Preliminary Results in the Mechanism Study of Neutral Temperature Inversion Layer — A General Circulation Model Approach

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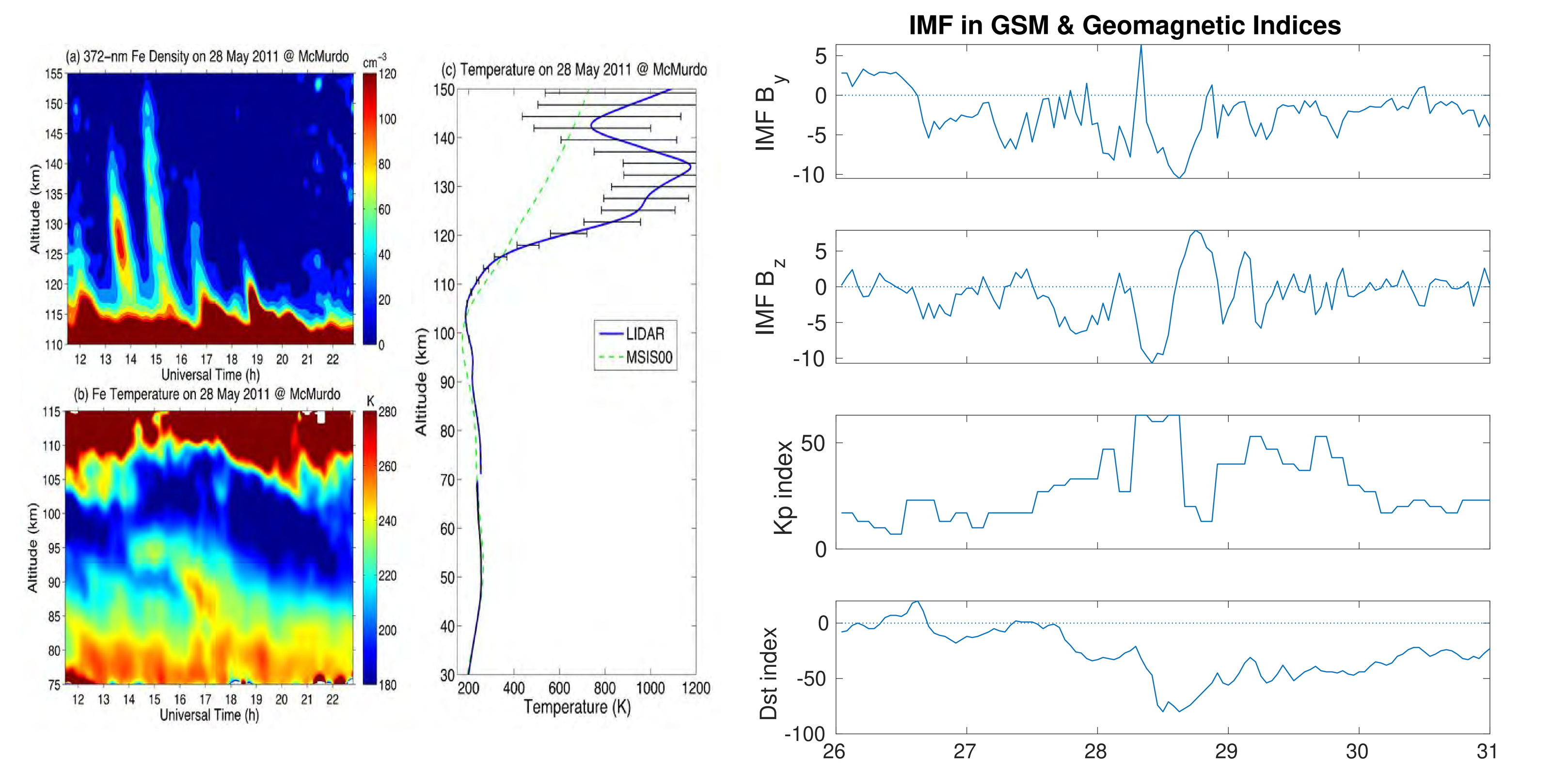
Motivation

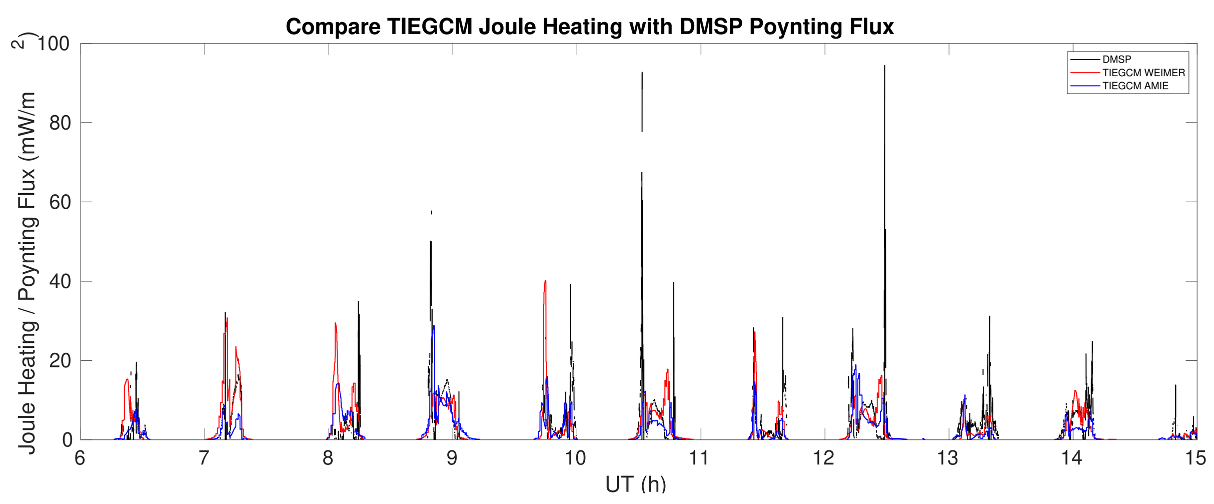
The neutral temperature inversion layer (NTIL) at about 130km was first reported by Xinzhao et al., using Iron Boltzmann lidar at McMurdo, Antarctica. The hourly Kp index reaches and hourly Dst index are shown below, indicating it is a moderate storm. Since NTIL is a farely localized structure, to study its mechanism in general circulation models calls for the need to deal with small scale features in a large scale background.



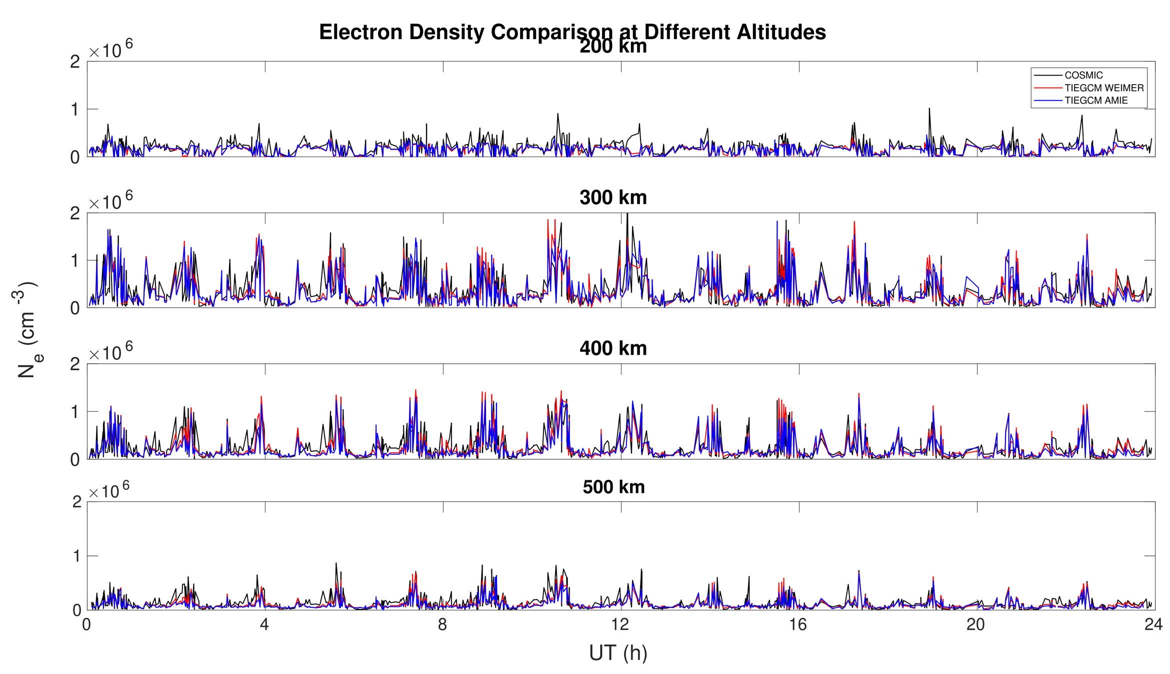
Observed vertical neutral temperature profile with interplanetary magnetic field and geomagnetic indices.

Reality Check

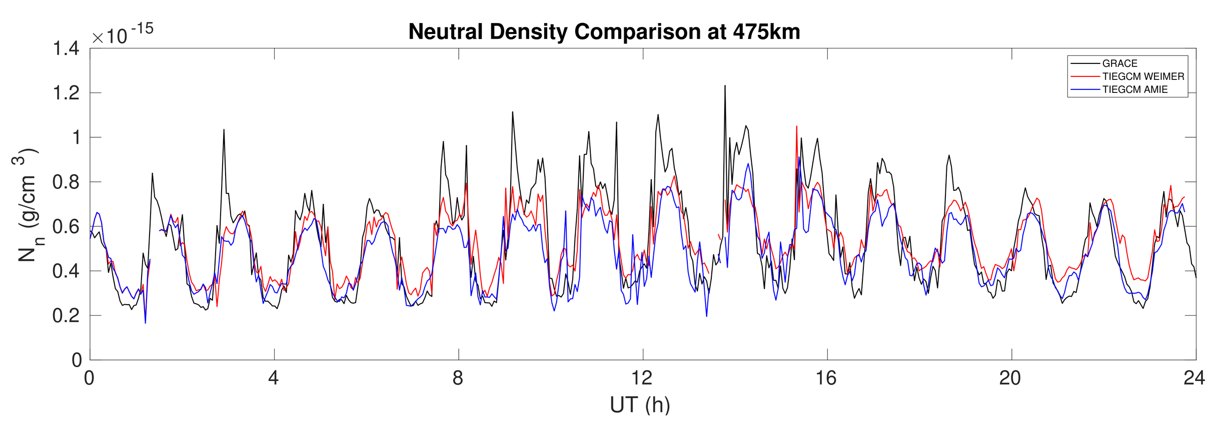
We compared TIEGCM driven by empirical Weimer model with various satellite based observations, and some of the results are listed below.



Comparison of Joule heating with Poynting flux mesured by DMSP shows that TIEGCM generally captured the trend, but there are significant underestimates at about 10:30 UT and 12:30 UT.



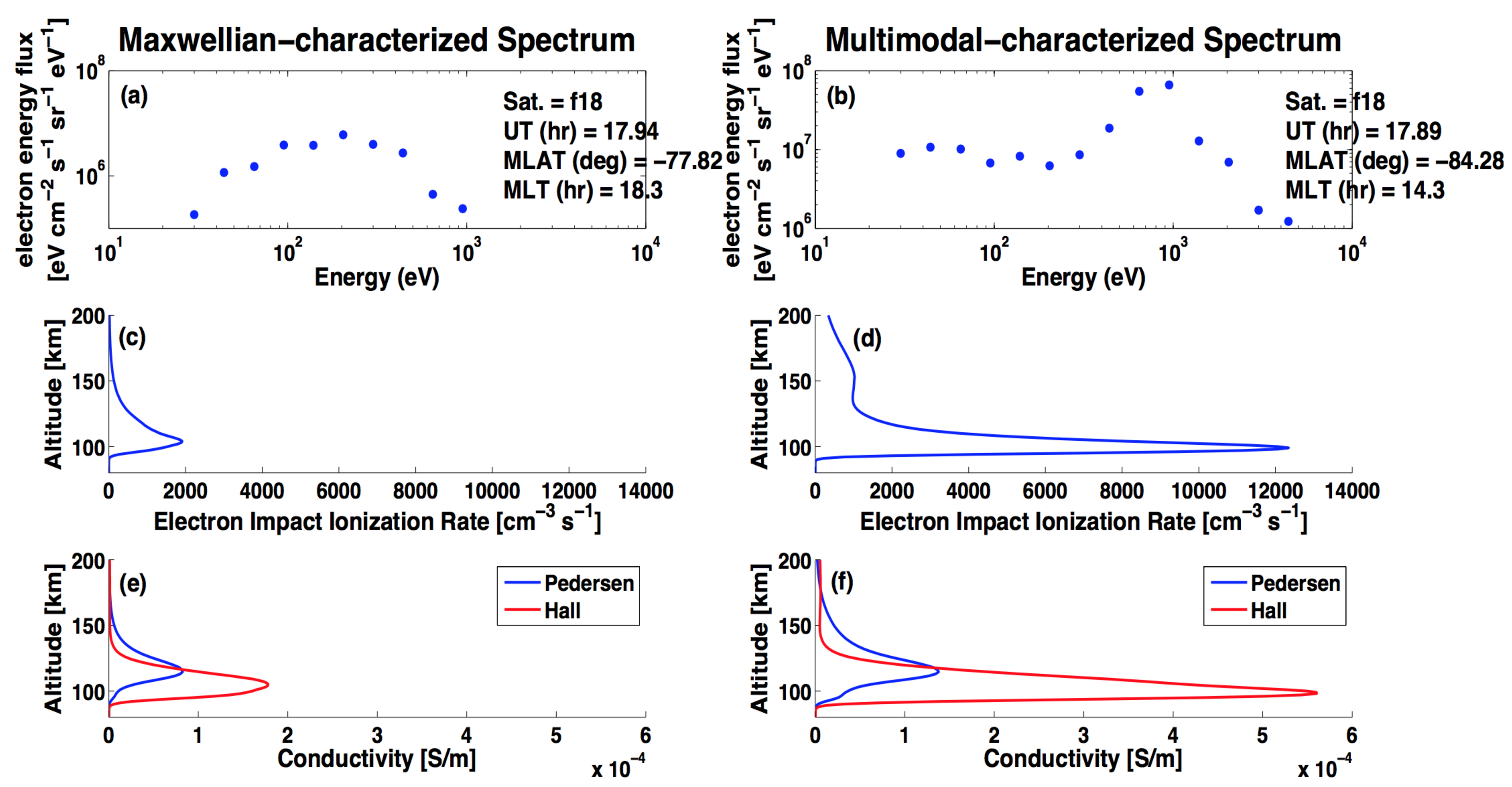
Comparing electron density with COSMIC measurements at different altitudes, TIEGCM agrees with COSMIC measurements pretty well, even minute-wise intensification in storm time is captured.



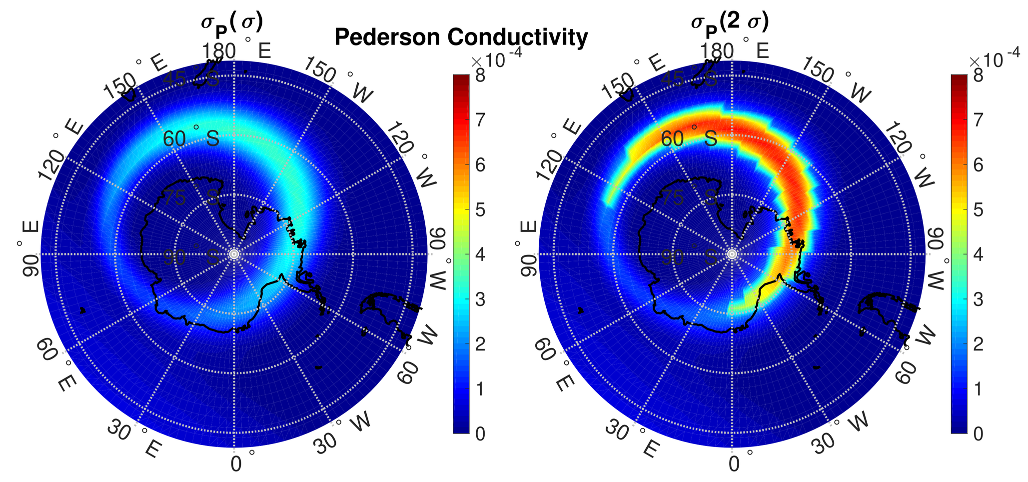
Comparing neutral density with GRACE, TIEGCM accords well in general, but underestimates during storm time can clearly be seen.

Sensitivity Test

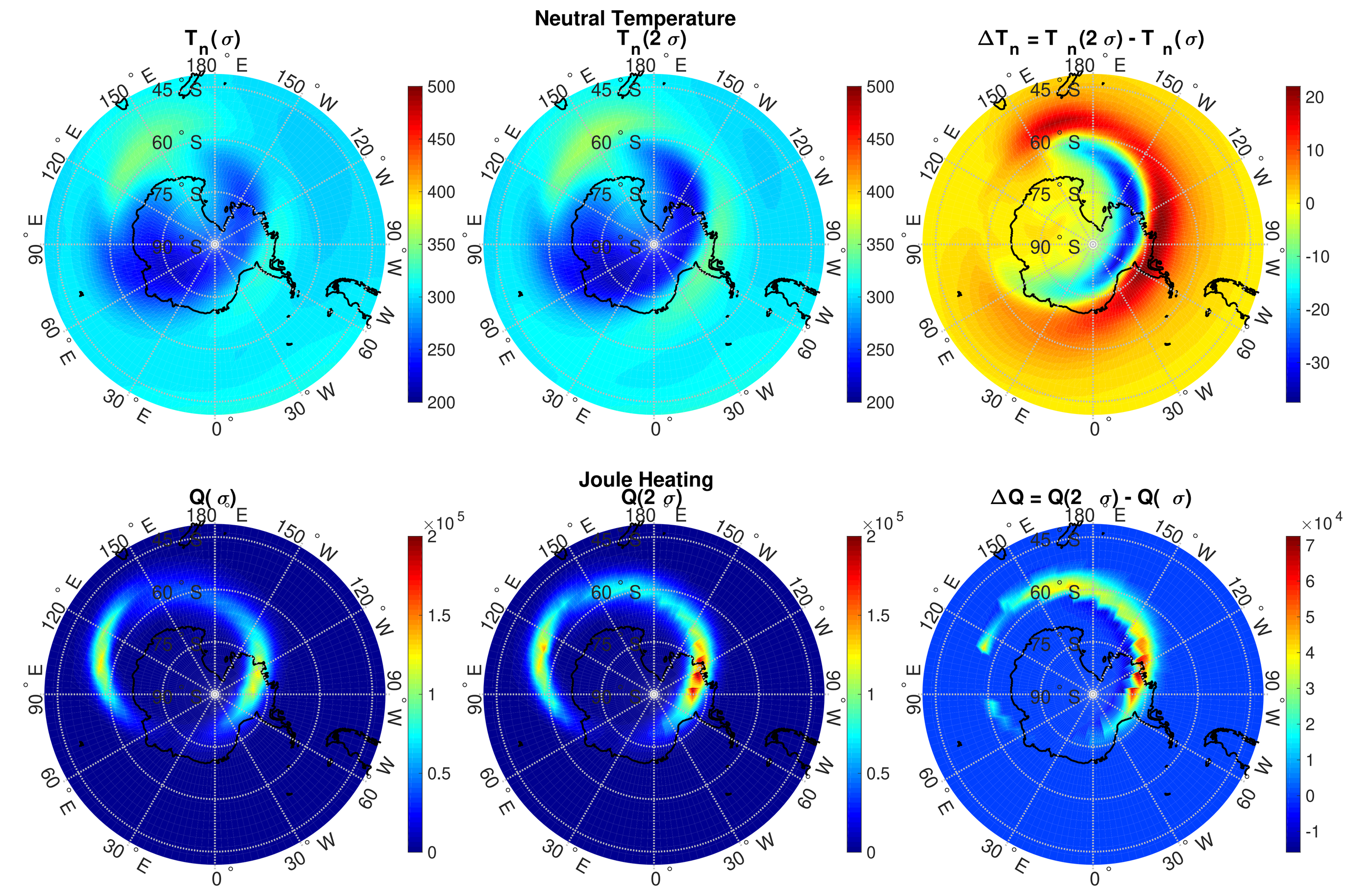
During storm time, ionization rate in the aurora region will increase. This might be caused by the enhancement of local conductivity.



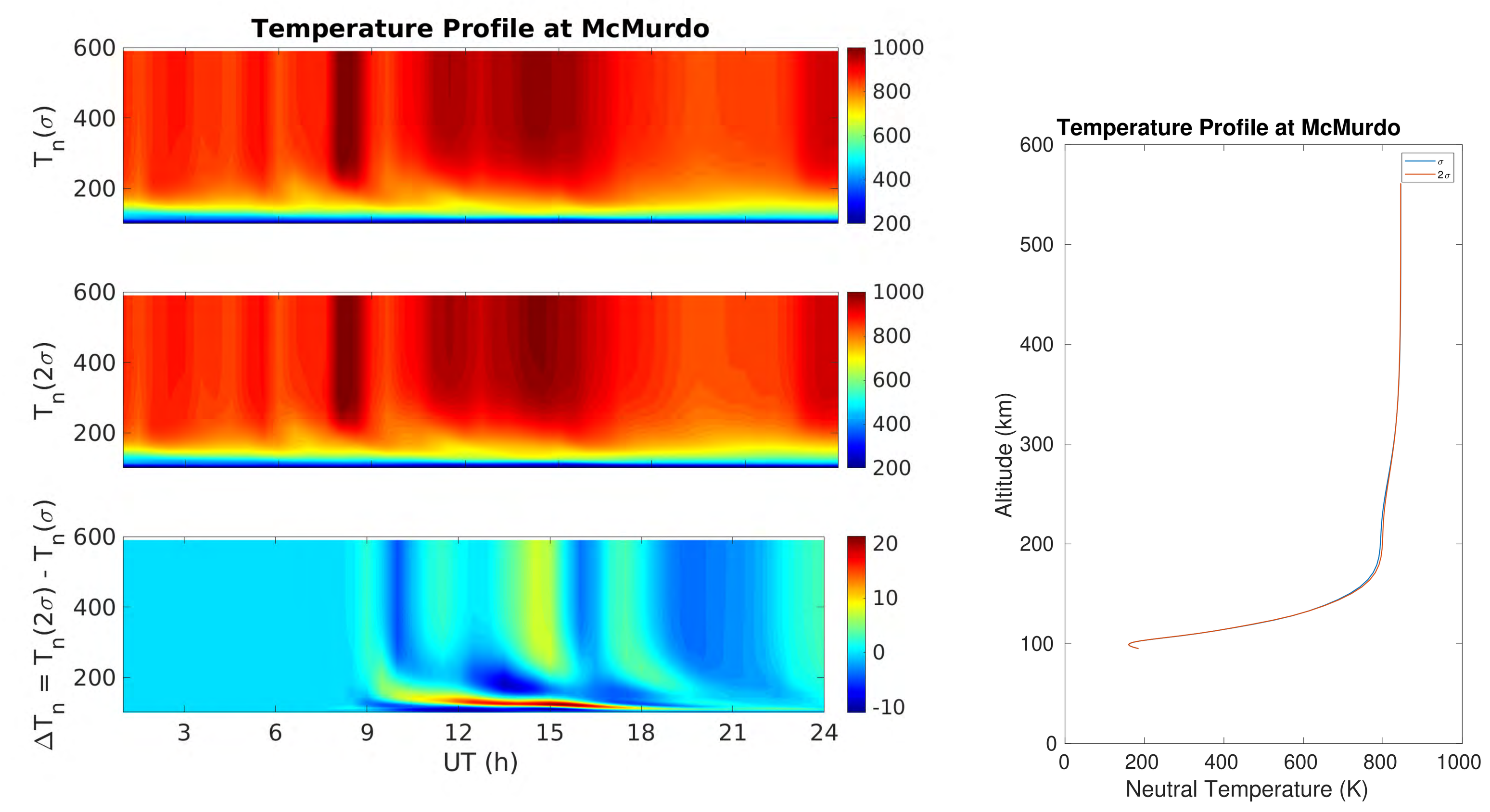
Ionization rate enhancement is accompanied by conductivity increase.



We did some preliminary sensitivity test in TIEGCM to see how it responds to conductivity change. We manually increase the Pederson/Hall conductivity by an arbitrary factor (here we choose 2) in the aurora region, and then see its responce at time in between. Here we apply conductivity increase in aurora region during 06:00 UT and 12:00 UT, and look at neutral temperature and Joule heating profile at 09:00 UT.



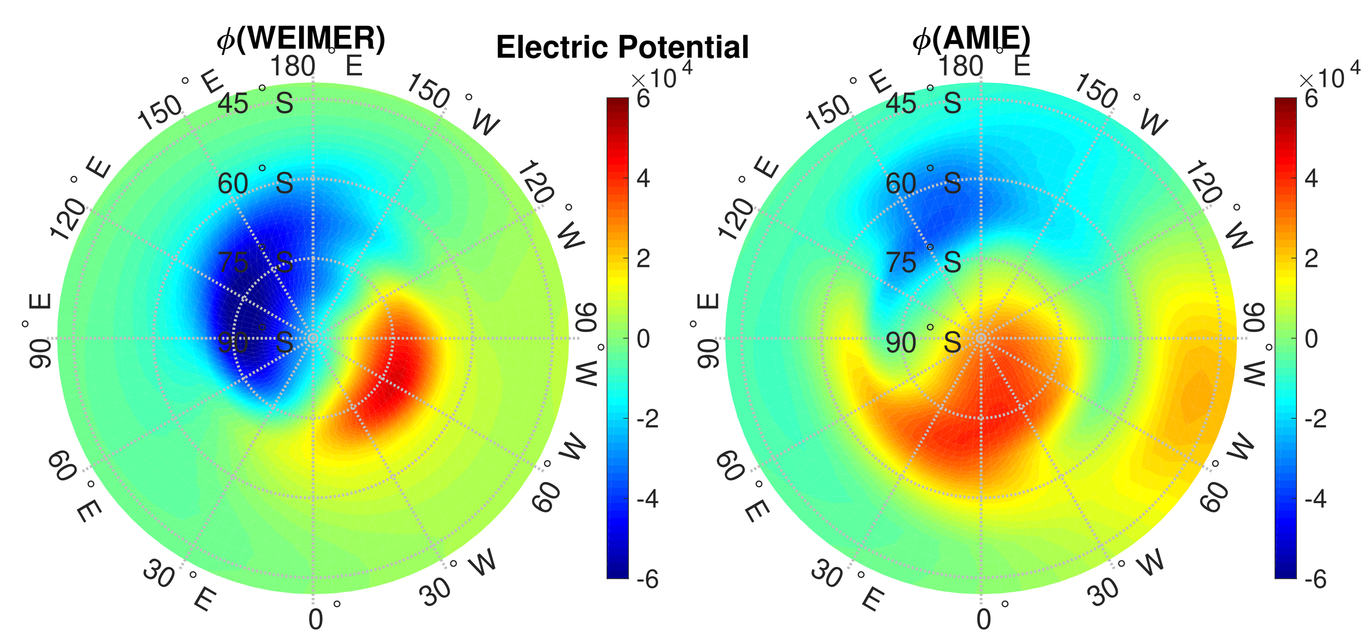
Neutral temperature and Joule heating responses to conductance increase. The results shows that Joule heating in the aurora region increases significantly but neutral temperature responds in a more complex mannar. Inner aurora loop cools down and outer loop gets heated.



Neutral temperature responses at McMurdo. From vertical temperature profile, we conclude that simply multiply conductivity by a factor of 2 is not enough to explain the NTIL.

Future work

Empirical model itself depending on some space environment parameters might not be sufficient to provide small scale features. We probably need an more observation based scheme to give a more realistic convection pattern. AMIE is a such kind of empirical model assimilating various types of data to provide fine structures in high latitude. TIEGCM has been designed to directly use AMIE outputs as its high latitude driver, and we have already noticed some differences in high latitude convection pattern when we use AMIE incorporating magnetometer data comparing with Weimer model, we expect finer structure if we incorporate more observations into AMIE. Some of the results are show in "Reality Check" section.



Electric potential map given by TIEGCM driven by Weimer model and AMIE. We can see from the picture that the two cell pattern is somewhat distorted between two runs.

References

Chu Xinzhao, Huang Wentao, Fong Weichun, Yu Zhibin, Wang Zhangjun, Smith John A., and Gardner Chester S. First lidar observations of polar mesospheric clouds and fe temperatures at mcmurdo (77.8°s, 166.7°e), antarctica. *Geophysical Research Letters*, 38(16). doi: 10.1029/2011GL048373. URL `https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2011GL048373`.