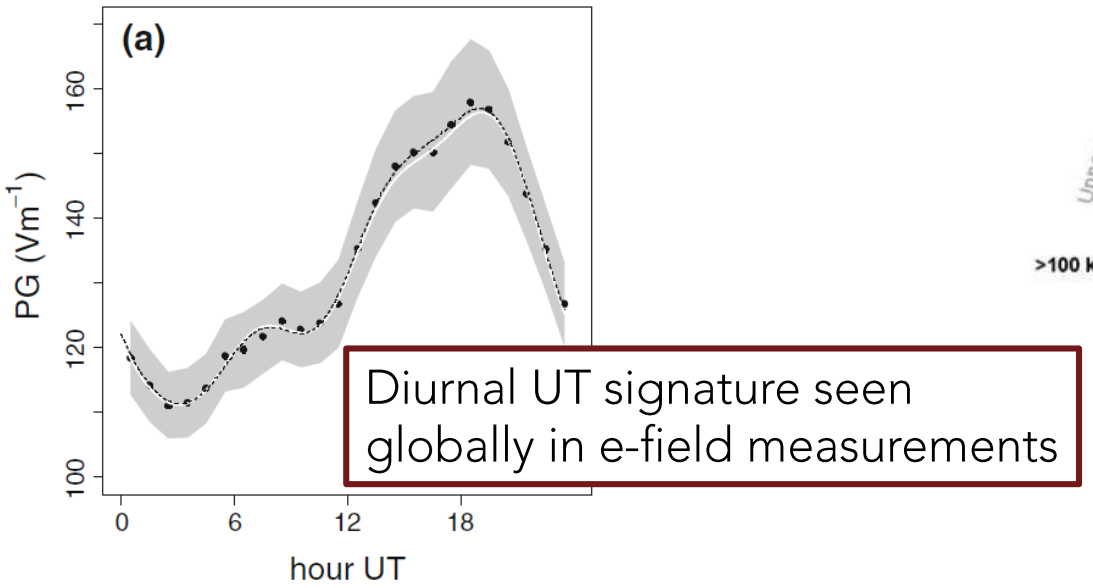


Global Model (WACCM-GEC)

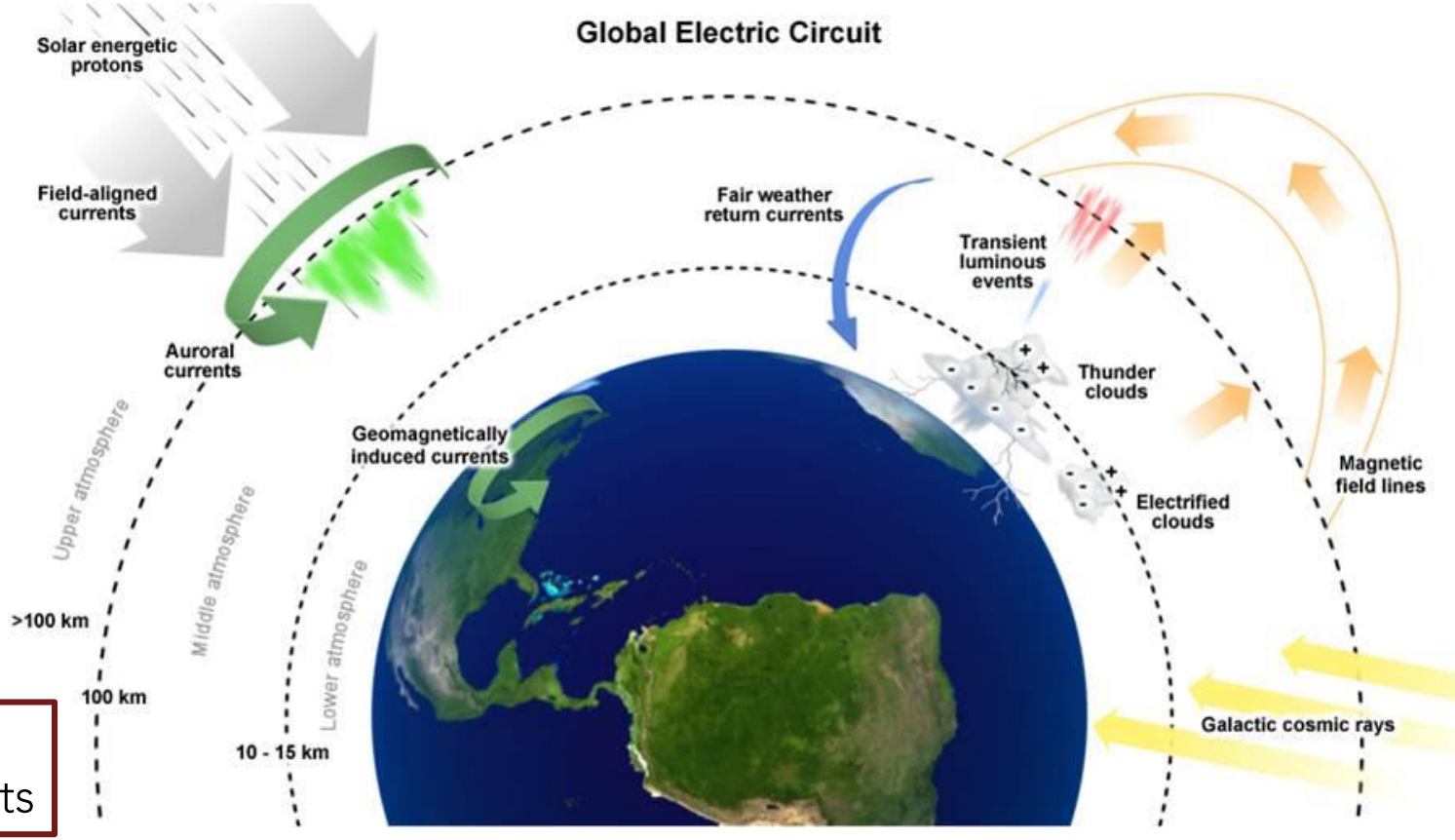
- Conclusion

GEC Background

- Thunderstorms create a potential difference between the ground and ionosphere (capacitor)



Diurnal UT signature seen globally in e-field measurements



WACCM-GEC

- New module for physical representation of conductivity and current sources
- Incorporation of magnetospheric potential
- 3D electric field calculated at each model time-step

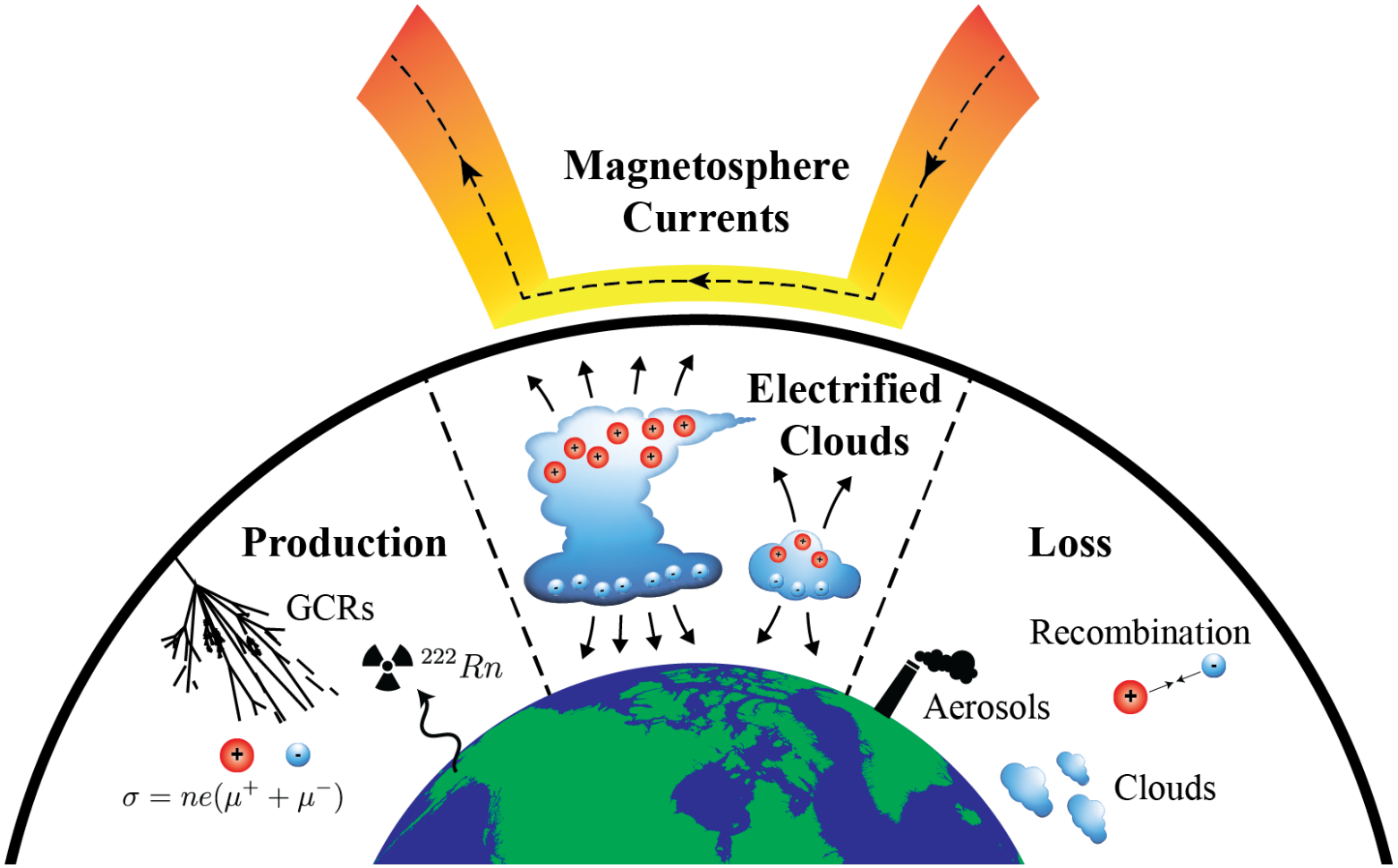
- Solves current continuity equation Lucas et. al 2015

$$\nabla \cdot \sigma \nabla \phi = S$$

Baumgaertner et. al 2013 & 2014

Kalb et. al (in prep)

Electrical Processes in the Atmosphere



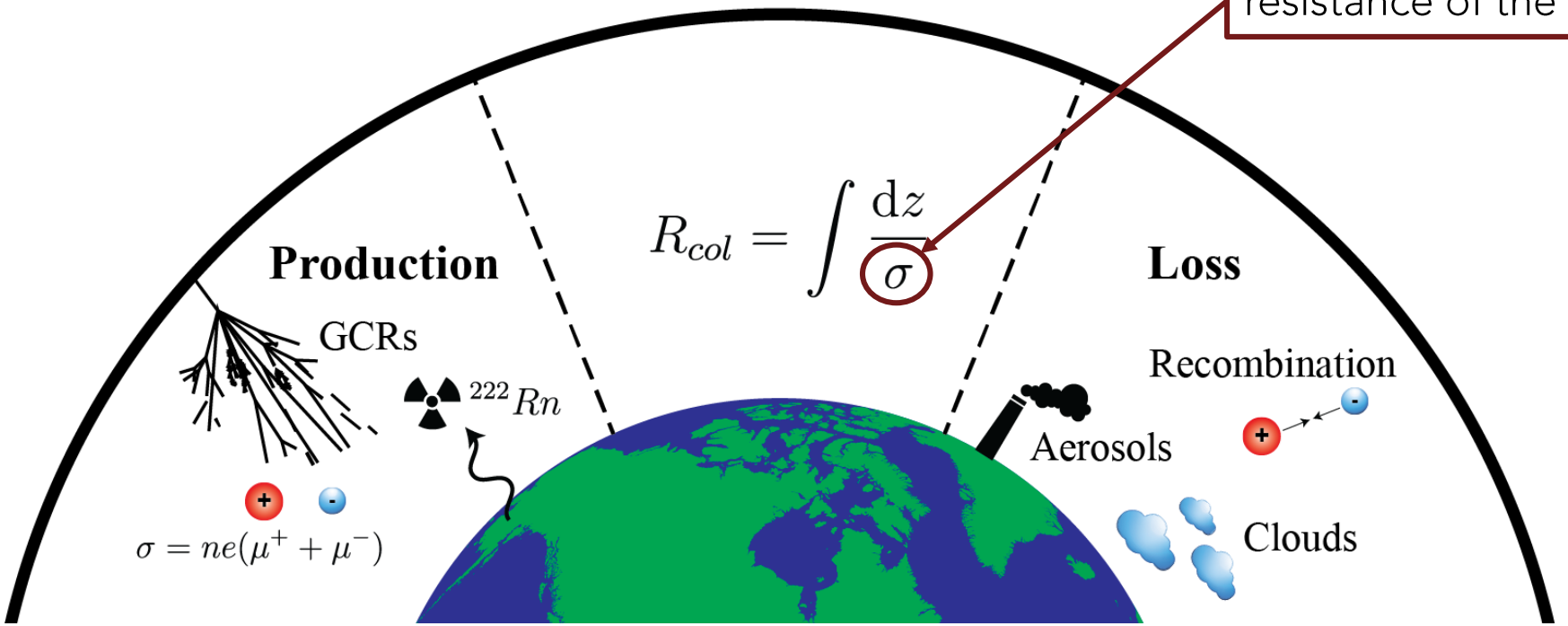
WACCM-GEC Conductivity

Baumgaertner et. al 2013 & 2014

$$R_{tot} = \left(\sum_{col} \frac{A_{col}}{R_{col}} \right)^{-1}$$

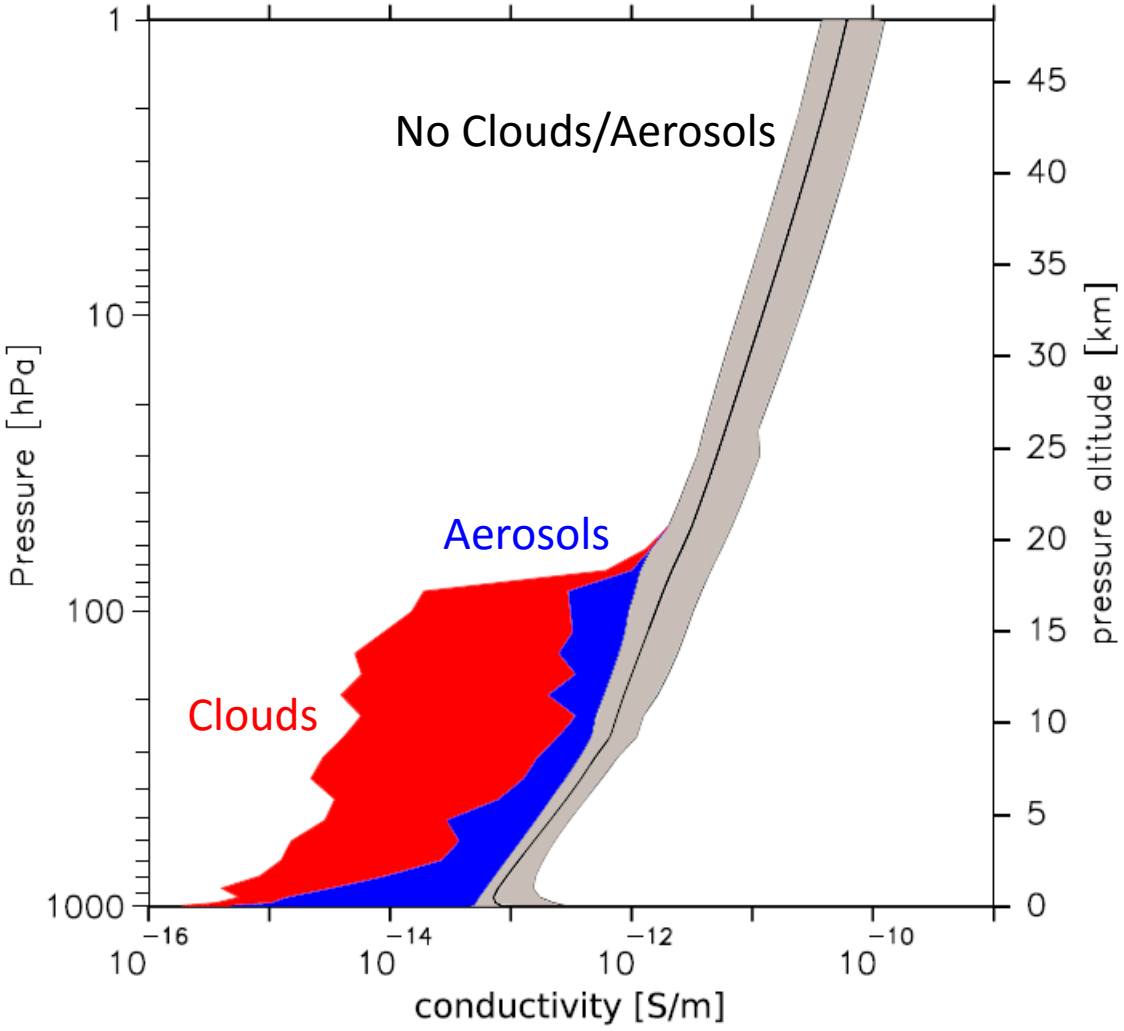
Global conductivity distribution leads to column resistances and the total resistance of the atmosphere

$$R_{col} = \int \frac{\mathrm{d}z}{\sigma}$$



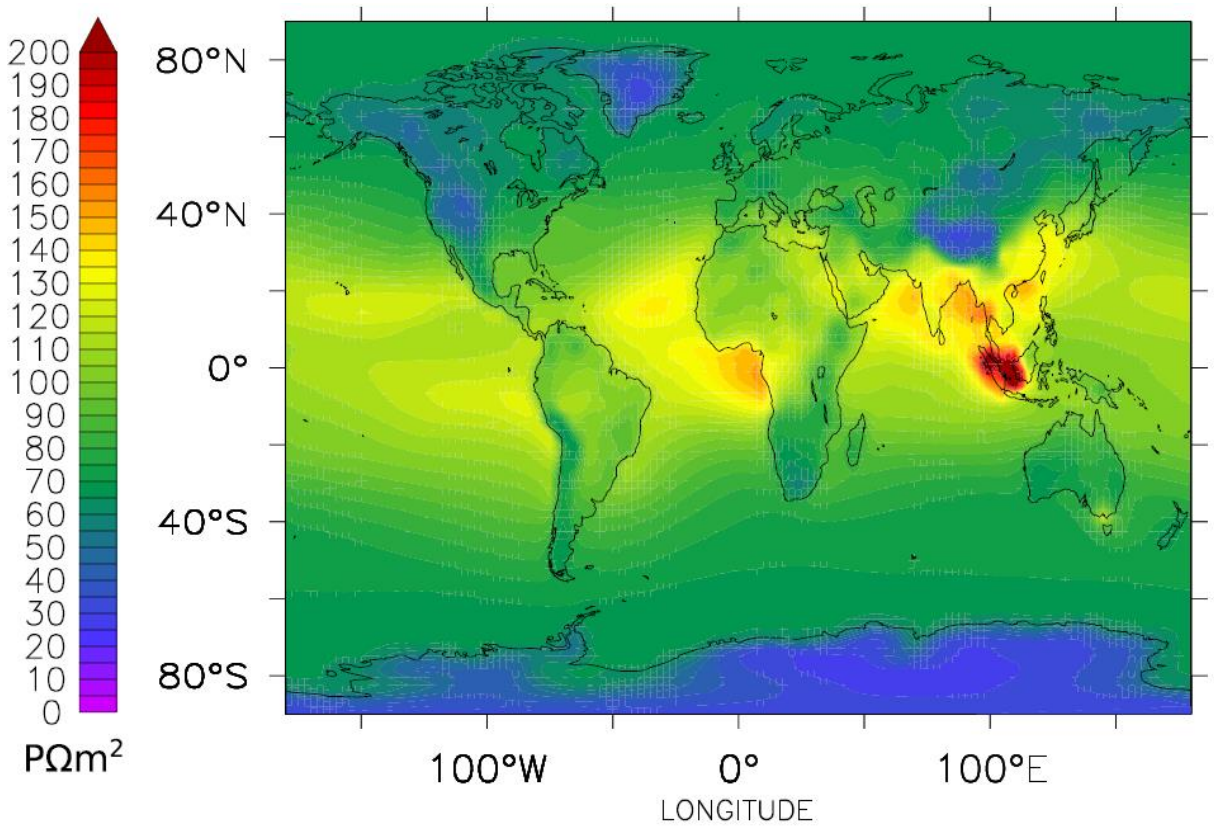
WACCM-GEC Conductivity

- Production (ion creation)
  - Radon (surface emission file)
  - GCRs (parameterization or NAIRAS)
  - SPEs (within WACCM)
- Loss
  - Recombination
  - Attachment to aerosols (CARMA)
  - Attachment to clouds (ISCCP)

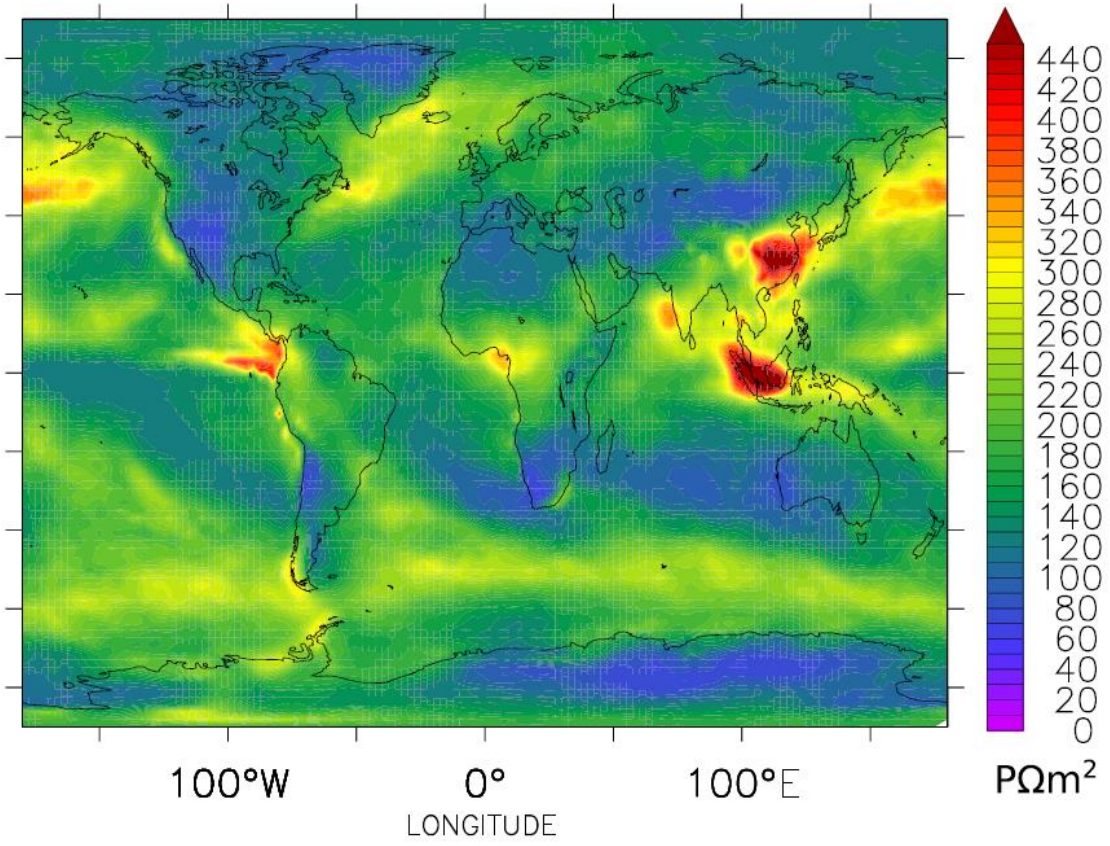


WACCM-GEC Conductivity

Without clouds



With clouds

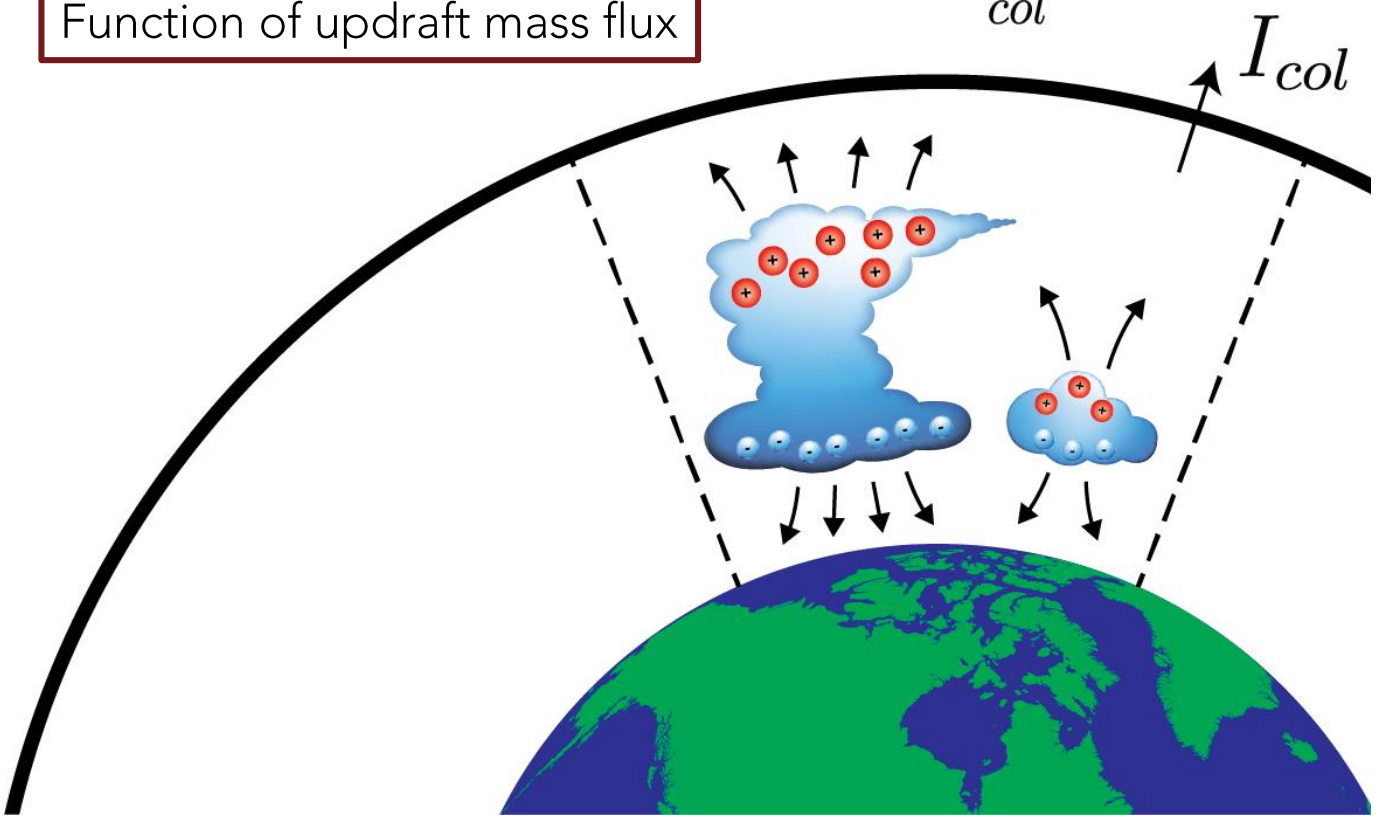


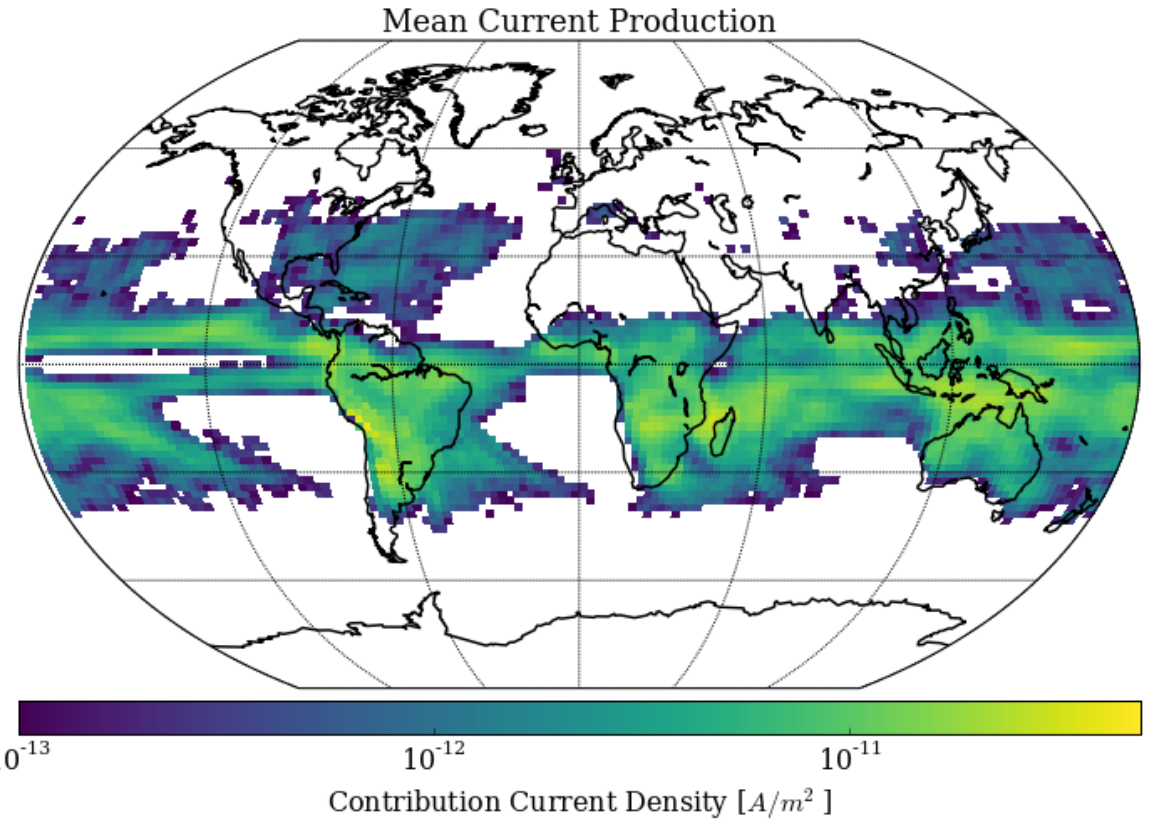
WACCM-GEC Sources

Kalb et. al (in prep)

$$I_{GEC} = \sum_{col} I_{col}$$

Function of updraft mass flux





WACCM-GEC Ionosphere Potential

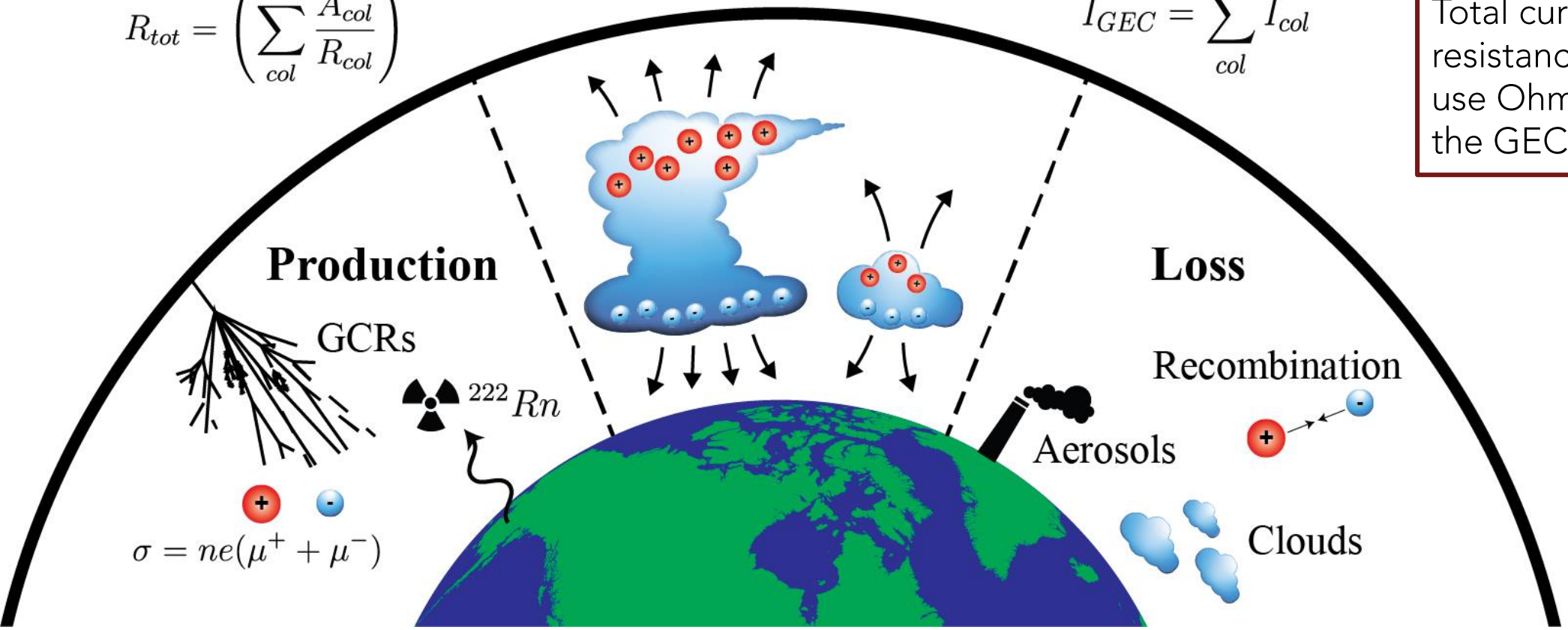
Lucas et. al 2015

$$PD_{GEC} = I_{GEC} R_{tot}$$

$$R_{tot} = \left(\sum_{col} \frac{A_{col}}{R_{col}} \right)^{-1}$$

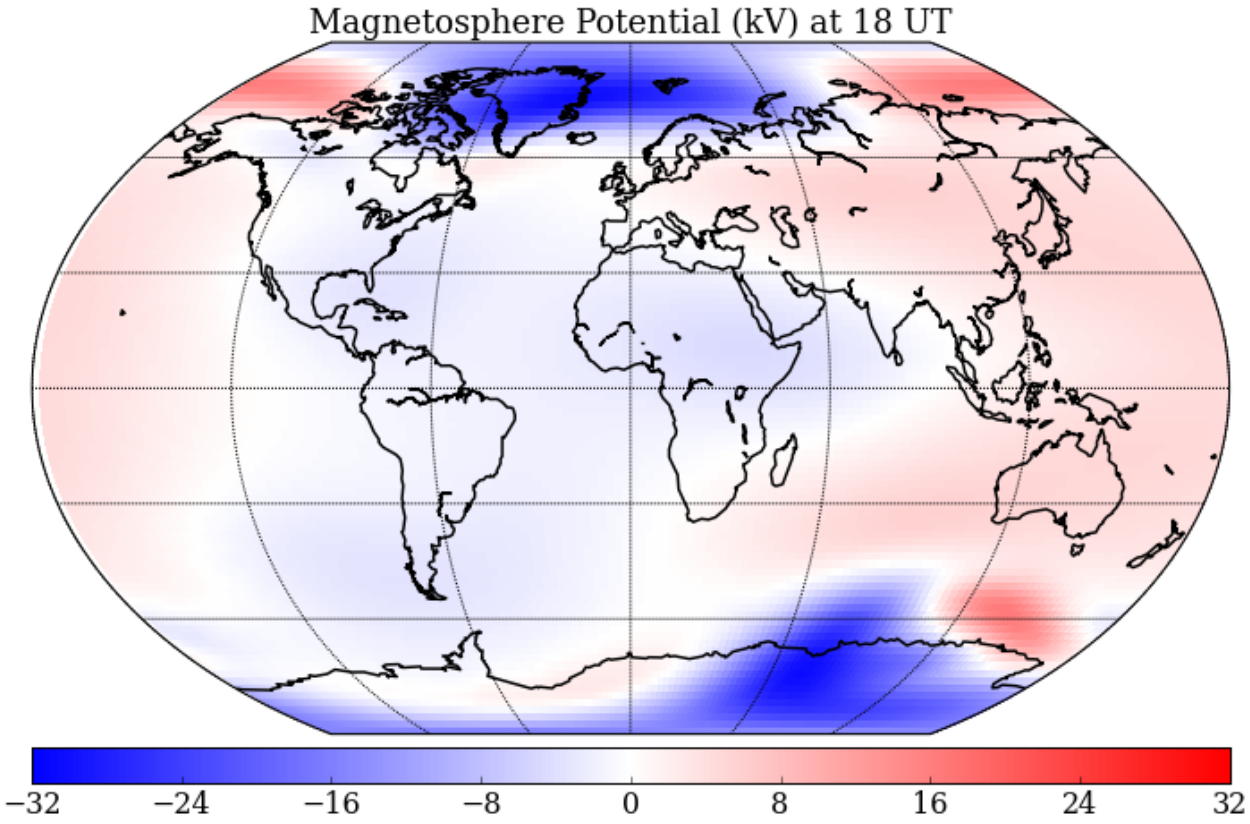
$$I_{GEC} = \sum_{col} I_{col}$$

Total current and total resistance are known, use Ohm's law to get the GEC potential



WACCM-GEC Magnetosphere

- Magnetospheric currents generate cross-cap potentials at high latitudes
- Need to modify the uniform upper boundary condition

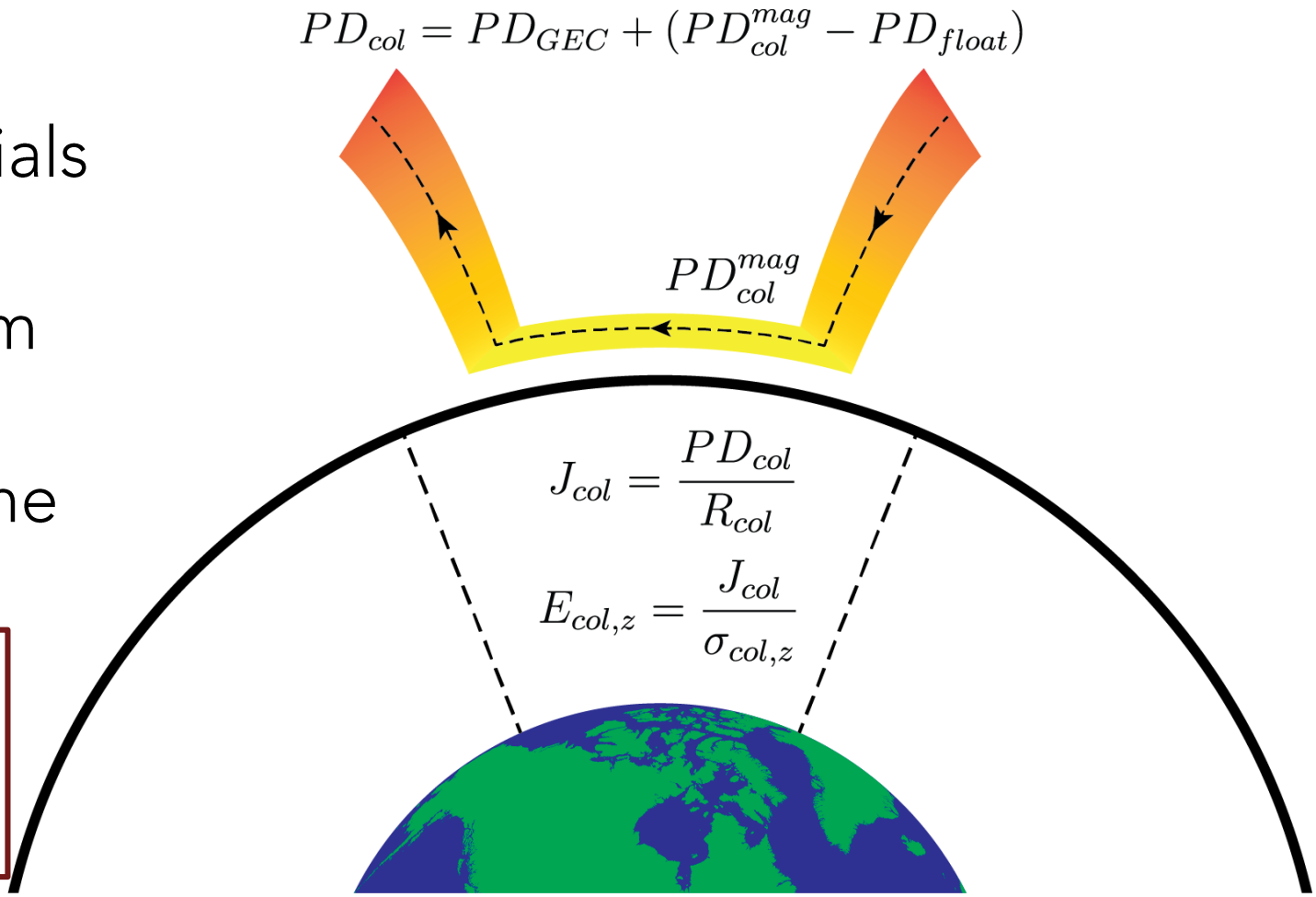


WACCM-GEC Magnetosphere

- Magnetospheric currents generate cross-cap potentials at high latitudes
- Need to modify the uniform upper boundary condition
- No current flow between the GEC and magnetosphere

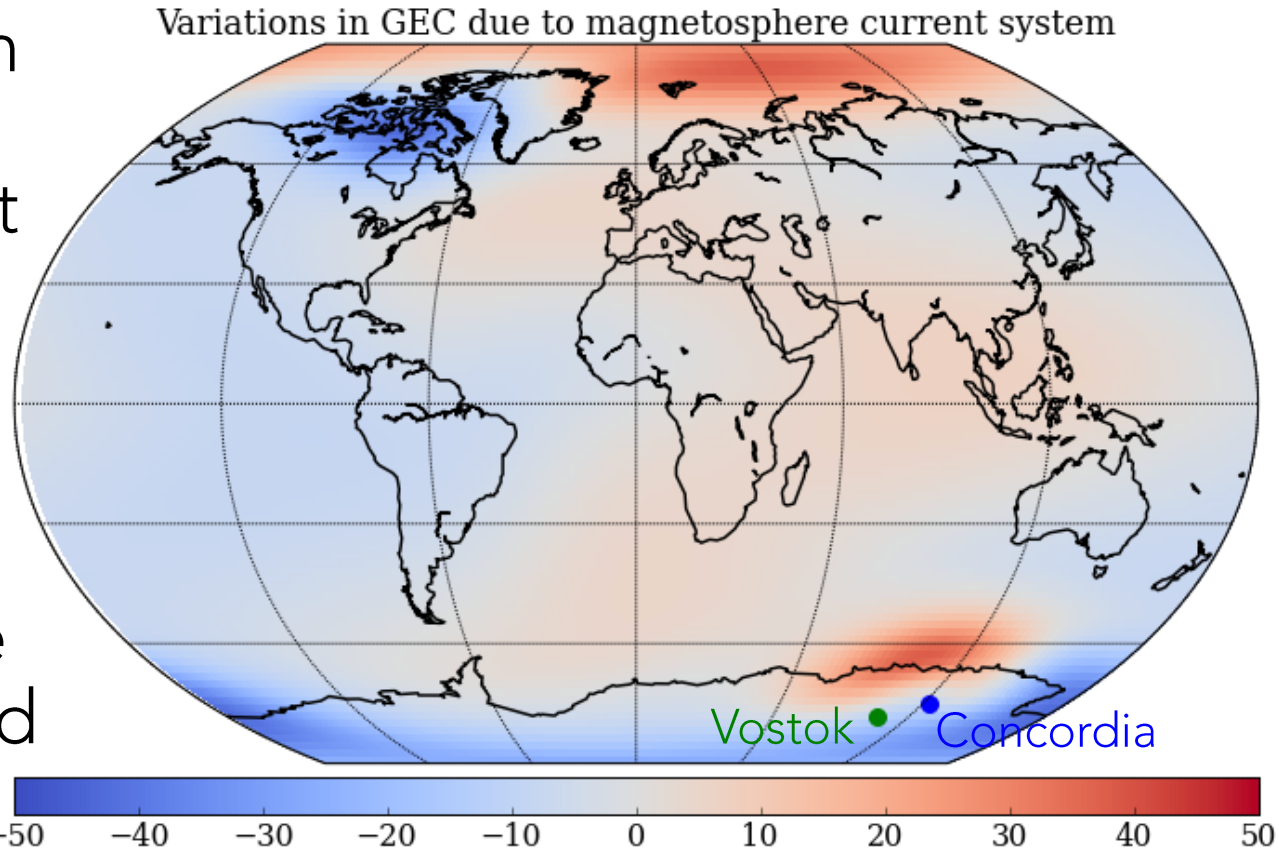
Integrate the leakage current through each column contributed by the magnetosphere

$$PD_{float} = \int_{4\pi} \frac{PD_{col}^{mag}}{R_{col}} \mathrm{d}S \ * R_{tot}$$



WACCM-GEC Phase Relationships

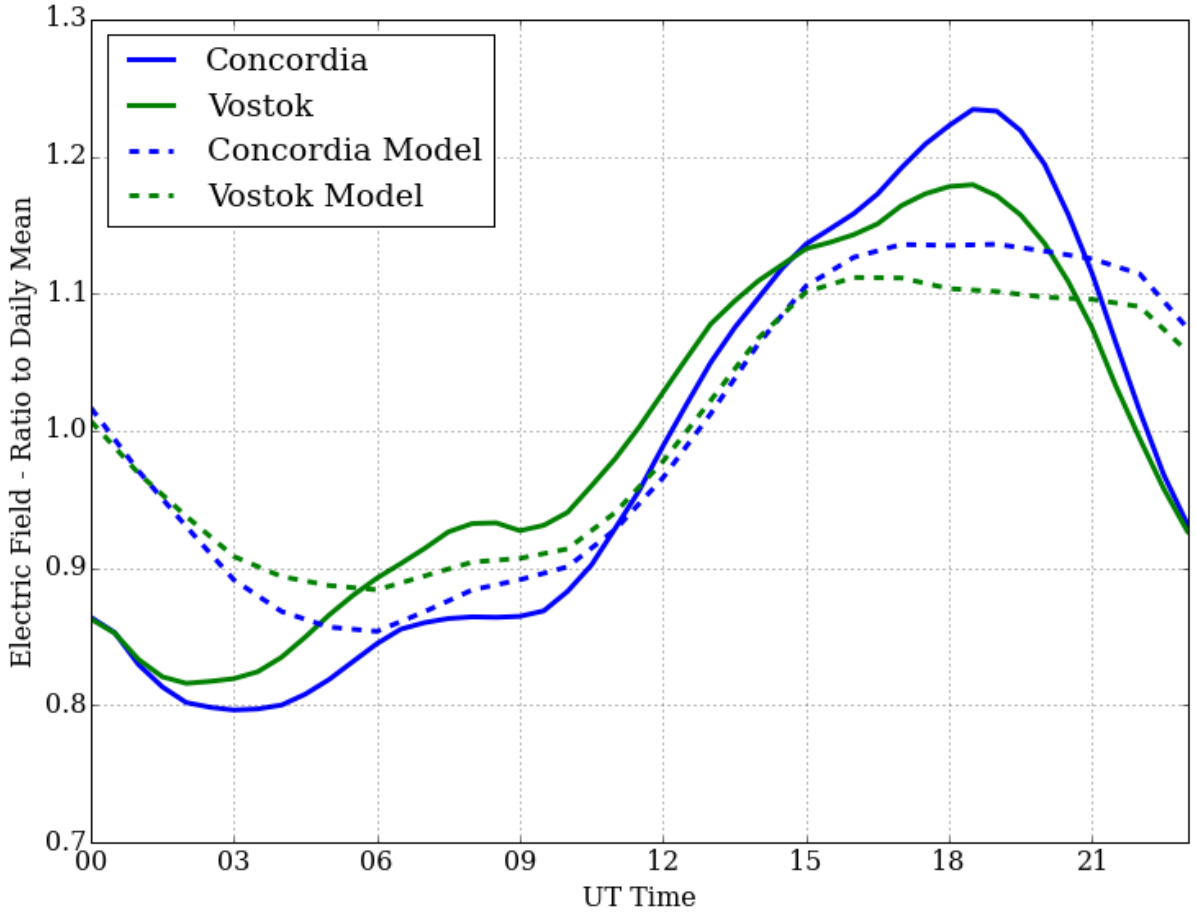
- Magnetosphere current system rotates in geomagnetic coordinates, while GEC current system rotates in geographic coordinates
- Unique phasing signature can be seen at high latitude locations, where a 50% change in electric field can be detected in solar quiet conditions



$$\%\ Change = 100\frac{A_{col}^{mag}}{A_{GEC}}\cos(\phi_{col}^{mag} - \phi_{GEC})$$

WACCM-GEC Results

- Observational data obtained from Vostok and Concordia in Antarctica
- Model simulation during Jan-Mar 2010
- Peaks are off (need to improve source currents)
- Phasing is correct



WACCM-GEC Summary

- Created a model of the GEC within a community climate model
- Realistic representations of conductivity and current sources
- Incorporates the magnetospheric current system
- Unique phasing signature at high-latitudes shows as much as a 50% change in surface electric field variation (could be more during geomagnetically active times)
- Simulation results from Vostok and Concordia show good agreement with observational data

Questions?

- Contact: greg.m.lucas@gmail.com
- References
  - Baumgaertner, A. J. G., Thayer, J. P., Neely, R. R., & Lucas, G. (2013). Toward a comprehensive global electric circuit model: Atmospheric conductivity and its variability in CESM1 (WACCM) model simulations. Journal of Geophysical Research: Atmospheres, 118(16), 9221-9232.
  - Baumgaertner, A. J. G., Lucas, G. M., Thayer, J. P., & Mallios, S. A. (2014). On the role of clouds in the fair weather part of the global electric circuit. Atmospheric Chemistry and Physics, 14(16), 8599-8610.
  - Lucas, G. M., Baumgaertner, A. J. G., Thayer, J. P. (2015). A global electric circuit model within a community climate model. Journal of Geophysical Research: Atmospheres, doi:10.1002/2015/JD023562