Conductance Models in CCMC SWMF v2021

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Outline

- COMPASS: a new COnductance Model based on PFISR And SWARM Satellite observations
- Empirical Conductance models available at CCMC SWMF

Motivation

- Develop a new conductance model to improve the ionospheric electrodynamic (IE) module within the Space Weather Modeling Framework (SWMF).

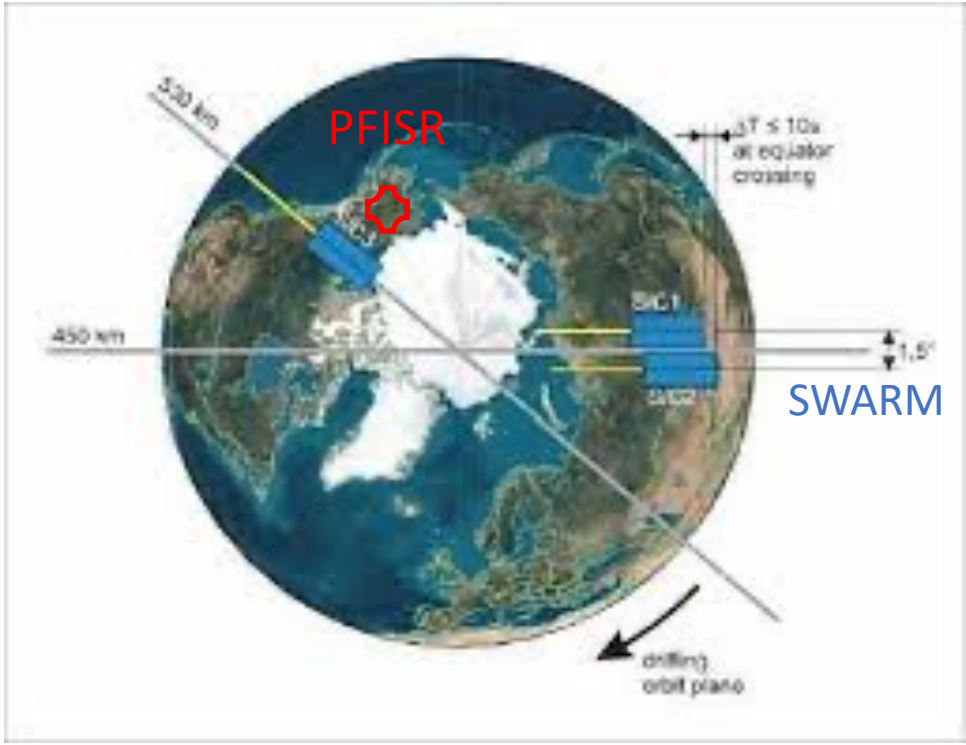
Conductance=f(FAC, MLT, …)

- Previous: FAC and conductance are both based on AMIE inversion technique.
- Now: FAC and conductance are from simultaneous observations from SWARM and PFISR.

Wang, Z., & Zou, S. (2022). COMPASS: A new COnductance Model based on PFISR And SWARM Satellite observations. *Space Weather*, 20, e2021SW002958. https://doi.org/10.1029/2021SW002958

Build the dataset

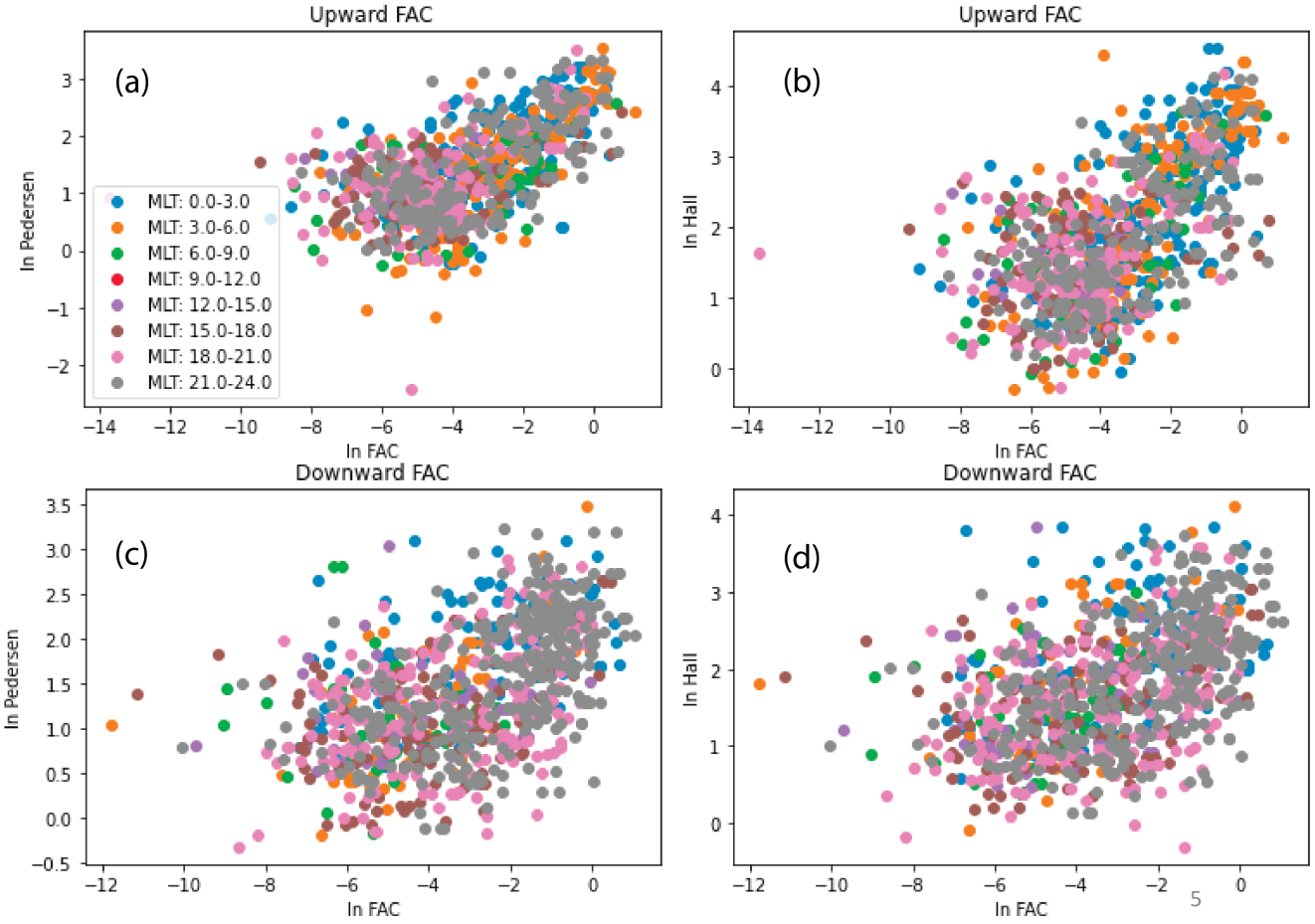
- FACs are from SWARM.
- Conductances are calculated using electron densities from PFISR.
- Definition of conjunctions between PFISR and SWARM: Δlon<4°, Δlat<0.075°
- Conjunctions between 2014 and 2020: ~3900



Data source: https://amisr.com/amisr/ and https://vires.services/

Overview of all conjunctions

- There is a power law relationship between FACs (both upward and downward) and conductance.



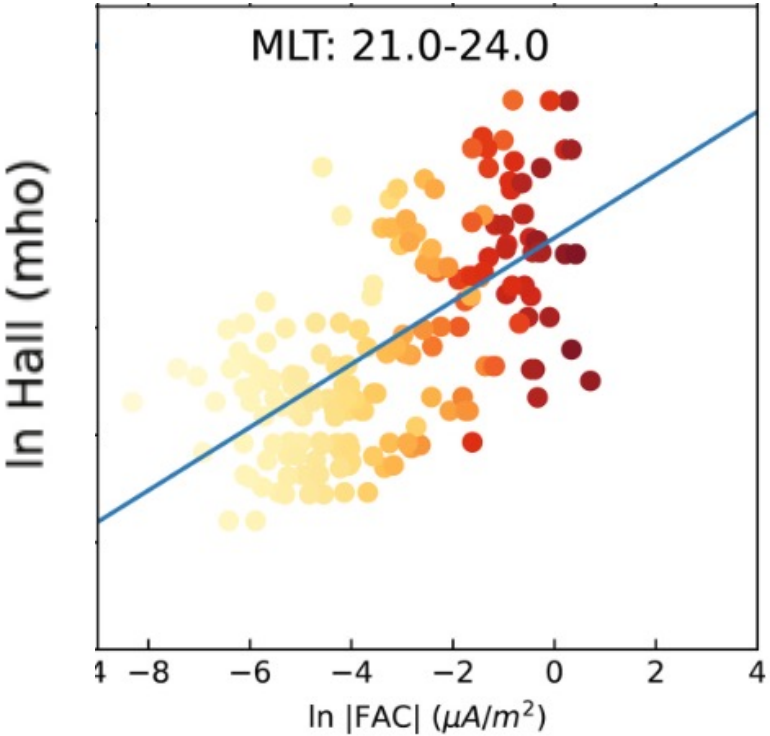
Fitting Technique

Weighted Least Square is used to fit:

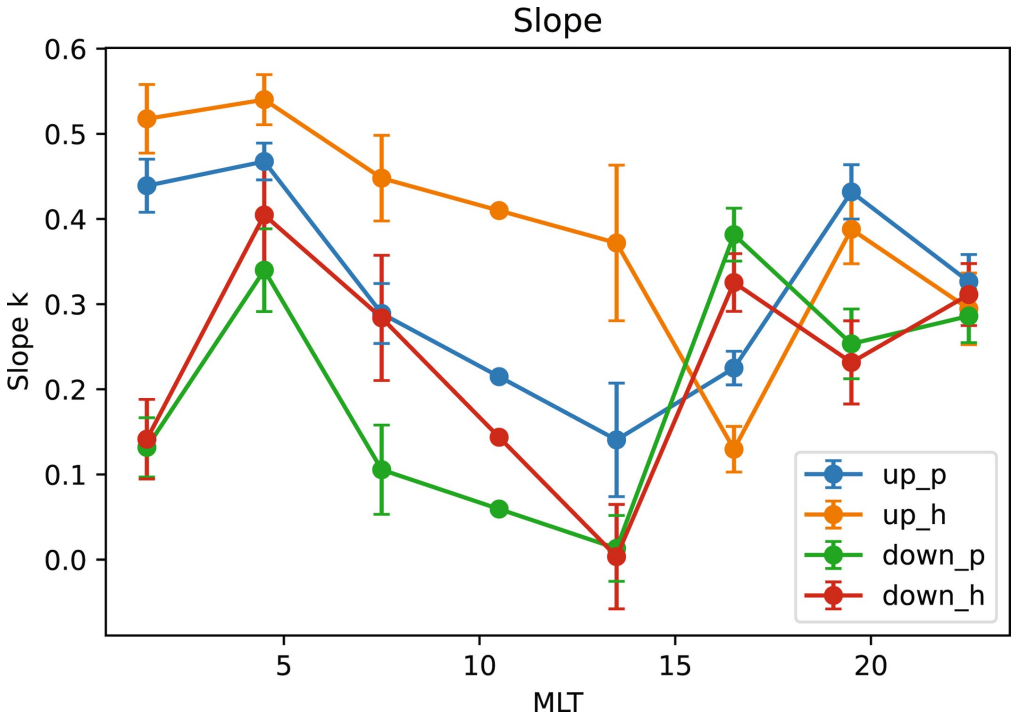
$$\Sigma_{P\ or\ H} = c|J_{//}|^{a},$$

where a and c are parameters depending on MLT and polarity of FAC.

More weights are given to larger FAC and conductance.



Discussions: MLT dependence of fitting parameters

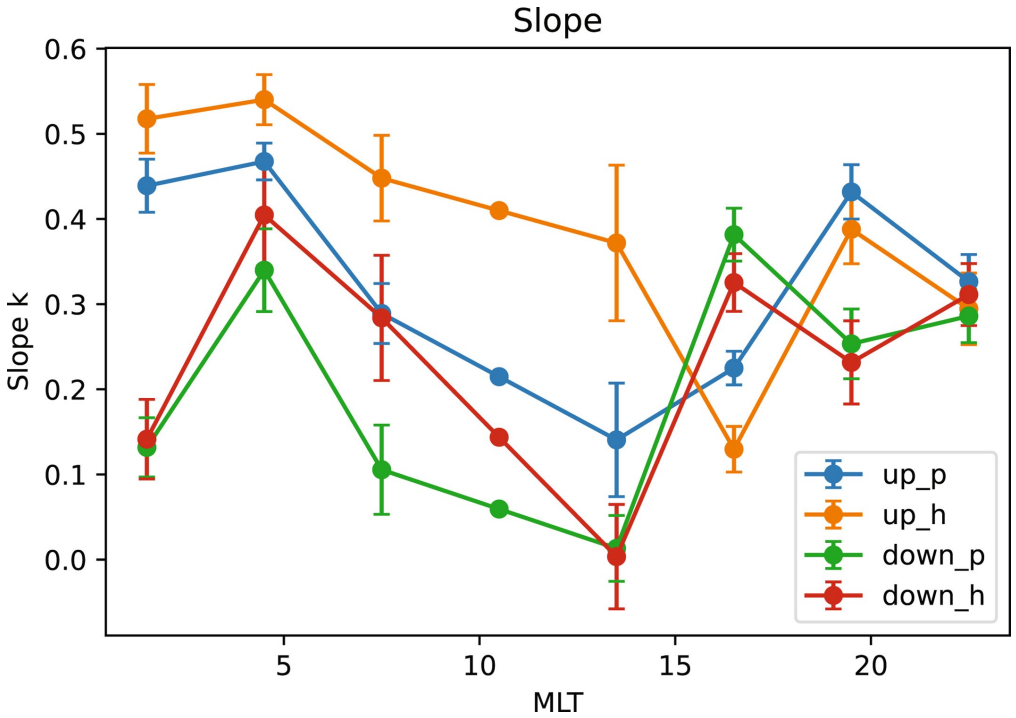


Dayside v.s. nightside

Slopes are larger on the nightside.

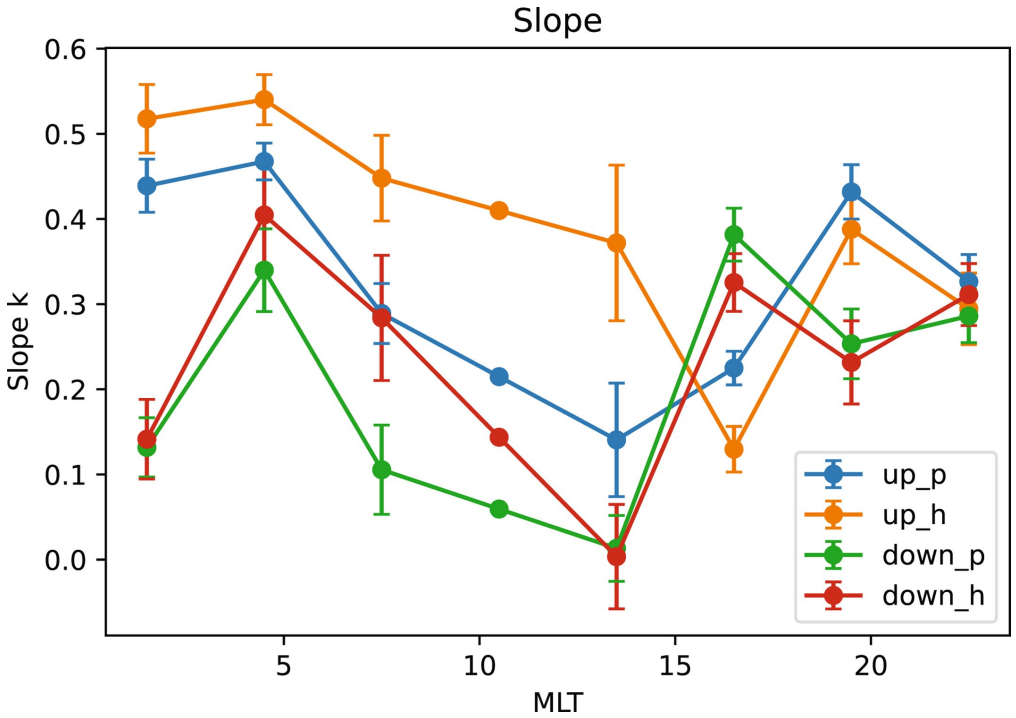
Larger average energy of precipitation electrons on the nightside, producing larger conductance, even if FACs are the same.

Discussions: MLT dependence of fitting parameters



Upward vs downward FACs: The slopes of upward FACs are larger, except dusk side. Downward FACs are carried by proton precipitation on the dusk side.

Discussions: MLT dependence of fitting parameters



Hall vs Pedersen:

The slopes of Hall conductance are larger than those for Pedersen, except dusk side.

All features agree with previous findings.

Takeaways

- Conductance varies as a power of FACs, and the power indices for different MLTs are between 0 and 0.6.
- Both upward and downward FACs are positively correlated with both Hall and Pedersen conductances.
- Power indices are larger on the nightside.
- The slopes of upward FACs are larger than downward FACs, except dusk side.
- The slopes of Hall conductance are larger than those of Pedersen, except dusk side.

Outline

1. COMPASS: a new COnductance Model based on PFISR And SWARM Satellite observations
2. New conductance models available in CCMC SWMF v2021

FAC-driven Model List

- Ridley Legacy Model (Ridley et al, 2004)
- Conductance Model for Extreme Events (Mukhopadhyay et al, 2020)
- ADELPHI (Robinson et al, 2020)
- COMPASS (Wang et al, 2022)

FAC-driven conductance is later combined with conductance driven by F10.7.

- Ridley Legacy Model (RLM)

$$\Sigma_{HorP} = A_0 - A_1 e^{-A_2^2 |J_{\parallel}|}$$ Inverse-exponential

A_0, A_1, A_2 depend on MLT, MLAT, and direction of FAC. $J_{//}$ and Σ are from AMIE.

- Conductance Model for Extreme Events (CMEE)

The formula is same as RLM. CMEE uses AMIE data in 2003, while RLM used AMIE data in January 1997, a relatively quiet month.

- ADELPHI

$$\Sigma_{P\ or\ H} = b + k|J_{//}|,$$

k and b are parameters depending on MLT and polarity of FAC. $J_{//}$ are from AMPERE and Σ are from PFISR. During storm time.

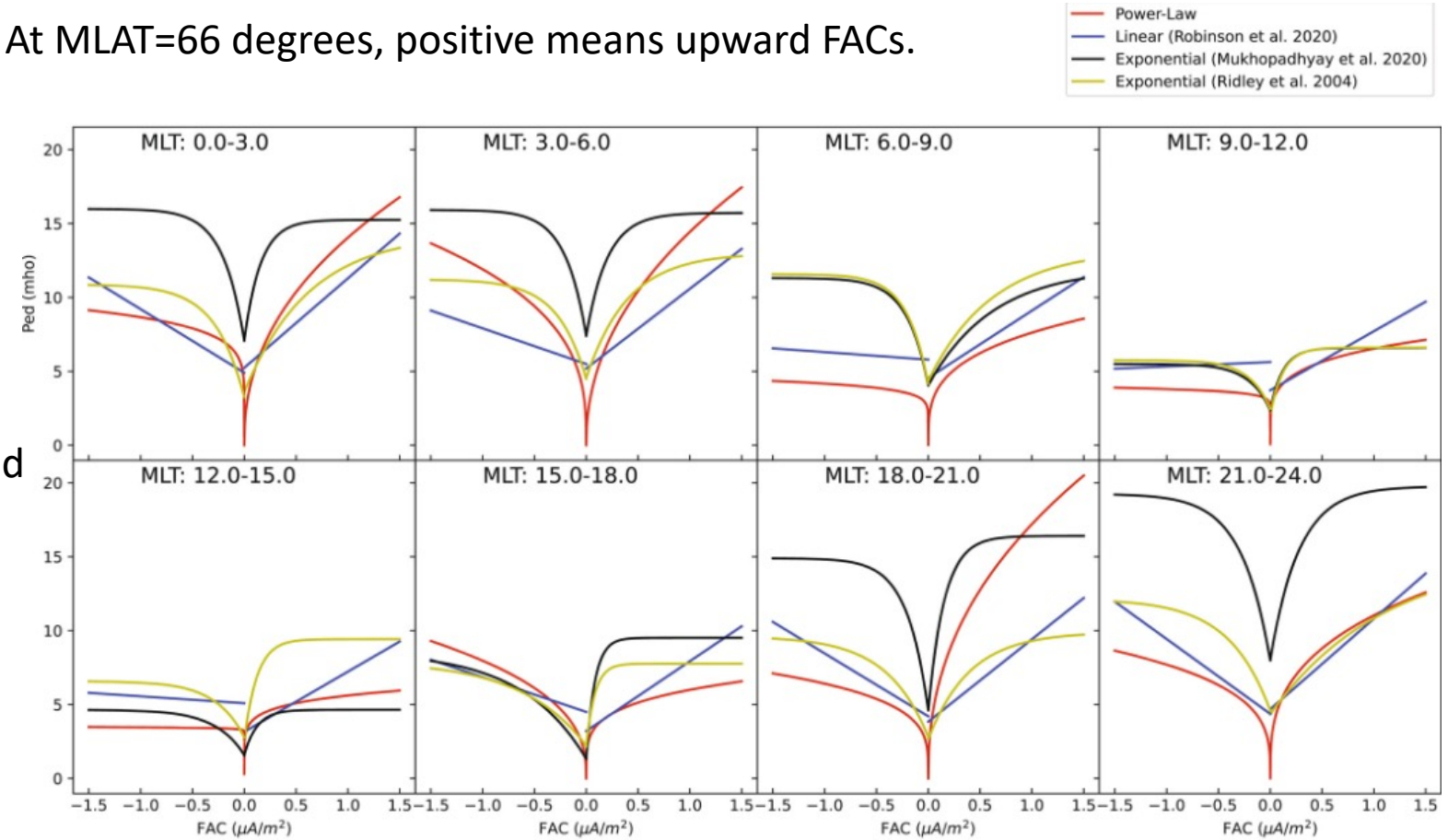
- COMPASS

$$\Sigma_{P\ or\ H} = c|J_{//}|^{a},$$

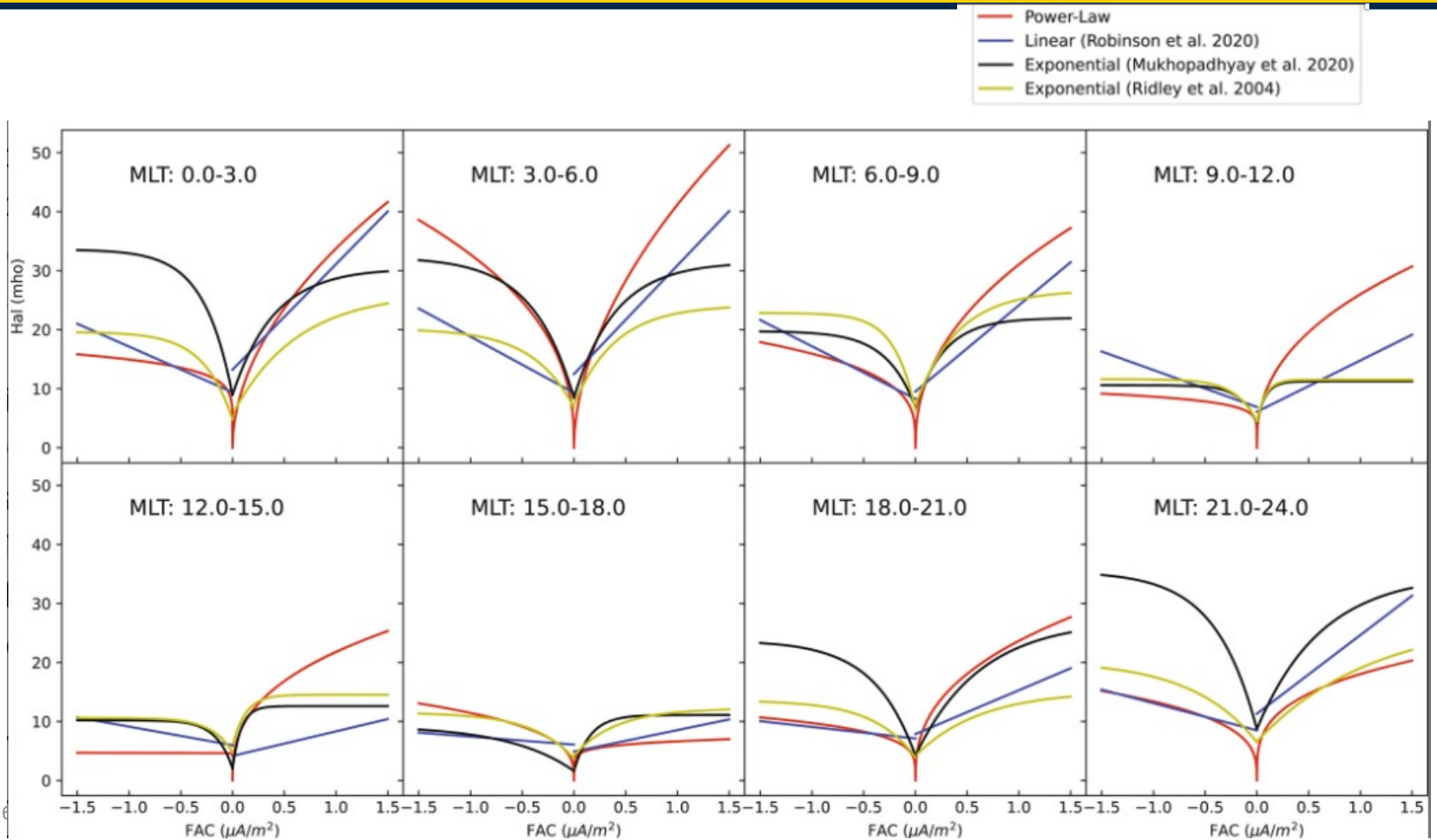
a and c are parameters depending on MLT and polarity of FAC. $J_{//}$ are from SWARM and Σ are from PFISR.

At MLAT=66 degrees, positive means upward FACs.

Ped



Hall


Power-Law
Linear (Robinson et al. 2020)
Exponential (Mukhopadhyay et al. 2020)
Exponential (Ridley et al. 2004)
MLT: 0.0-3.0
MLT: 3.0-6.0
MLT: 6.0-9.0
MLT: 9.0-12.0
MLT: 12.0-15.0
MLT: 15.0-18.0
MLT: 18.0-21.0
MLT: 21.0-24.0
Hal (mho)
FAC (μA/m²)

- Due to the different choices of functional forms, the differences among these models increase for larger FACs, for example, during intense or super storms.
- Assessment efforts on their performances and impacts are underway.
- A diverse set of conductance models offer ensemble forecast opportunity with uncertainty quantification.

Bonus: A more flexible constant conductance model

Northern and Southern hemisphere can have different constant conductance.

e.g., $\Sigma_P = 5S$ in the northern hemisphere, and $\Sigma_P = 1S$ in the southern hemisphere.

Takeaways

More conductance models will be/are available in SWMF Run on Request at CCMC.

- Ridley Legacy Model (Ridley et al, 2004)
- COMPASS. (Wang et al, 2022)
- Conductance Model for Extreme Events (Mukhopadhyay et al, 2020).
- ADELPHI (Robinson et al, 2020).
- A more flexible constant conductance model. Should be good to study hemispheric asymmetry.