Relation between Conductivity and Field-Aligned Currents: PFISR and SWARM Observations

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Abstract

Ionosphere plays an important and active role in the magnetosphere-ionosphere-thermosphere coupling processes. It allows magnetospheric currents to close, thereby allowing magnetospheric convection to occur. The amount of current that can be carried through the ionosphere is controlled by the ionospheric conductivity. At high latitudes, besides the solar EUV radiation, energetic particle precipitation is also important. In this study, an empirical relationship between conductivity and field-aligned currents (FACs) is derived, which is of vital importance for the MHD simulation of the global magnetosphere. Incoherent Scattering Radars (ISRs) can measure the conductivity directly and SWARM satellite can give a high-resolution measurement of the FAC. Since Nov 2013, SWARM and PFISR start to operate simultaneously. SWARM satellites fly over PFISR 12 times each month, providing a large dataset for studying the relation between conductivity and FACs. We best fit the data points using various functions. The parameters in the functions will depend on both the direction of the FAC and day/night. A strong linear relation between upward FAC and conductance is found on the night side. The relation can be written as $\Sigma_P = 6.216 J_\uparrow + 3.33$ and $\Sigma_H = 13.26 J_\uparrow + 5.80$ respectively, where conductance is in mho and FAC is in $\mu A/m^2$. With this new empirical model of the conductance, a map of the conductance can be generated based on AMPERE FAC.

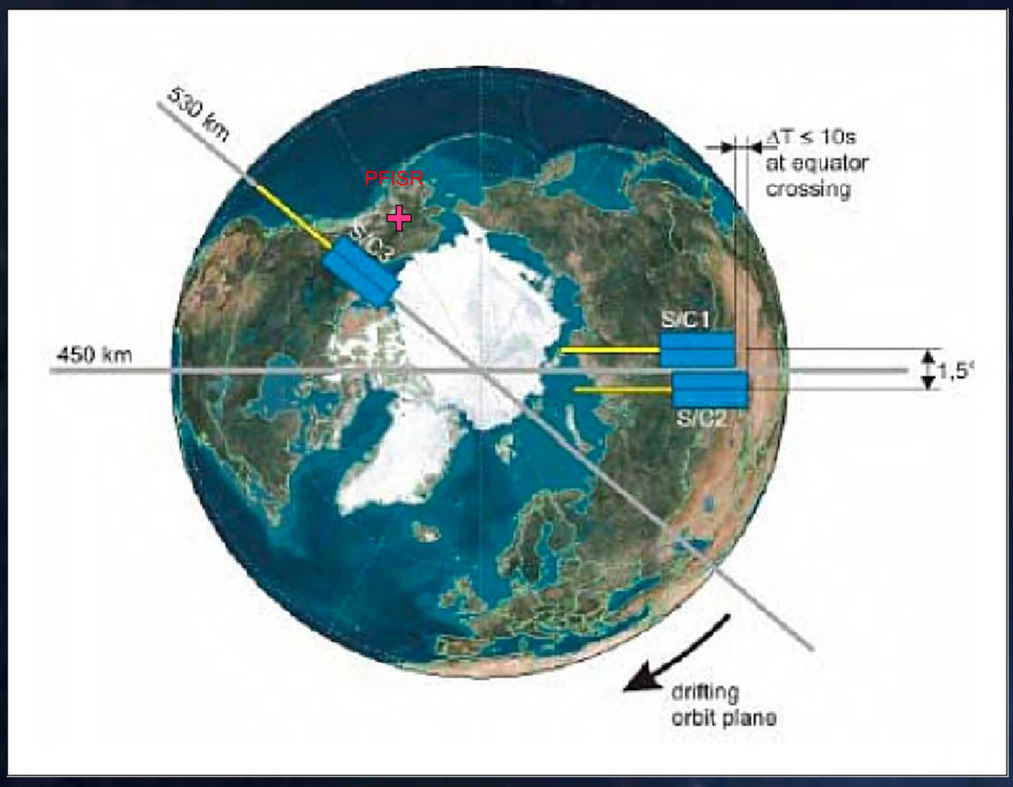

Figure 1. The conjunction between SWARM and PFISR.

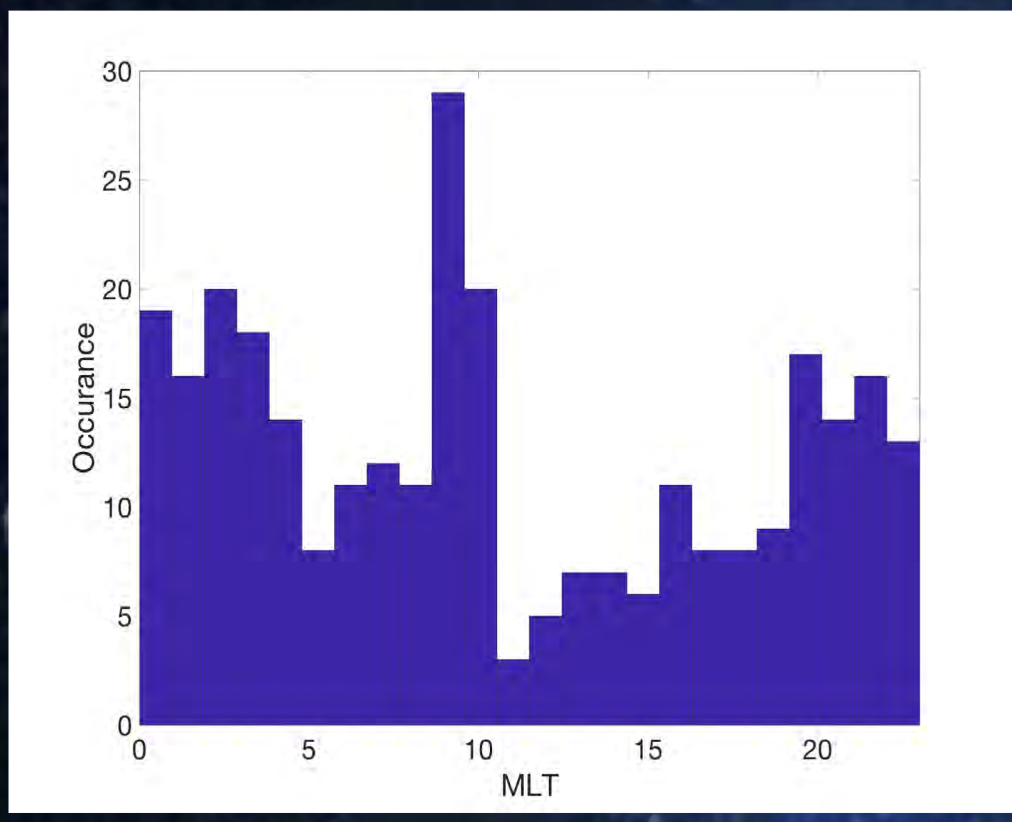

Figure 2. The distribution of conjunction between PFISR and SWARM over MLT

Σ=A*J+B	A	B	COVAR
Σ_P AND UPWARD	6.216	3.33	0.87
Σ_H AND UPWARD	13.26	5.8	0.88
Σ_P AND DOWNWARD	6.6	3.811	~0.6
Σ_H AND DOWNWARD	14.59	5.662	~0.6

Table 1. The parameters between conductance and FAC.

Methods

1. Choose data base of conductance and FAC. The conductance is from Poker Flat Incoherent Radar (PFISR). ISR can provide the most accurate measurements of conductance up till now. PFISR locates at Alaska and during most time in the aurora oval. FAC is from the SWARM mission. Swarm consists of three identical satellites. The three satellites are in a near-polar (87.5° inclination) orbit at an altitude of about 500 km. Based on the magnetic field measurements, SWARM can provide the product of the FAC with the assumption that FAC current sheets are perpendicular to the flight direction.
2. Find the conjunctions between SWARM and PFISR. The criterion is as follows: (1) the latitude difference between the satellites and PFISR is less than 0.1 degree. The reason why we choose such strict criterion is that the FAC or the aurora arc can have very small spatial scales, e. g. less than 10 km. These small-scale structures are often smoothed out in previous studies, which leads to the inaccuracy in the empirical model. (2) the longitude difference between the satellite and PFISR is less than 2 degrees. The FAC or aurora arc usually expands zonally. Thus, the criterion can be slightly relaxed. We can have ~1500 conjunctions over all.

Then, all cases are divided into 4 sectors: dayside/night side and upward/downward. Dayside/night side is determined by the solar zenith angle (SZA). In the dayside, the solar radiation contribution is subtracted. The MLT distribution of all cases is shown in Figure 2. It is not evenly distributed, which may be related with the orbits of the satellites.

Results

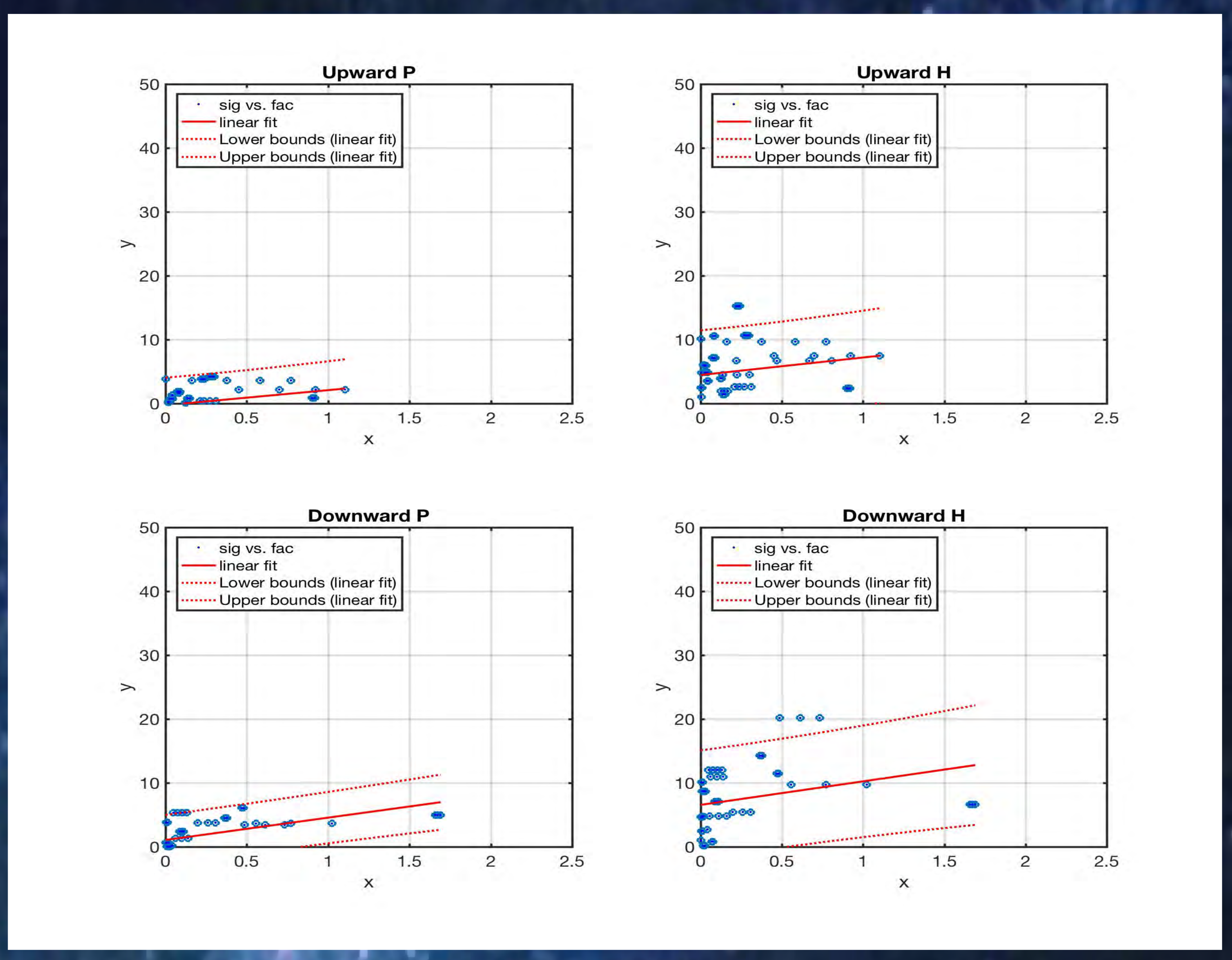

Figure 3. Relation between FAC (x axis) and conductance (y axis) on the day side.

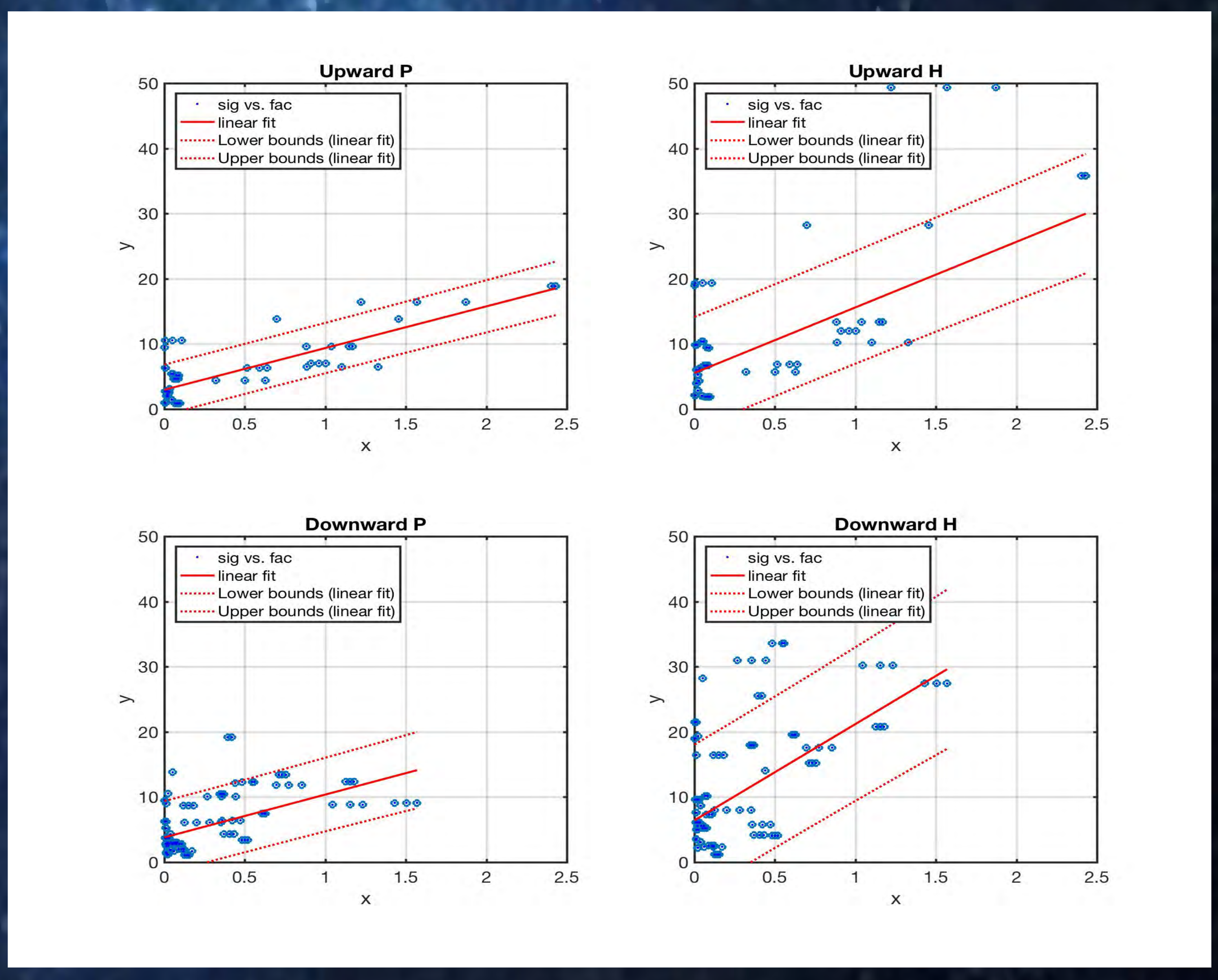

Figure 4. Relation between FAC (x axis) and conductance (y axis) on the night side.

Discussions

The results for the day side are shown in Figure 3. We first use a linear function to fit all the points. The red solid line is the fitting result and the dashed line represents the upper and lower boundary when the confidence level is larger than 90%. The conductance is almost a constant and does not change a lot with the FAC. The may be due to the inaccurate estimation of the solar radiation contribution. We also use other functions to fit the data points, such as exponential, power law. However, linear function does the best job.

The results for the night side are shown in Figure 4. We use the same method to fit the data as mentioned above. The covariance coefficients between upward FAC and Pederson/Hall conductance are 0.87 and 0.88 respectively. It is clear that there is a strong linear relation between upward FAC and conductance on the night side. However, relation is less clear for downward FAC (covariance coefficients ~0.6). The strong relation with upward FAC may be due to the close relation between upward FAC and electron precipitation. The relation can be written as $\Sigma_P = 6.216 J_\uparrow + 3.33$ and $\Sigma_H = 13.26 J_\uparrow + 5.80$ respectively (as shown in Table 1).

Based on Table 1, we build a new empirical model of the conductance. With the AMPERE FAC as input, a map of the conductance can be achieved (Figure 5 top). Solar radiation contribution is also added on the dayside. It is also compared with the SWMF RIM conductance distribution (Figure 5 bottom). Fine conductance structures are captured in our results.

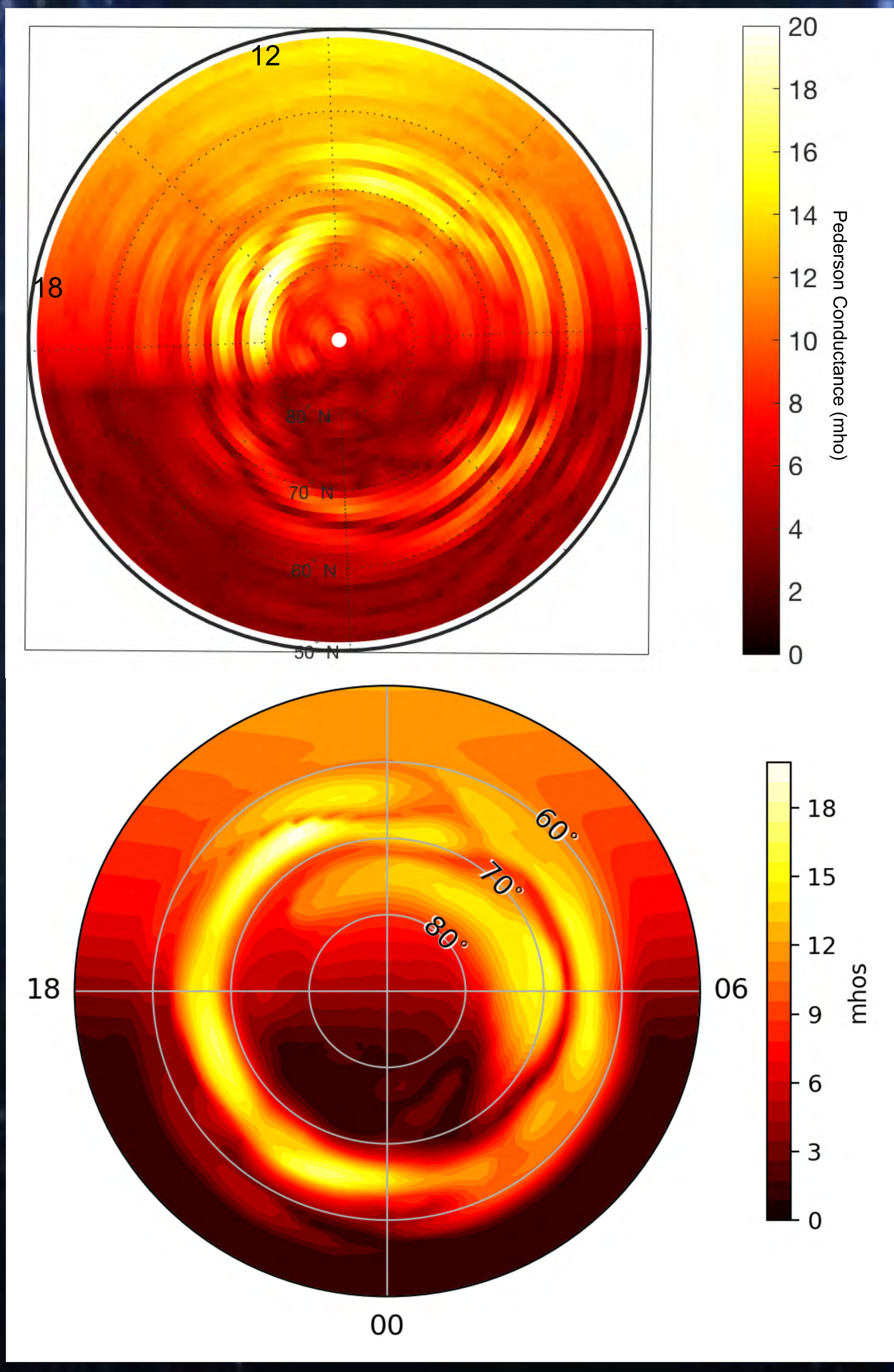

Figure 5. Pederson conductance distribution based on AMPERE FAC distribution and SWMF simulation on Sep 7, 2017 at 11UT.

Future Work

1. Add more cases to the statistical study.
2. Combine more ISR e.g. RISR
3. With more case, get the parameters for different MLT and MLAT.
4. Put the new conductivity model into global MHD simulation and compare with observations.