Interhemispheric Comparisons of Modeled Joule Heating During the 2013 and 2015 St. Patrick's Day Geomagnetic Storms

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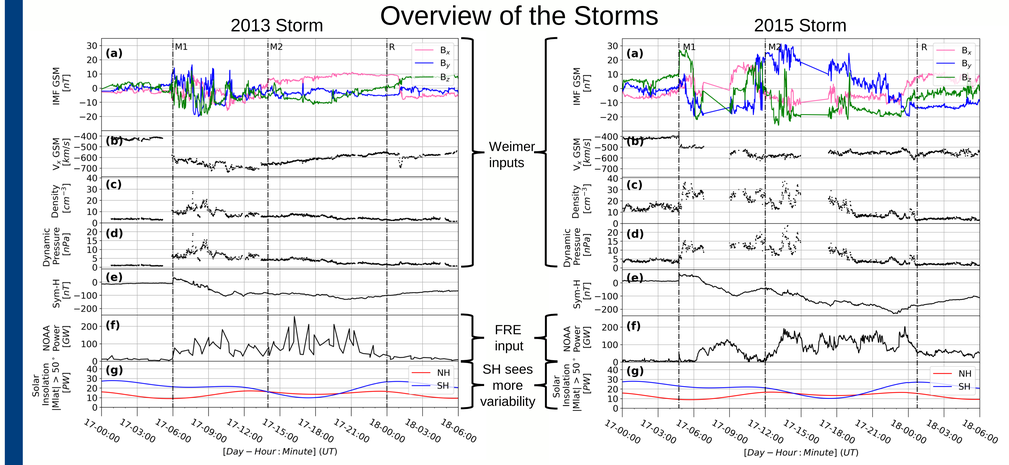
Motivation

- Understanding the storm time electromagnetic energy input into the Ionosphere-Thermosphere
  - Joule heating (JH) is produced by friction between neutral and ionized particles
  - JH is a significant source of energy deposition into the IT from the magnetosphere [1]
  - In our simulation JH is defined as collisions and frictional heating
- Understanding interhemispheric differences
  - 2013 and 2015 Saint Patrick's day storms
  - Equinox conditions
  - Assumed similar ionospheric conductivity profiles in both hemispheres
  - Allows for the isolation of the solar wind and IMF driving conditions for investigation of interhemispheric asymmetries[2]
- Investigating simulations driven with empirical and data-assimilated drivers

Methodology

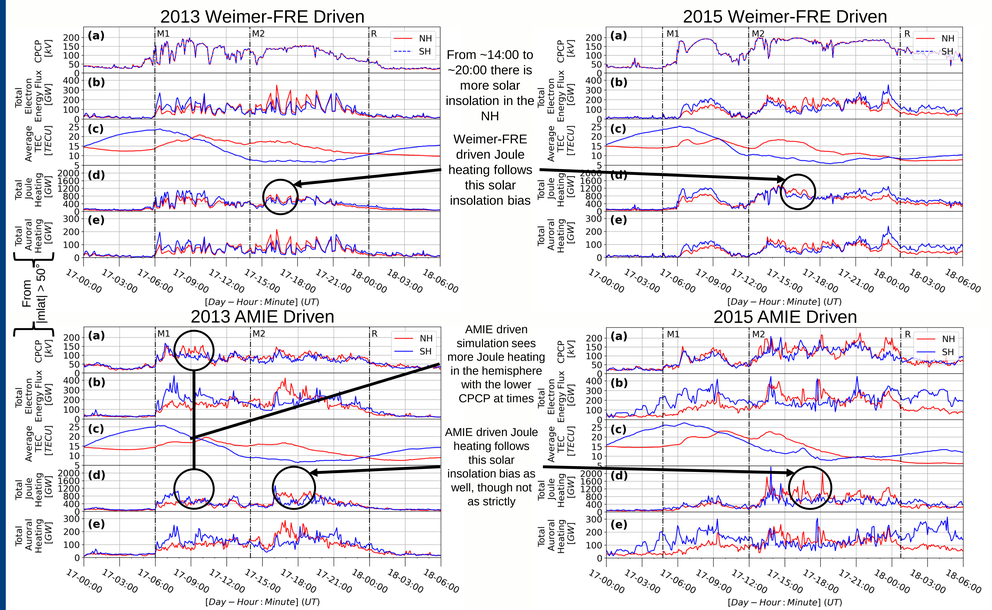
- University of Michigan Global Ionosphere-Thermosphere Model (GITM) [3]
  - 2° by 2° resolution
  - 50 layers of atmosphere: 100km to 600km
  - Daily $F_{10.7}$ for solar irradiance
- Empirical Drivers
  - Weimer model for high-latitude electric potential
  - One minute resolution IMF data
  - Fuller-Rowell Evans (FRE) model for auroral precipitation
  - NOAA Hemispheric power indices
- Data Assimilated Driver
  - Assimilated Mapping of Ionospheric Electrodynamics (AMIE)

Overview of the Storms



Simulation Results

Integrated and averaged IT energy budget parameters from above 50°N and below 50°S magnetitic latitude



2013 Weimer-FRE driven animation

2013 AMIE driven animation

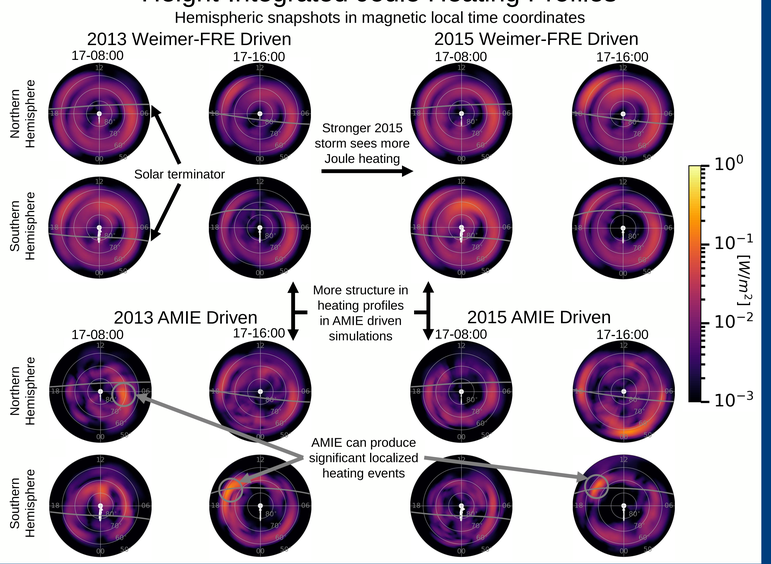
Animations with potential patterns, Joule and auroral heating, Hall and Pedersen conductances, and TEC

2015 Weimer-FRE driven animation

2015 AMIE driven animation

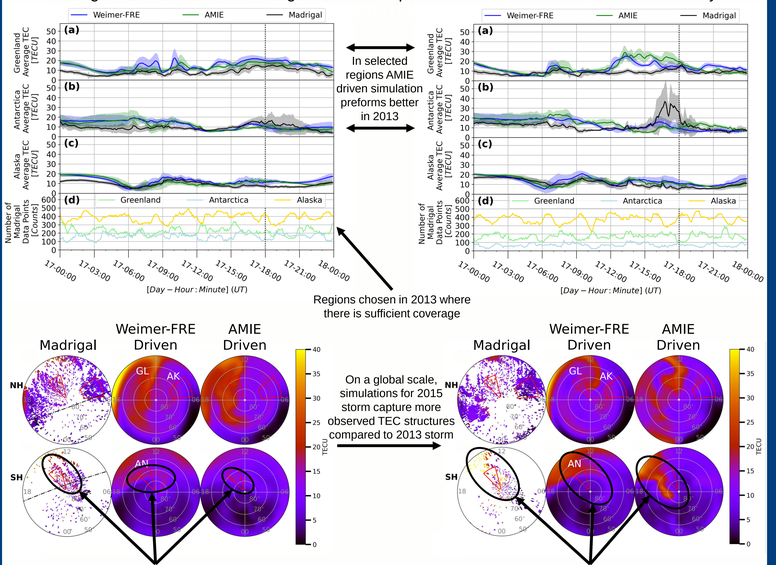
Height-Integrated Joule Heating Profiles

Hemispheric snapshots in magnetic local time coordinates



Model – Data Total Electron Content Comparisons

Madrigal TEC was used to investigate simulation performance of storm time electron variability



Conclusions

- Solar insolation has a significant effect on simulated hemispheric TEC, even at equinox
- Asymmetric TEC results in a diurnal variation in Joule and auroral heating aligned with solar insolation over the magnetic high-latitude regions
- Realistic drivers can produce more and intense localized heating events
- TEC comparisons perform better in the Northern Hemisphere, potentially indicating sampling bias

Future Work

- Further analysis of simulations
  - Preconditioning
  - Numerical experiments testing storm onset time
  - Grid size and compatibility with inputs
- Further quantitative comparisons
  - Potentially employ conditional mutual information theory and transfer entropy

Other Animations

2013 TEC animation

2015 TEC animation

References

[1] Deng, Y., and A. J. Ridley (2007), Possible reasons for underestimating Joule heating in global models: *E* field variability, spatial resolution, and vertical velocity, *J. Geophys. Res.*, *112*, A09308, doi:10.1029/2006JA012006.

[2] Xu, Z., Hartinger, M. D., Clauer, C. R., Peek, T., and Behlke, R. (2017). A comparison of the ground magnetic responses during the 2013 and 2015 st. patrick's day geomagnetic storms. Journal of Geophysical Research: Space Physics 122, 4023–4036. doi:10.1002/2016ja023338

[3] Ridley, A. J., Y. Deng, and G. Toth., 2006, The Global Ionosphere-Thermosphere Model (GITM). *J. Atmos. Solar-Terrestr. Phys. 68*, 839-864.

This study makes use of NASA OMNI data, NOAA HPI data, and CEDAR Madrigal World-wide GNSS Receiver Network data. The simulations were run on Chinook Supercomputer at UAF. GITM is an open-source code, developed by Aaron Ridley at the University of Michigan. The GITM output is processed using Spacepy package. The authors like to gratefully acknowledge all the data and model providers. NASA-LWS grant no: SMD-20-92157867. Thanks to Dr. Guan Le and the NASA SESI Program for supporting this research.

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