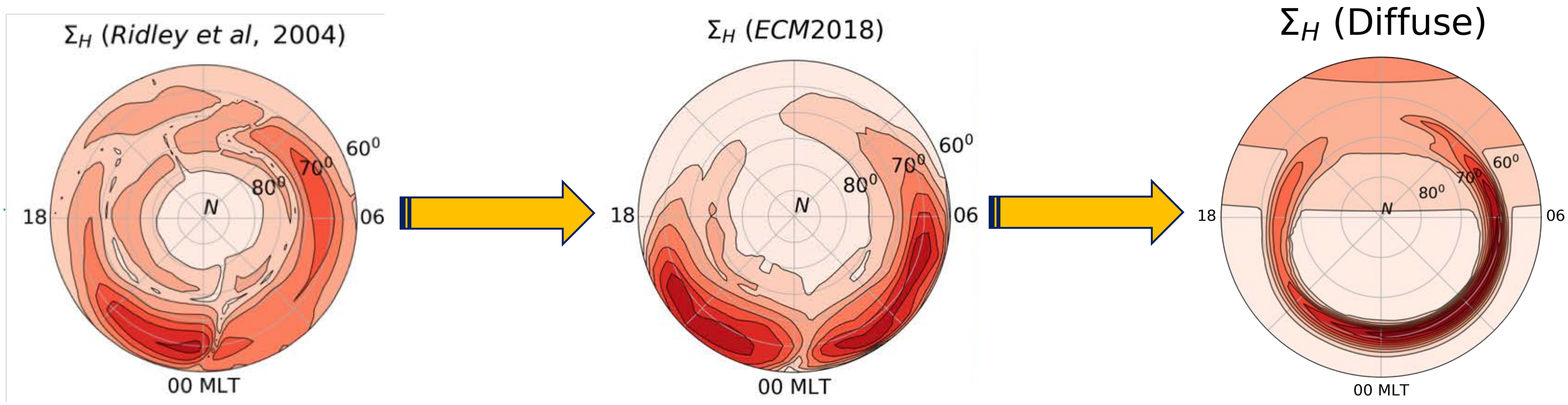
Ionospheric Conductance From the Magnetospheric Perspective



Agnit Mukhopadhyay, Aaron Ridley

& Daniel Welling, Michael Liemohn, Meghan Burleigh

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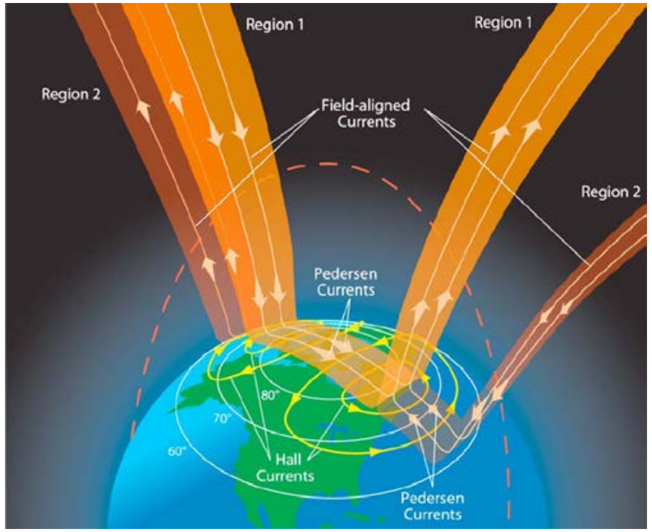
Outline

- Why does (the background) conductance matter?
- How does structure in the conductance drive structure in the potential?
- How does the SWMF specify the auroral conductance now?
  - How can we improve this a bit?
- How does/should the SWMF specify the auroral conductance?

Why does (the background) conductance matter?



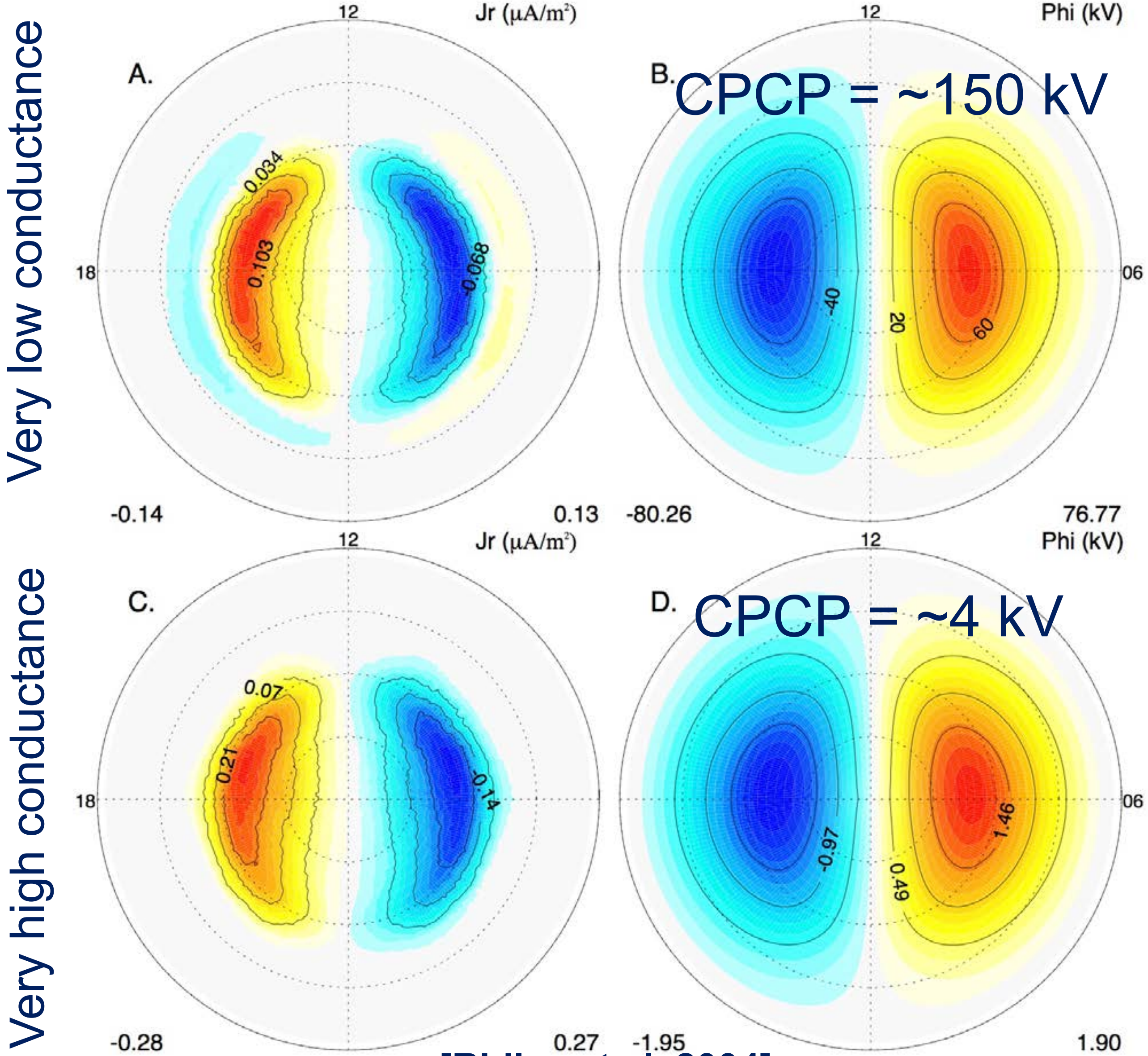
Field-aligned current — Conductance — Potential

$$j_R(R_I) = [\nabla_\perp \cdot (\Sigma \cdot \nabla \psi)_\perp]_{R=R_I}$$

- If you let the field-aligned current be constant, if the conductance goes up, then the potential must go down.

Potential vs Conductance

- When the conductance is low the potential is very high
- When the conductance is high the potential is very low



[Ridley et al. 2004]

Potential vs Conductance

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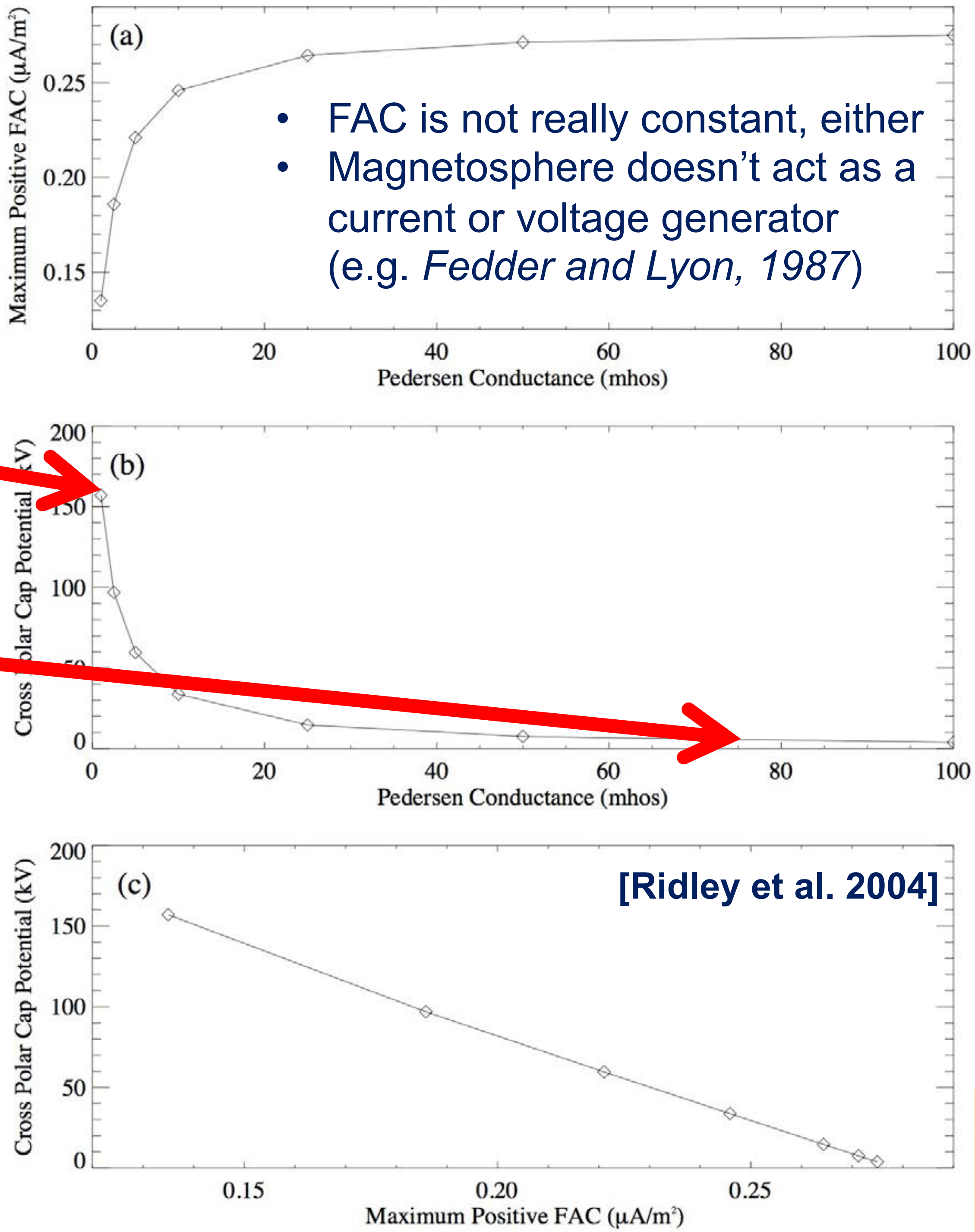
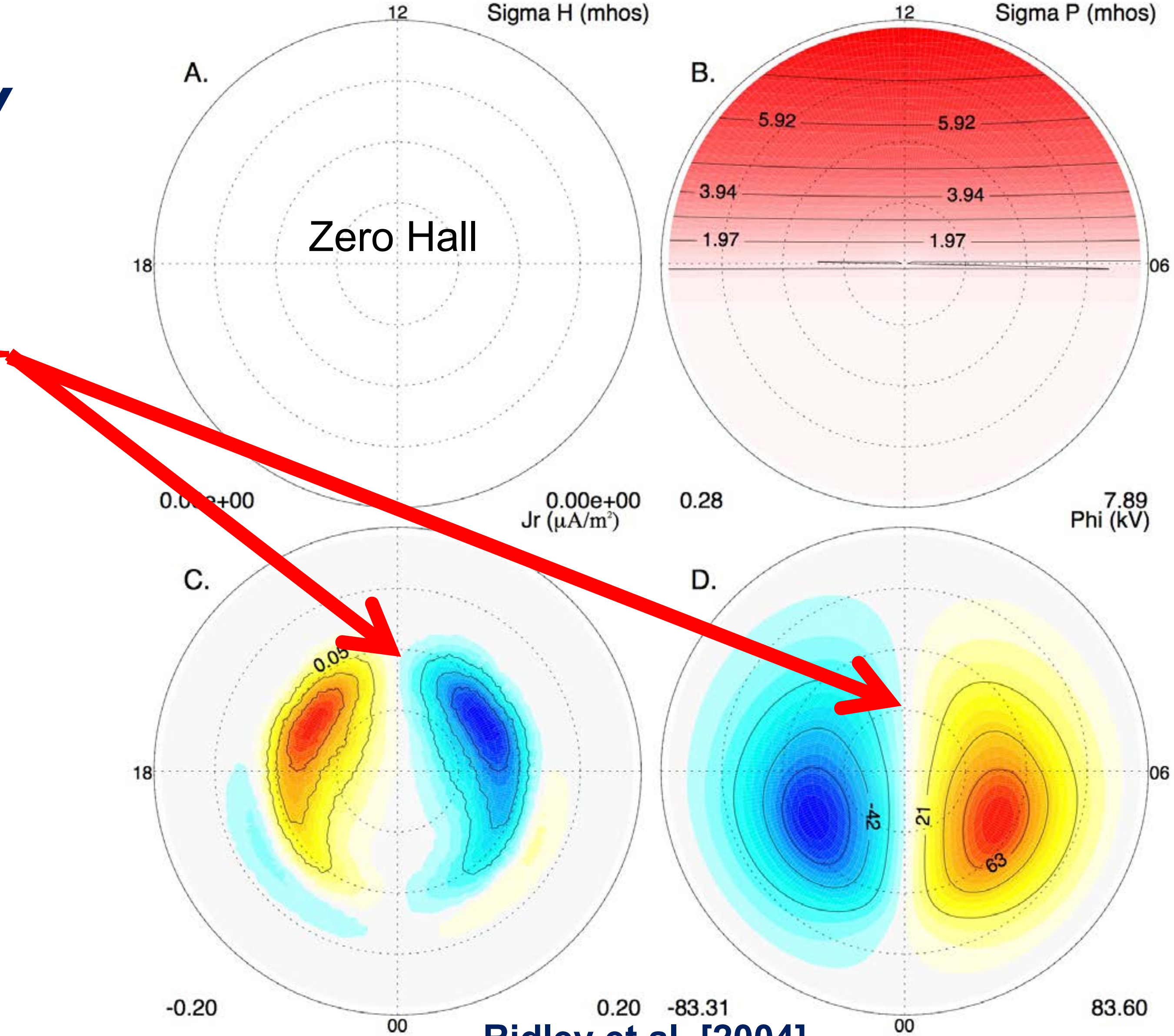


- FAC is not really constant, either
- Magnetosphere doesn't act as a current or voltage generator (e.g. *Fedder and Lyon, 1987*)

[Ridley et al. 2004]

Dayside Solar EUV

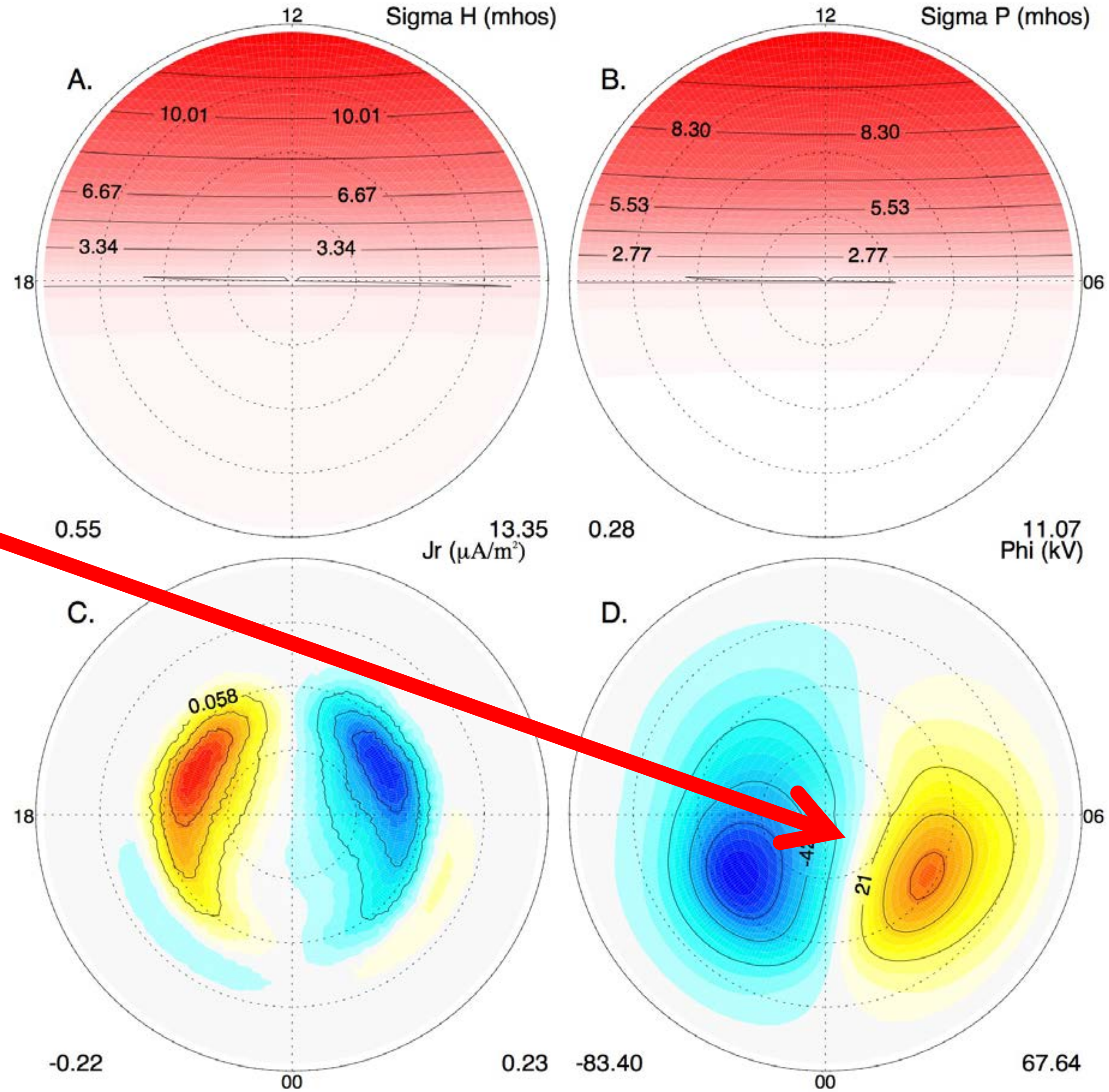
- Strong conductance on dayside, allows currents to flow on the dayside, pushes potential nightward.



Ridley et al. [2004]

Hall Conductance Gradient

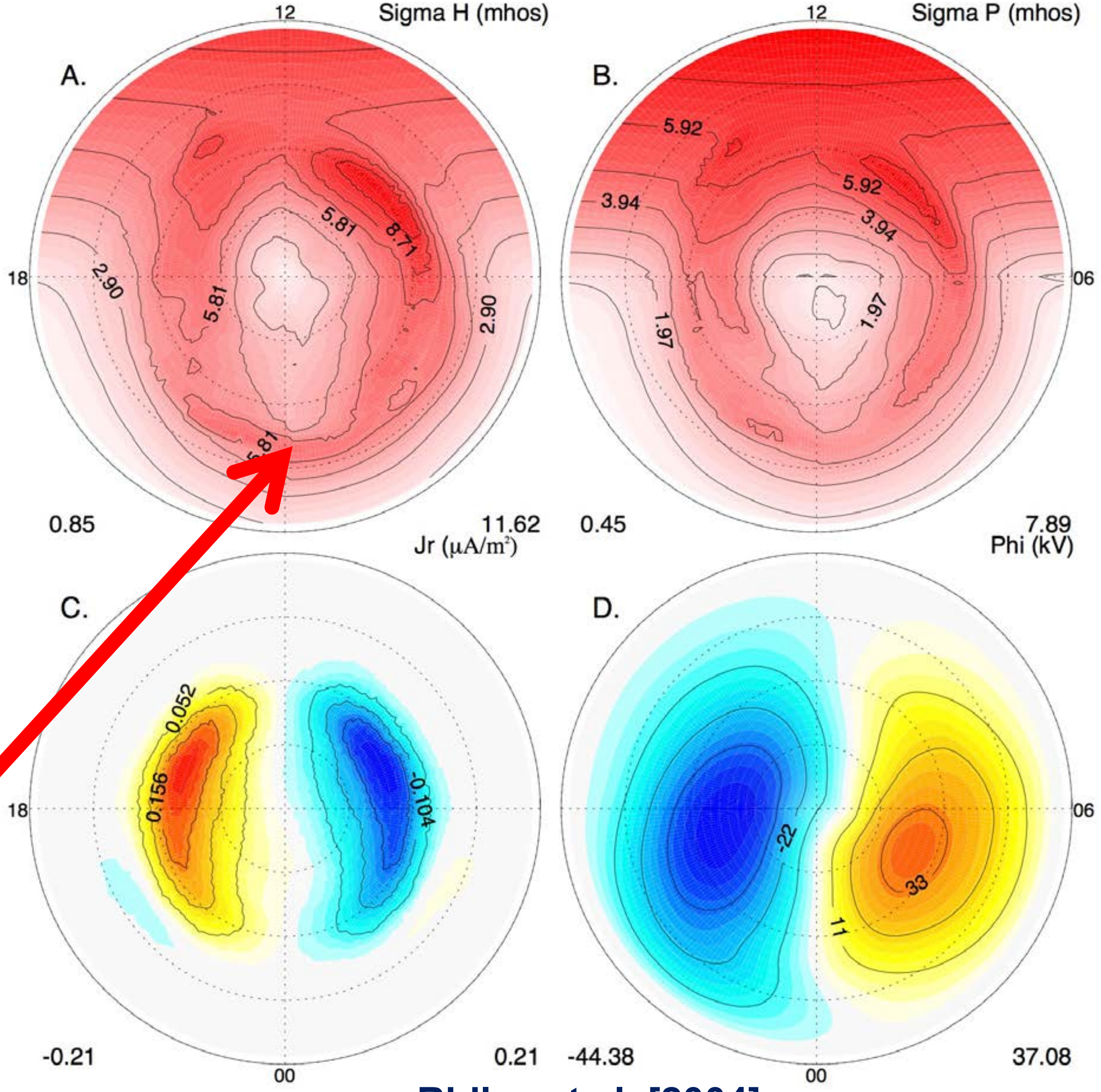
- Hall conductance gradients drives an electric field, that causes asymmetries in the potential pattern



Ridley et al. [2004]

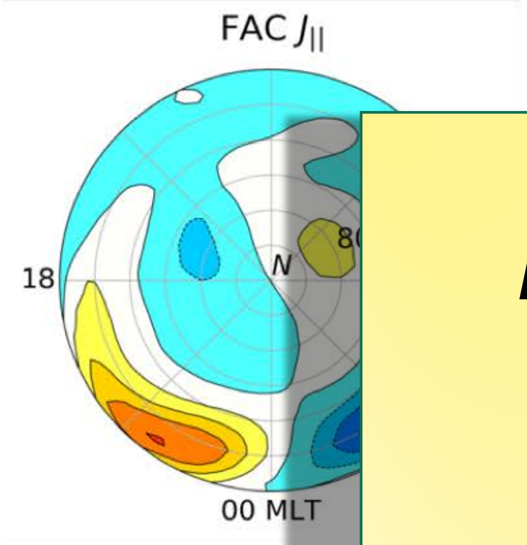
Adding an Aurora

- Aurora adds conductance on the nightside.
- Potential spreads back towards the dayside.
- Potential is distorted. Aurora is so washed out, that the potential is not strongly distorted.
  - No Harang Reversal



Ridley et al. [2004]

Auroral Conductance in SWMF

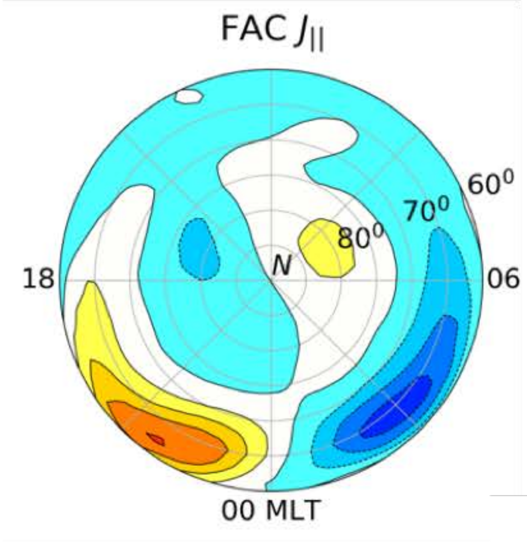


Data Question: Is one month of data enough to model extreme events?

Physics Question: Why not include physics in calculating the aurora?

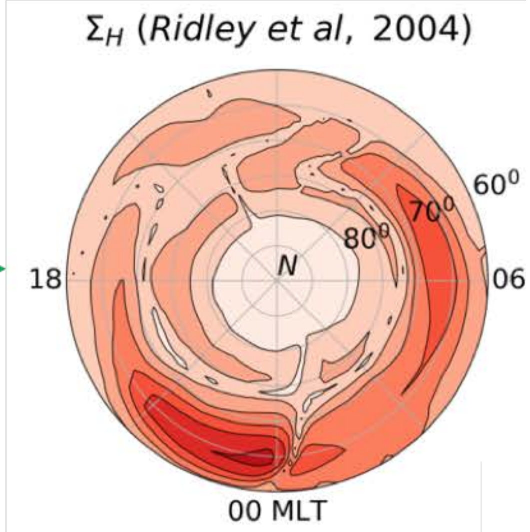
- SWMF use ls to be known.
  [Goodman, 19
- AMIE Data for the month of **January 1997** used to create coefficients [*Ridley et al., 2004*].

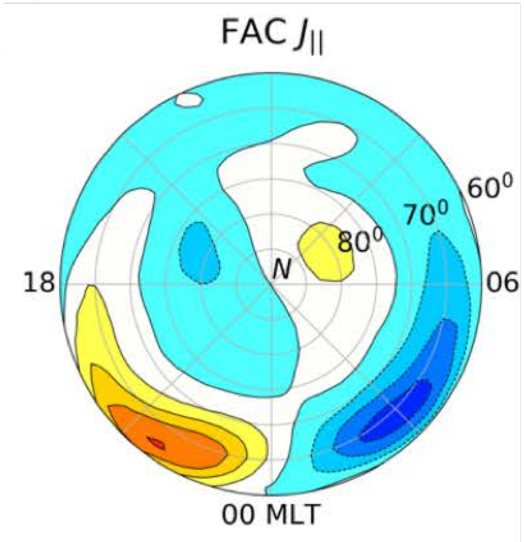
Auroral Conductance in SWMF



$$\Sigma = \Sigma_0 e^{-AJ_{\parallel}}$$

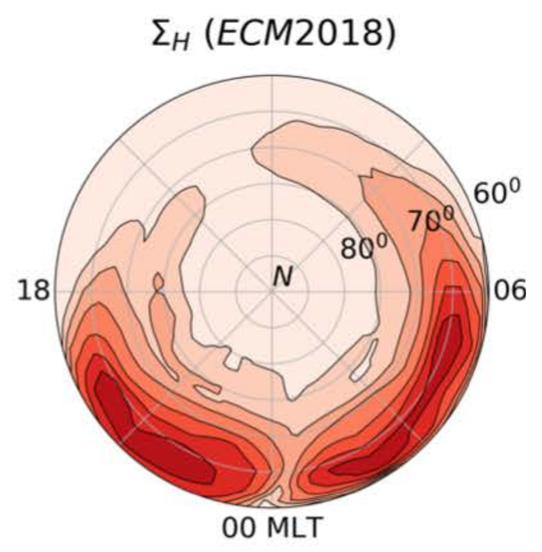
Fitted from **1 month** of **AIMIE mappings (January, 1997)**



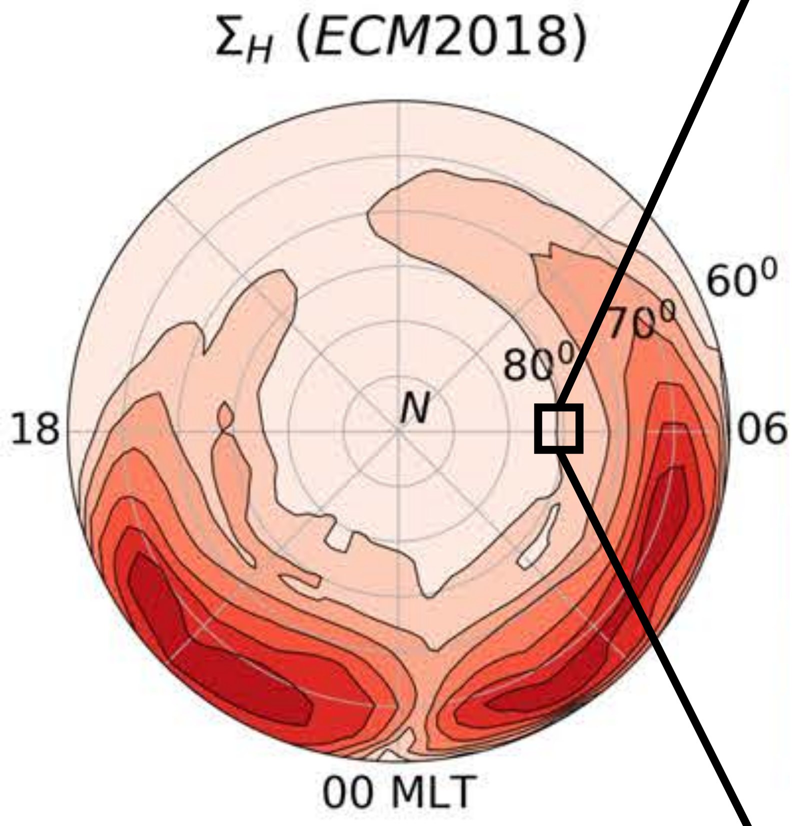


$$\Sigma = A_0 - A_1 e^{-AJ_{\parallel}}$$

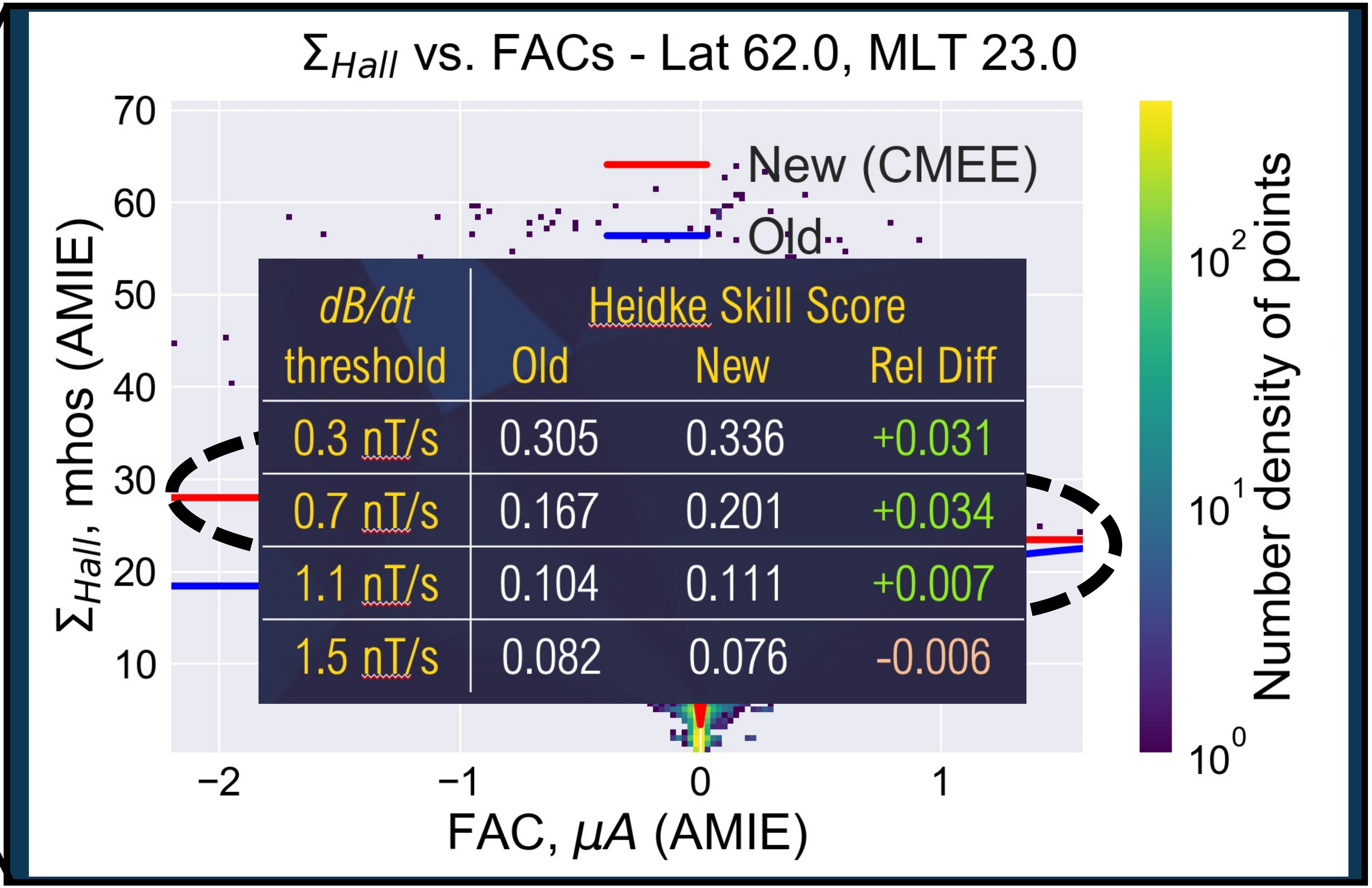
Fitted from **1 year** of **AMIE mappings (Whole year of 2003)**



Mukhopadhyay et al. [in prep]

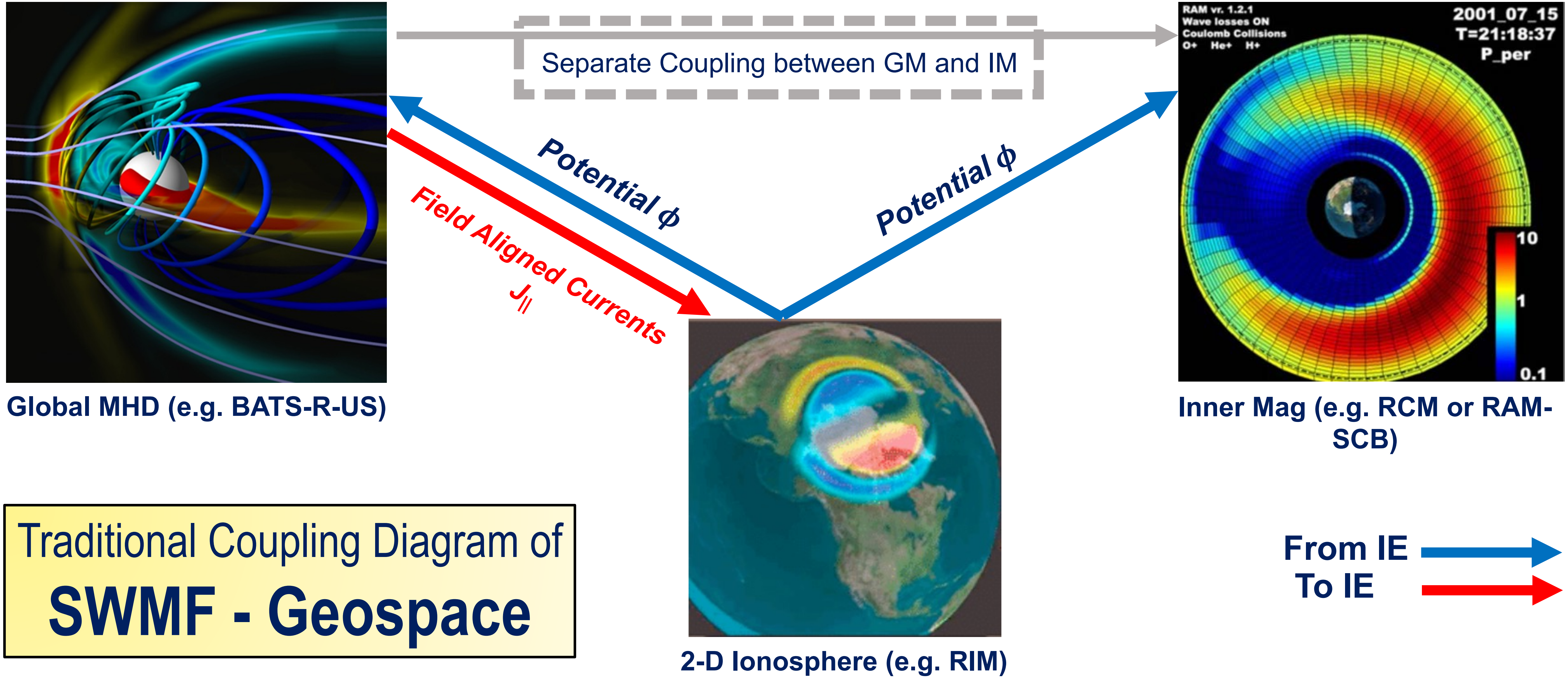


Mukhopadhyay et al. [in prep]



dB/dt threshold	Heidke Skill Score Old	Heidke Skill Score New	Heidke Skill Score Rel Diff
0.3 nT/s	0.305	0.336	+0.031
0.7 nT/s	0.167	0.201	+0.034
1.1 nT/s	0.104	0.111	+0.007
1.5 nT/s	0.082	0.076	-0.006

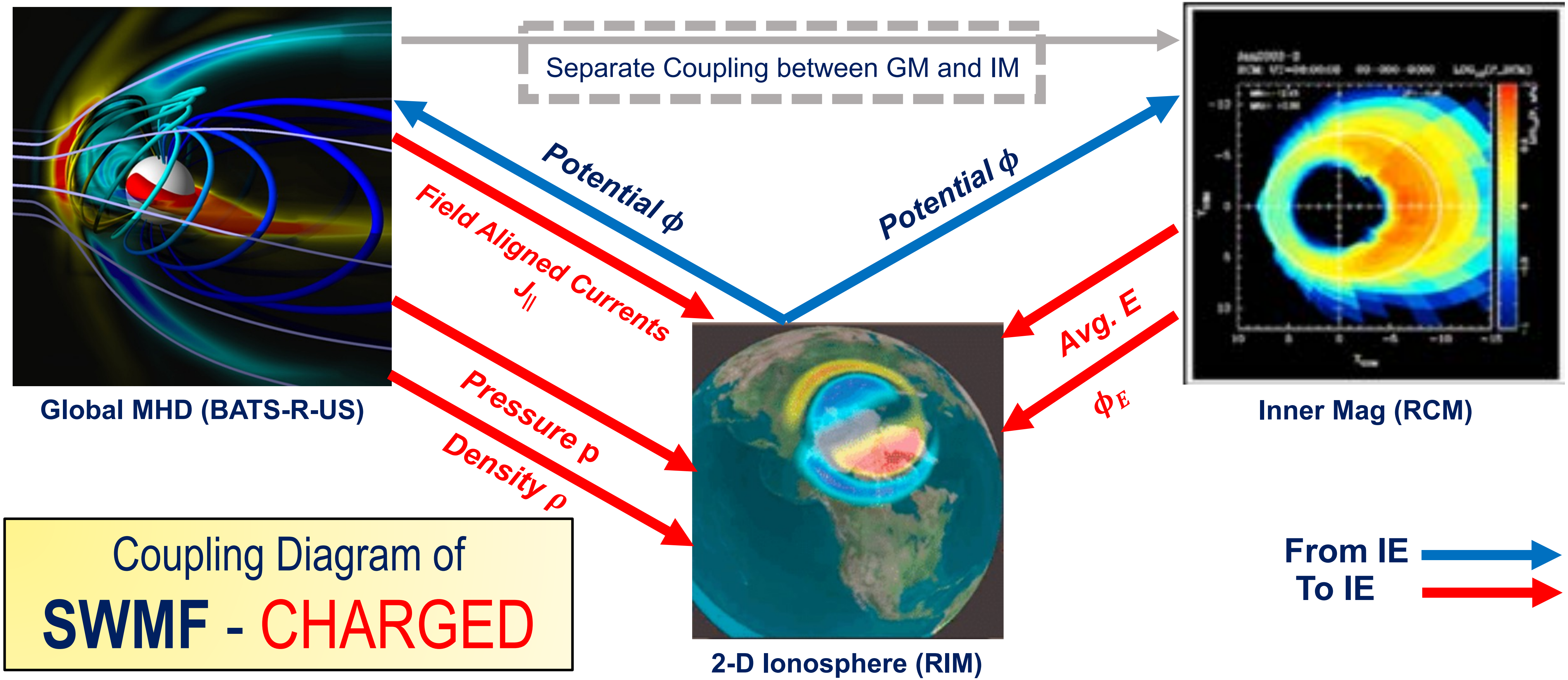
Adding Physics into the Aurora



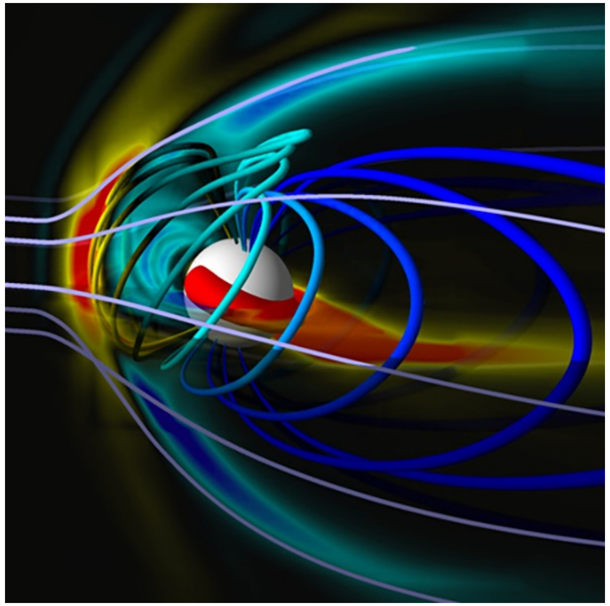
Traditional Coupling Diagram of

SWMF - Geospace

Adding Physics into the Aurora



Adding Physics into the Aurora



Global MHD (e.g. BATS-R-US)

SWMF - CHARGED

- Pressure and Density passed from MHD is used to calculate the Temperature: $P = nkT$
- Using the temperature, we find the diffuse number flux and energy flux for a given type of distribution function (e.g. *Gombosi, 1994*):

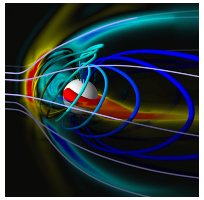
$$\phi_N = \int_0^{\infty} dv \int_0^{2\pi} d\varphi \int_0^1 d\mu \; \mu v^3 f(v)$$

$$\phi_E = \int_0^{\infty} dv \int_0^{2\pi} d\varphi \int_0^1 d\mu \; \mu v^3 \left(\frac{1}{2} m v^2\right) f(v)$$

We find the average energy of particles: $\bar{E} = \frac{\phi_E}{\phi_N}$

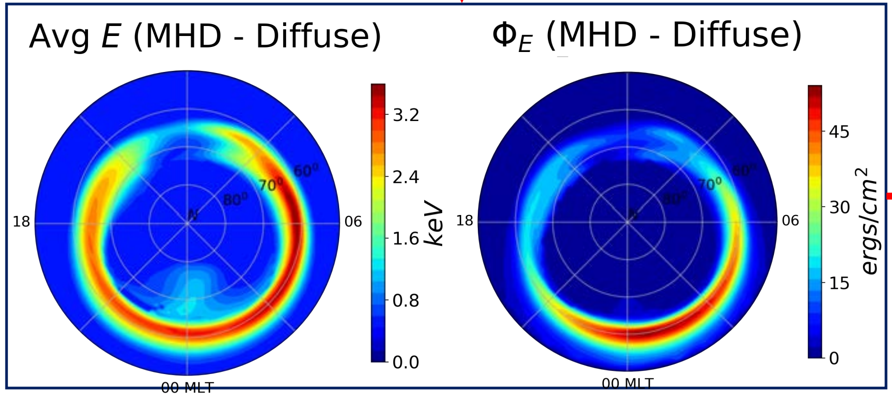
- A fraction of the total flux precipitates into the ionosphere. We assume this fraction from an empirical function (derived from *Wolf et al, 1991*).

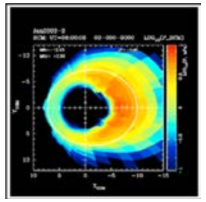
SWMF - CHARGED



Global MHD (BATS-R-US)

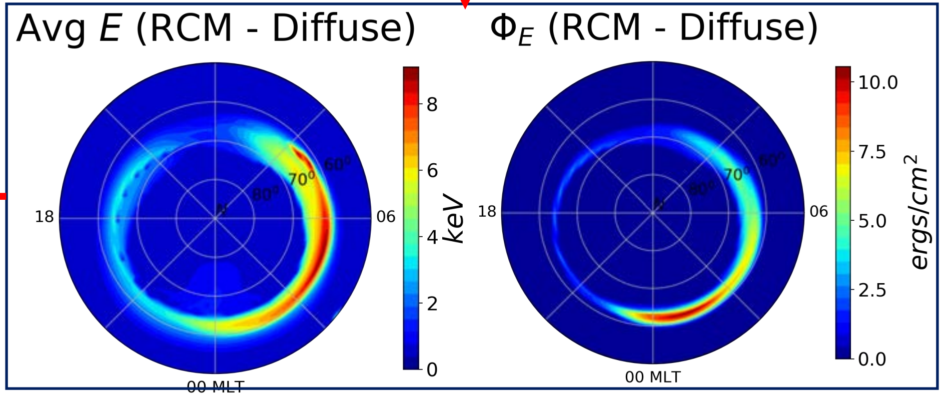
Kinetic Theory — *Assuming MB Distr.*



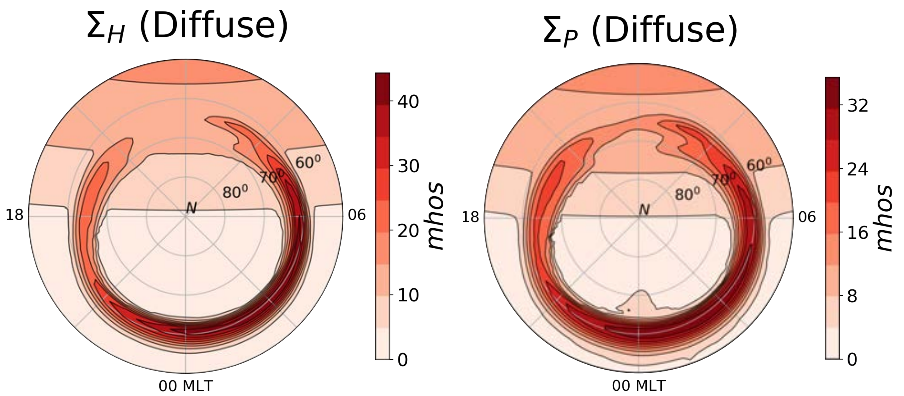


Inner Mag (RCM)

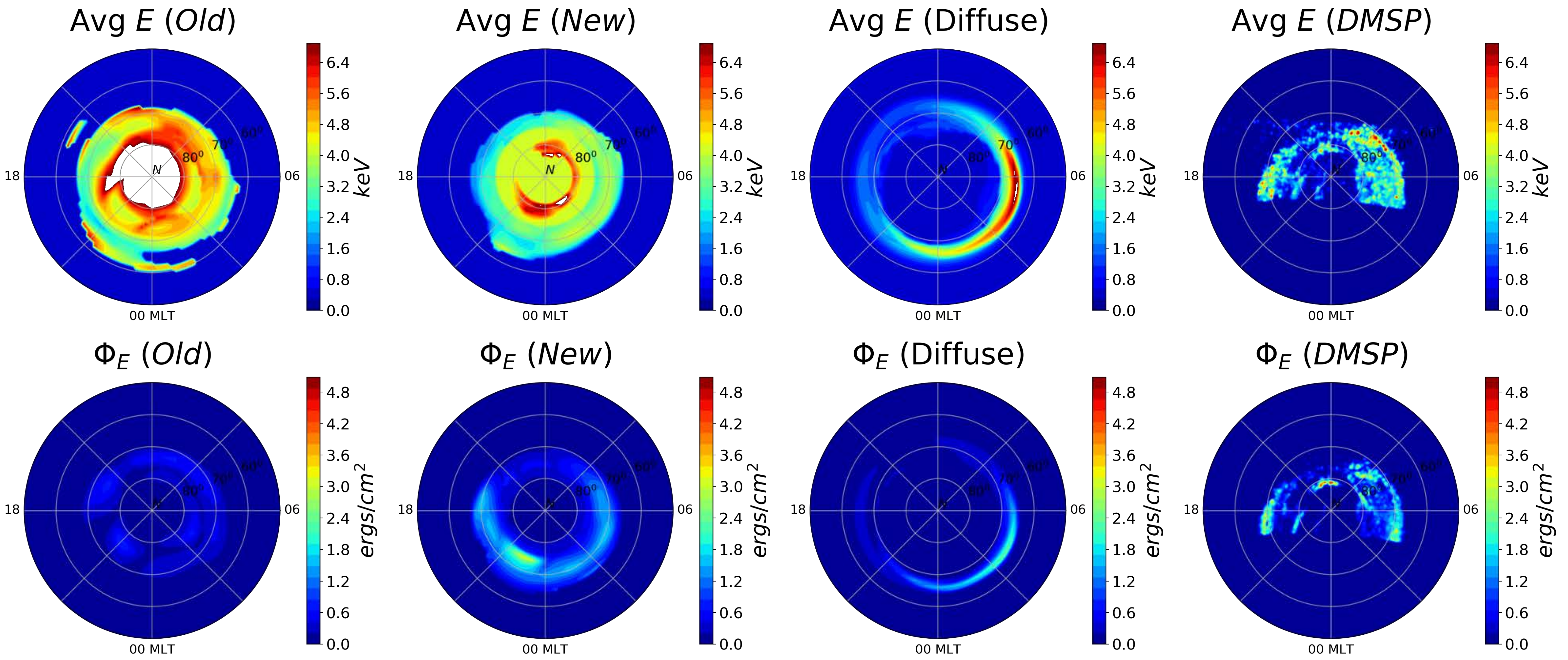
Precip Flux



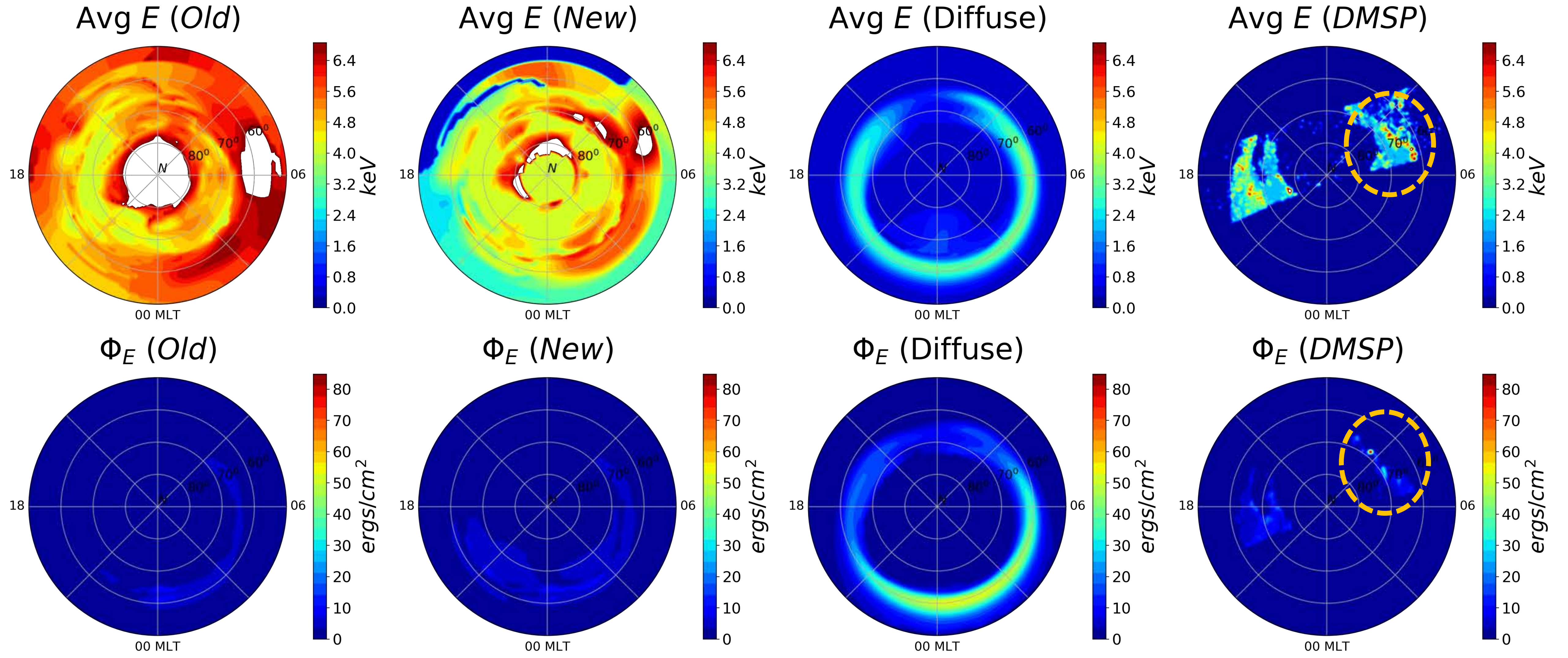
Robinson Relation



Case 1: March 2013 Event, 03/15/2013, 13:10 UT.



Case 2: April 2010 Event, 04/05/2010, 10:07 UT.



Long Road Ahead…

- Separate module to estimate **discrete precip** using *Knight [1973]* and *Freidman and Lemaire [1980]*, similar to *Wiltberger et al. [2009]*. Addition of **anomalous resistivity**.

- Distribution Function independent flux calculations. Usage of RAM-SCB, Two-Way Coupling with GITM

SWMF - CHARGED

- Coupling with additional SWMF components: Anisotropic MHD, PWOM

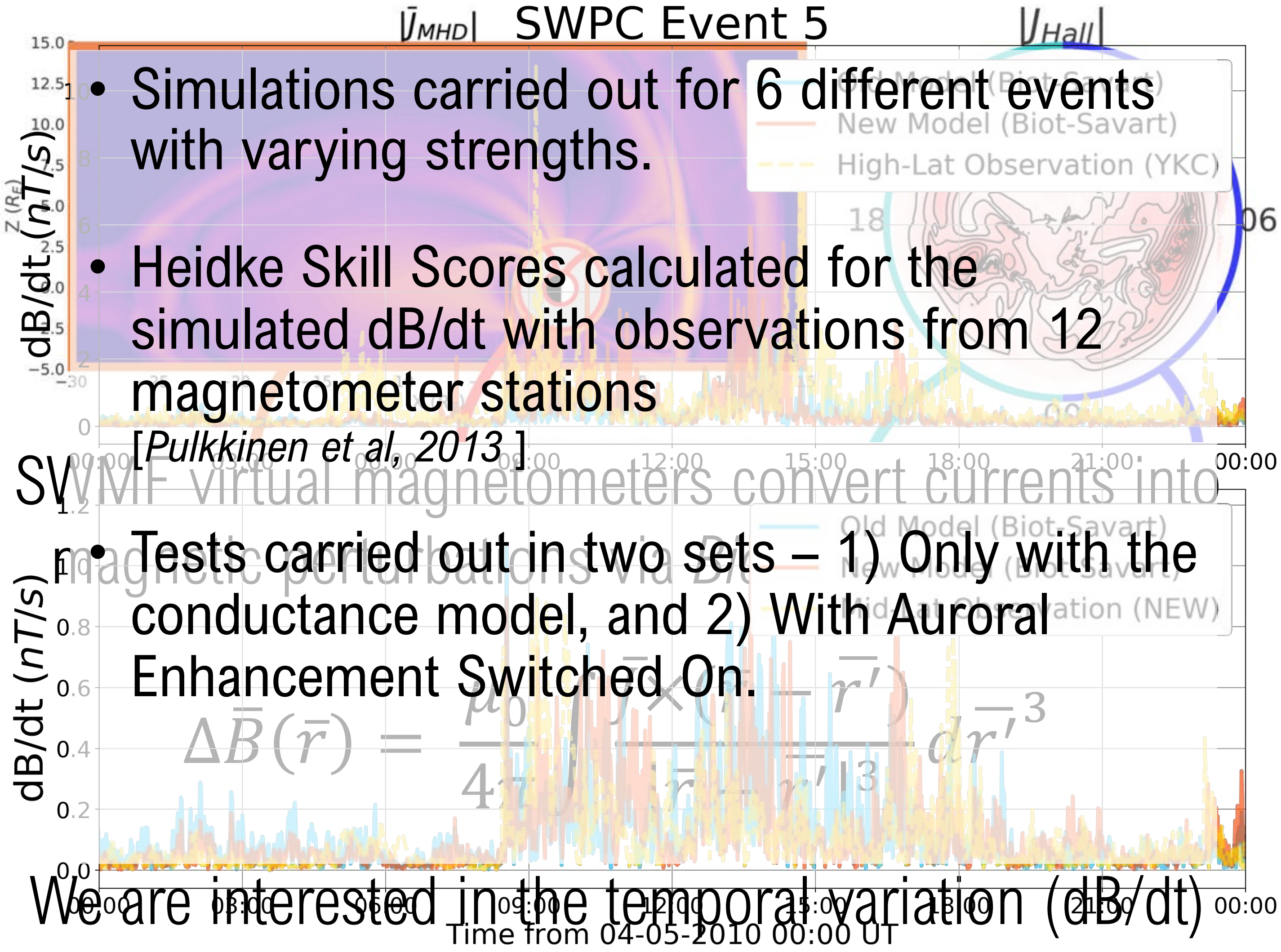
- Solutions from GM and IM need not be combined. IM solution to be used on closed field lines to maximum extent possible.

Thank You

Extra Slides

Do Space Weather Predictions Improve?

- Simulations carried out for 6 different events with varying strengths.
- Heidke Skill Scores calculated for the simulated dB/dt with observations from 12 magnetometer stations [Pulkkinen et al, 2013]
- Tests carried out in two sets – 1) Only with the conductance model, and 2) With Auroral Enhancement Switched On.



SWPC Event	Date/Time of Event	Min Dst
1	0600 UT 29 Oct, to 0600 UT 30 Oct, 2003	-353 nT
2	1200 UT 14 Dec, to 0000 UT 16 Dec, 2006	-139 nT
3	0000 UT 31 Aug, to 0000 UT 1 Sep, 2001	-40 nT
4	1000 UT 31 Aug, to 1200 UT 1 Sep, 2005	-131 nT
5	0000 UT 5 Apr, to 0000 UT 6 Apr, 2010	-73 nT
6	0900 UT 5 Aug, to 0900 UT 6 Aug, 2011	-113 nT

dB/dt threshold	Heidke Skill Score		
	Old	New	Rel Diff
0.3 nT/s	0.305	0.336	+0.031
0.7 nT/s	0.167	0.201	+0.034
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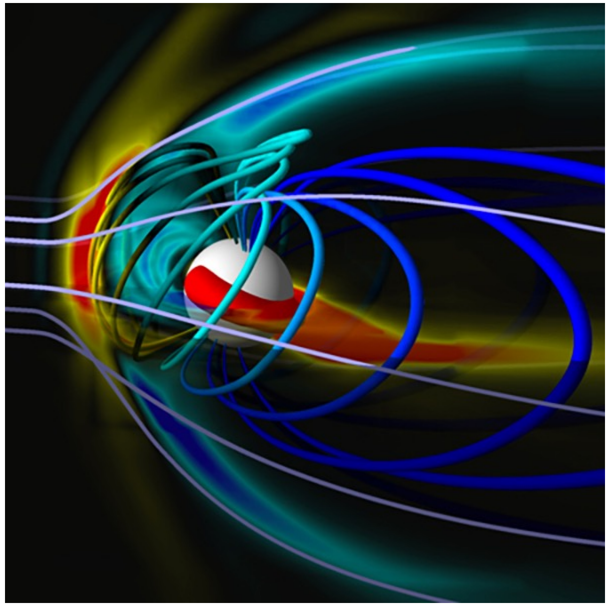
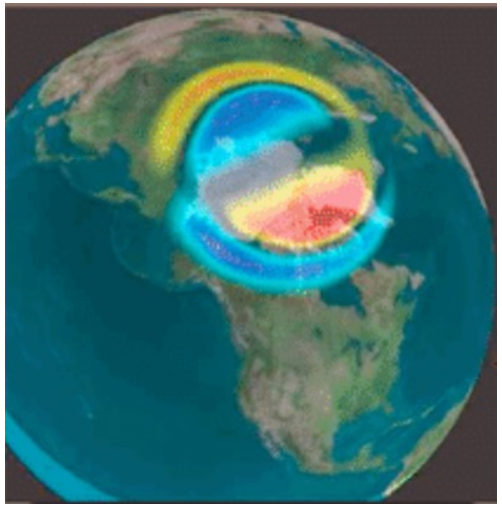
Adding Physics into the Aurora



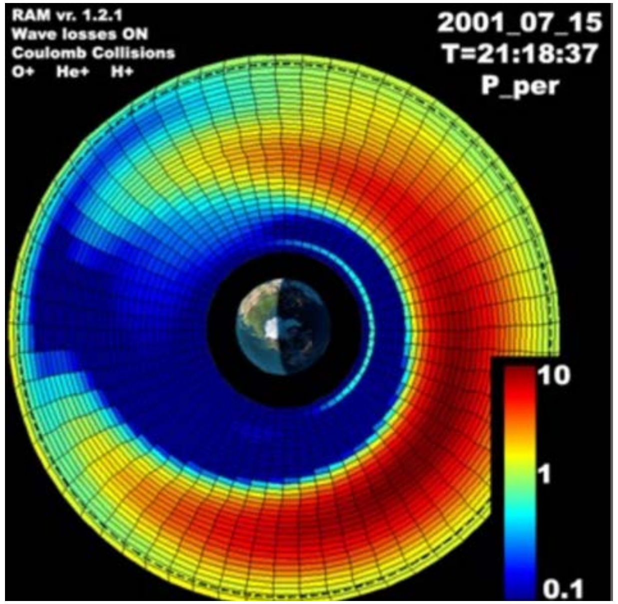
Global MHD (e.g. BATS-R-US)

- Produces hydrodynamic quantities of plasma – pressure, density, temperature.
- Global Picture is derivable.

- Calculates potential thru Ohm's Law
- Inputs – Field Aligned Currents, Conductance



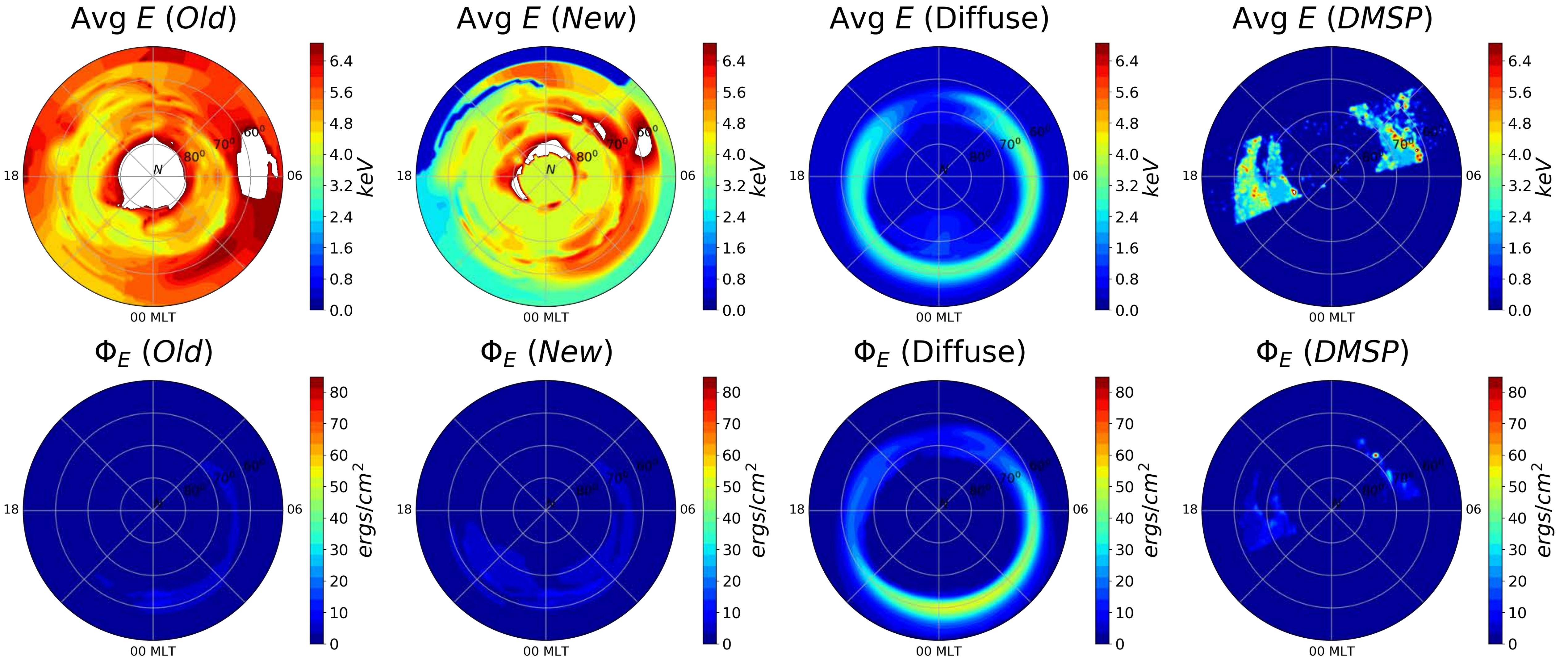
2-D Ionosphere (e.g. RIM)



Inner Mag (e.g. RCM or RAM-SCB)

- Contains routine to calculate the precipitative energy flux and average energy.
- Limited domain.

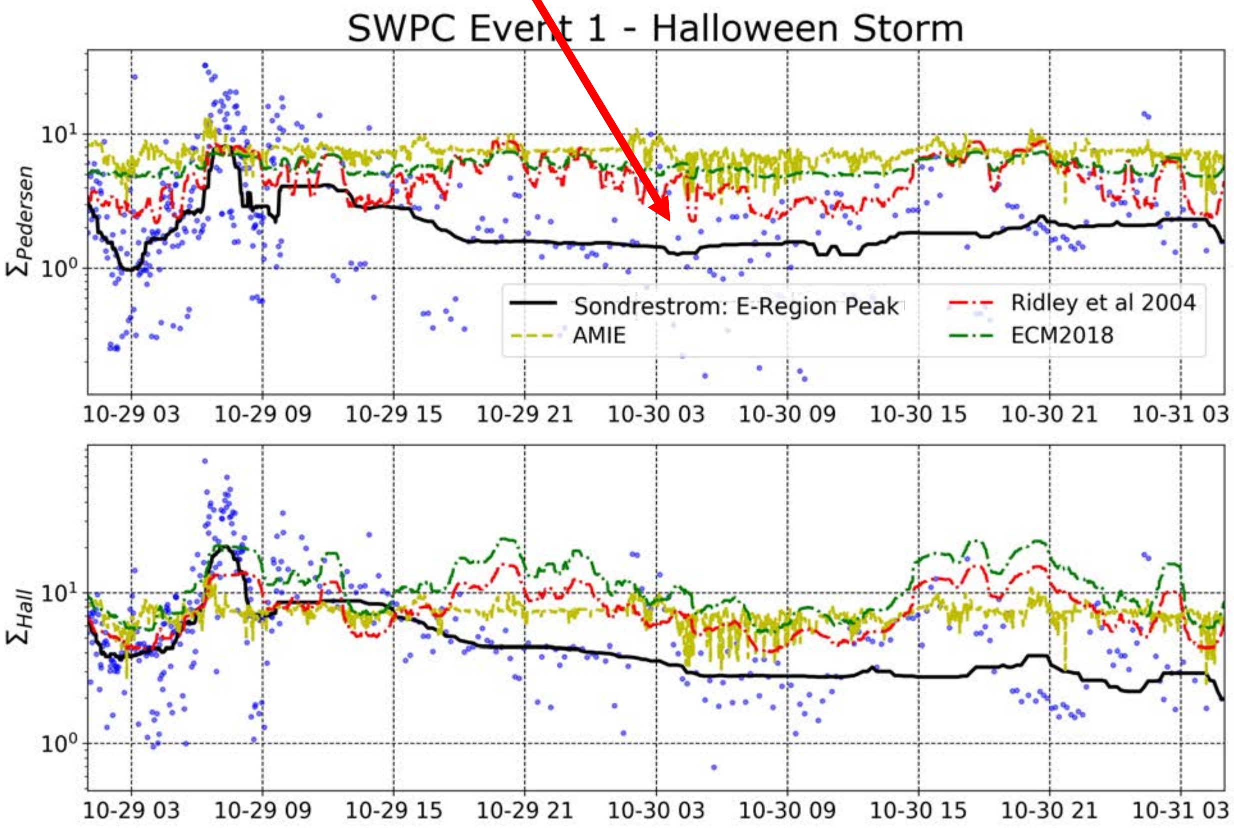
Case 2: April 2010 Event, 04/05/2010, 10:07 UT.

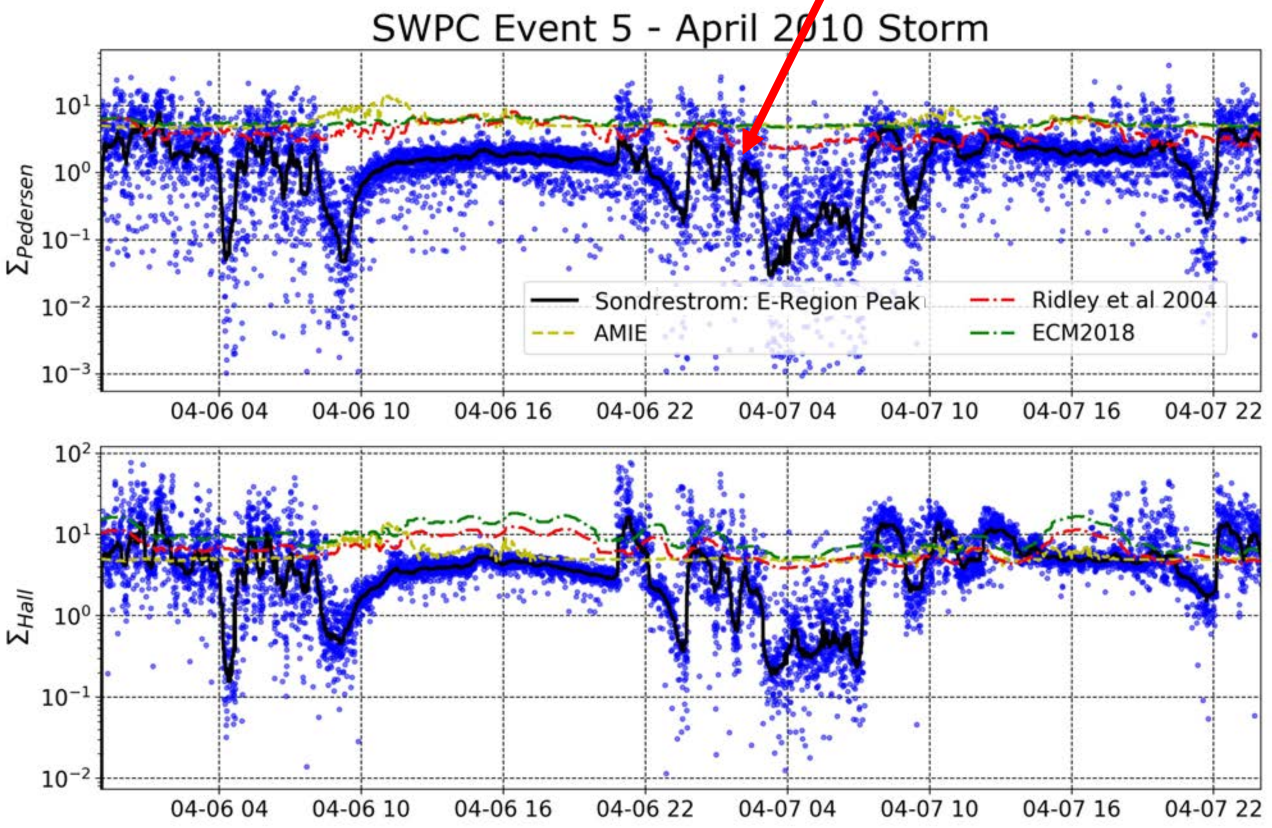


Is the Conductance really accurate?

No Match. Order of magnitude off!

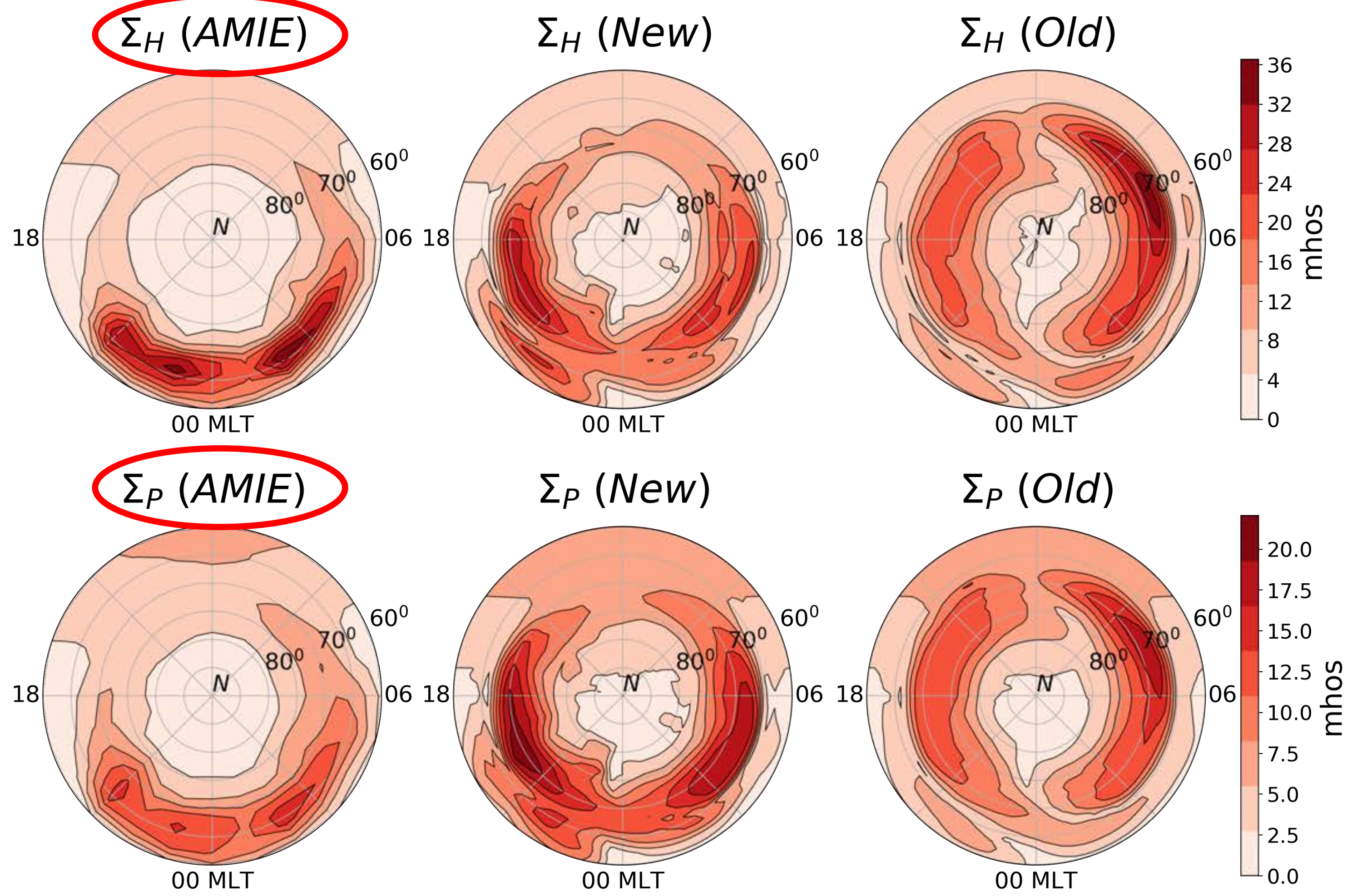
Troughs and Crests not captured by FAC-based changes

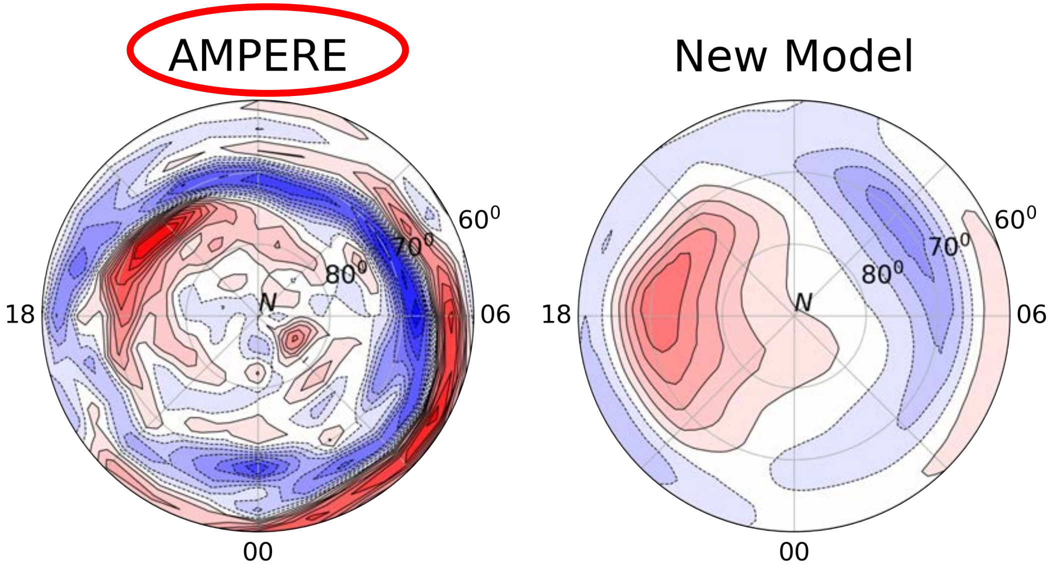


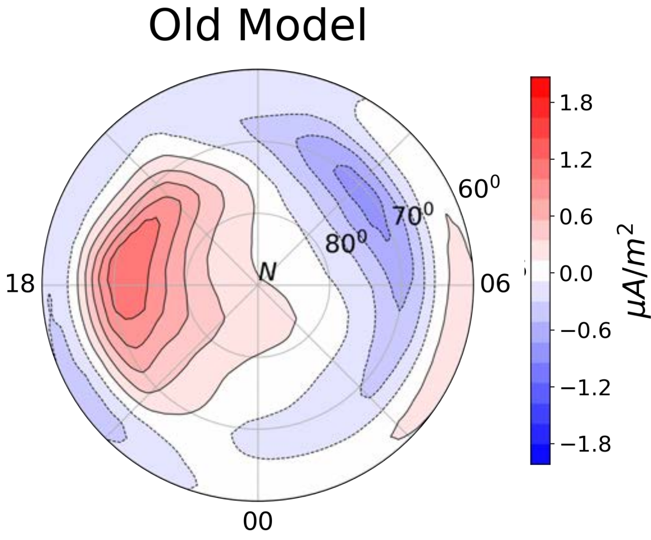


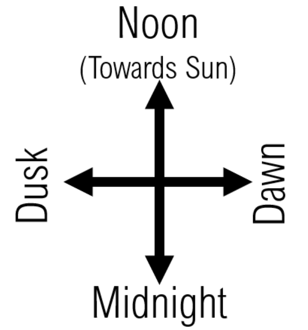
Mukhopadhyay et al., GEM MMV Conductance Challenge, 2018

Is the Conductance really accurate?









SWPC Event 6
05/08/2011
21:25 UT

Mukhopadhyay et al., GEM MMV Conductance Challenge, 2018

Conductance Model (contd.) – *Ridley et al. (2004)*

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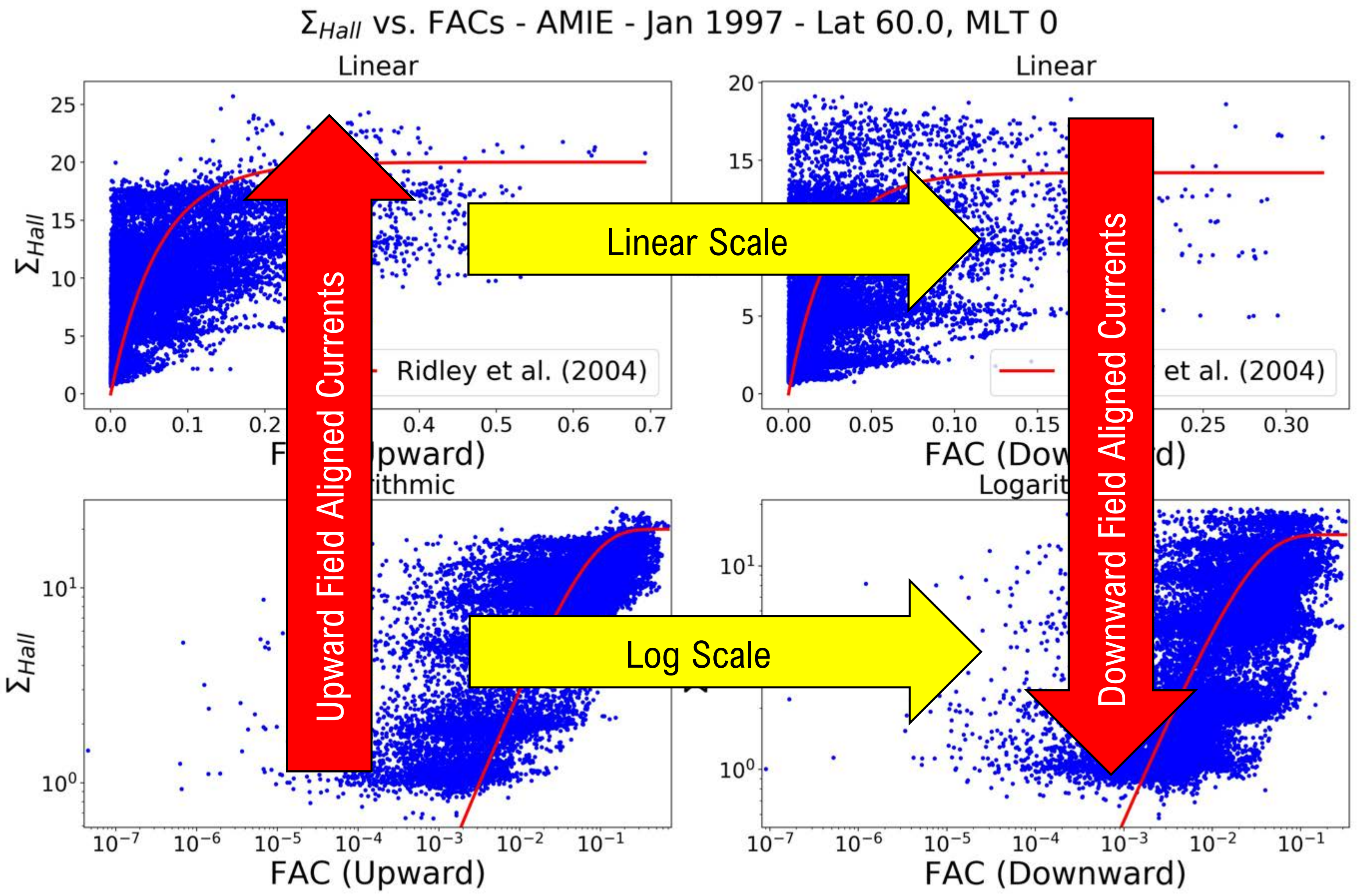

Conductance Model (contd.) – *Ridley et al. (2004)*

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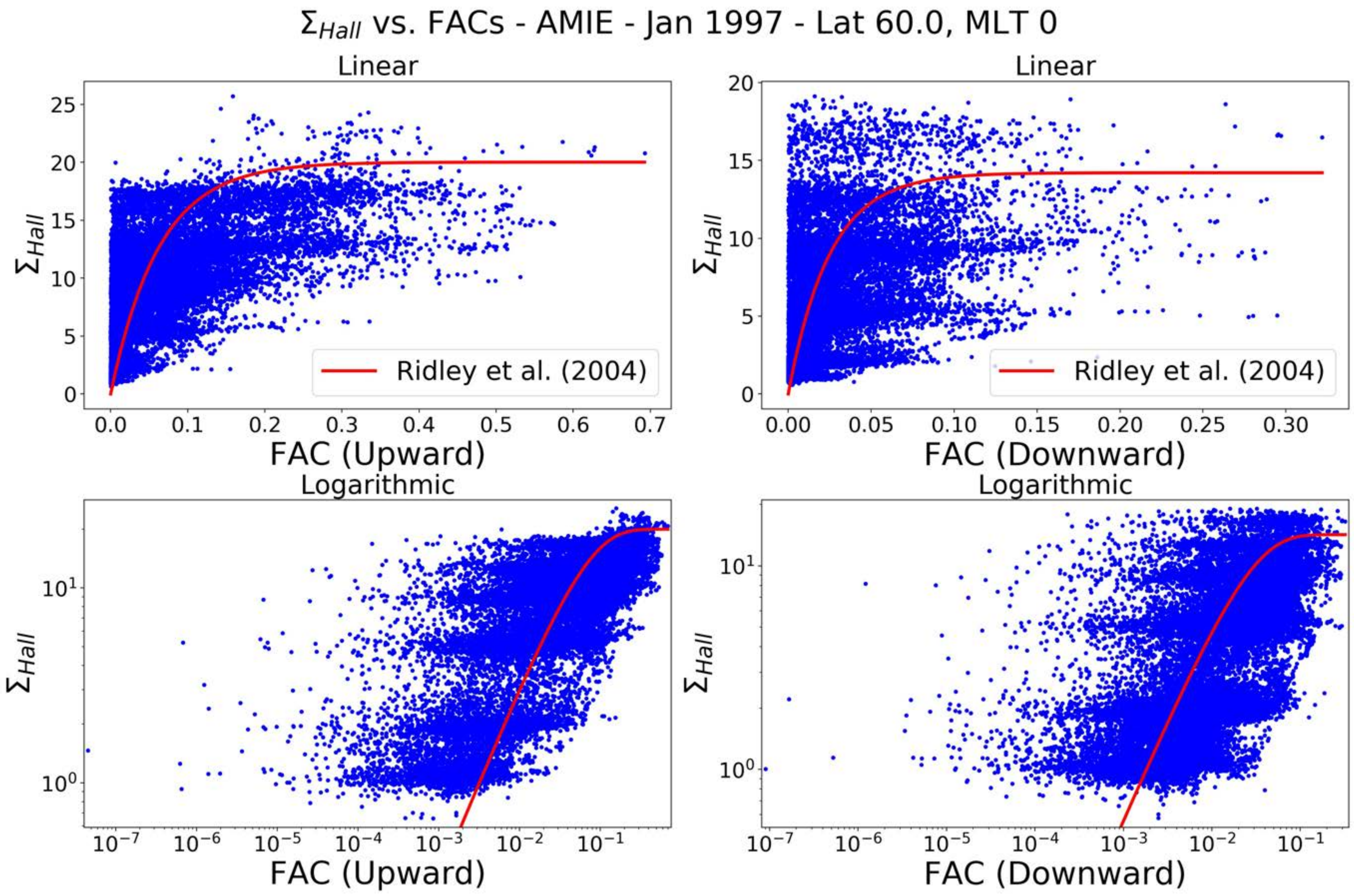
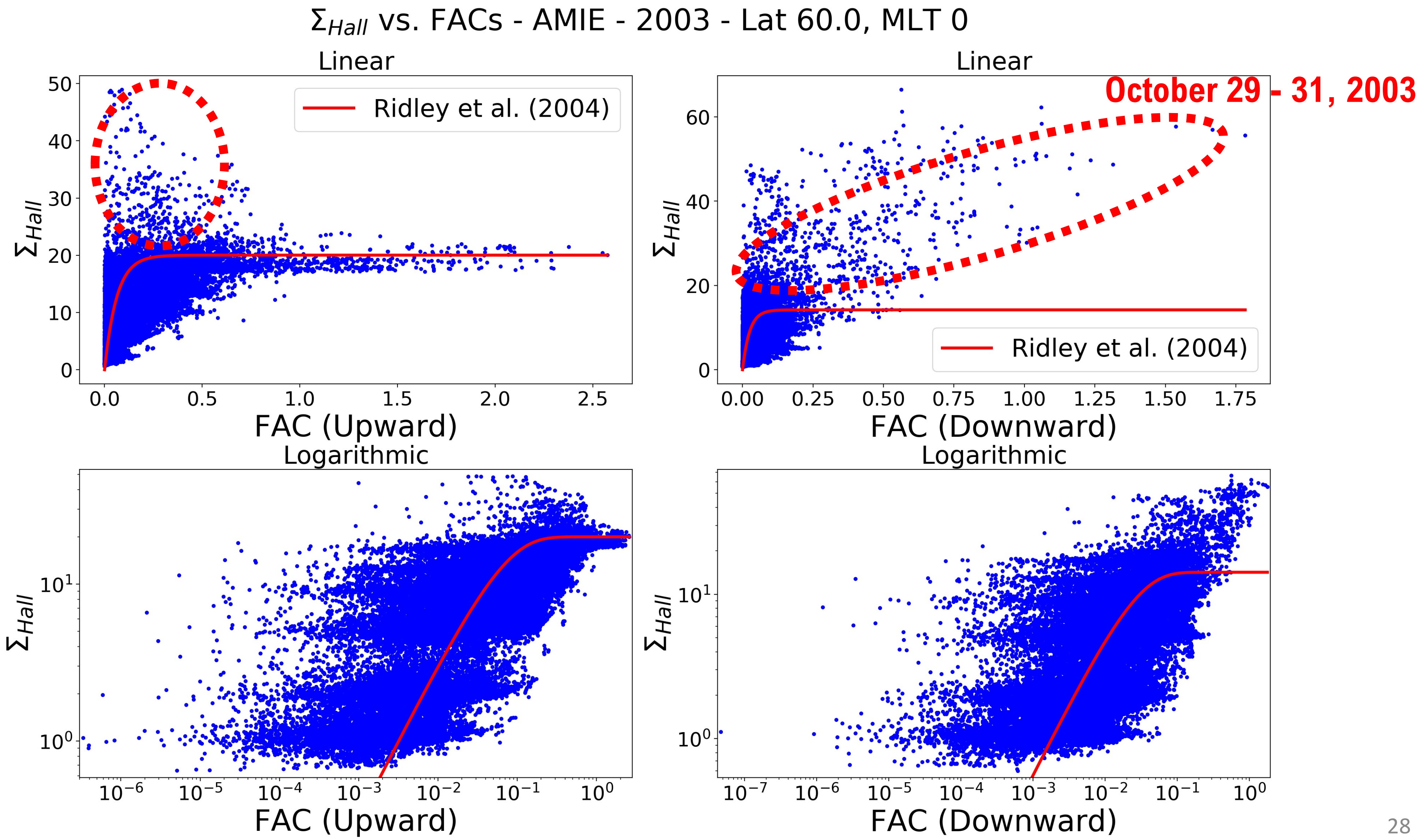


Conductance Model (contd.) – *Ridley et al. (2004)*

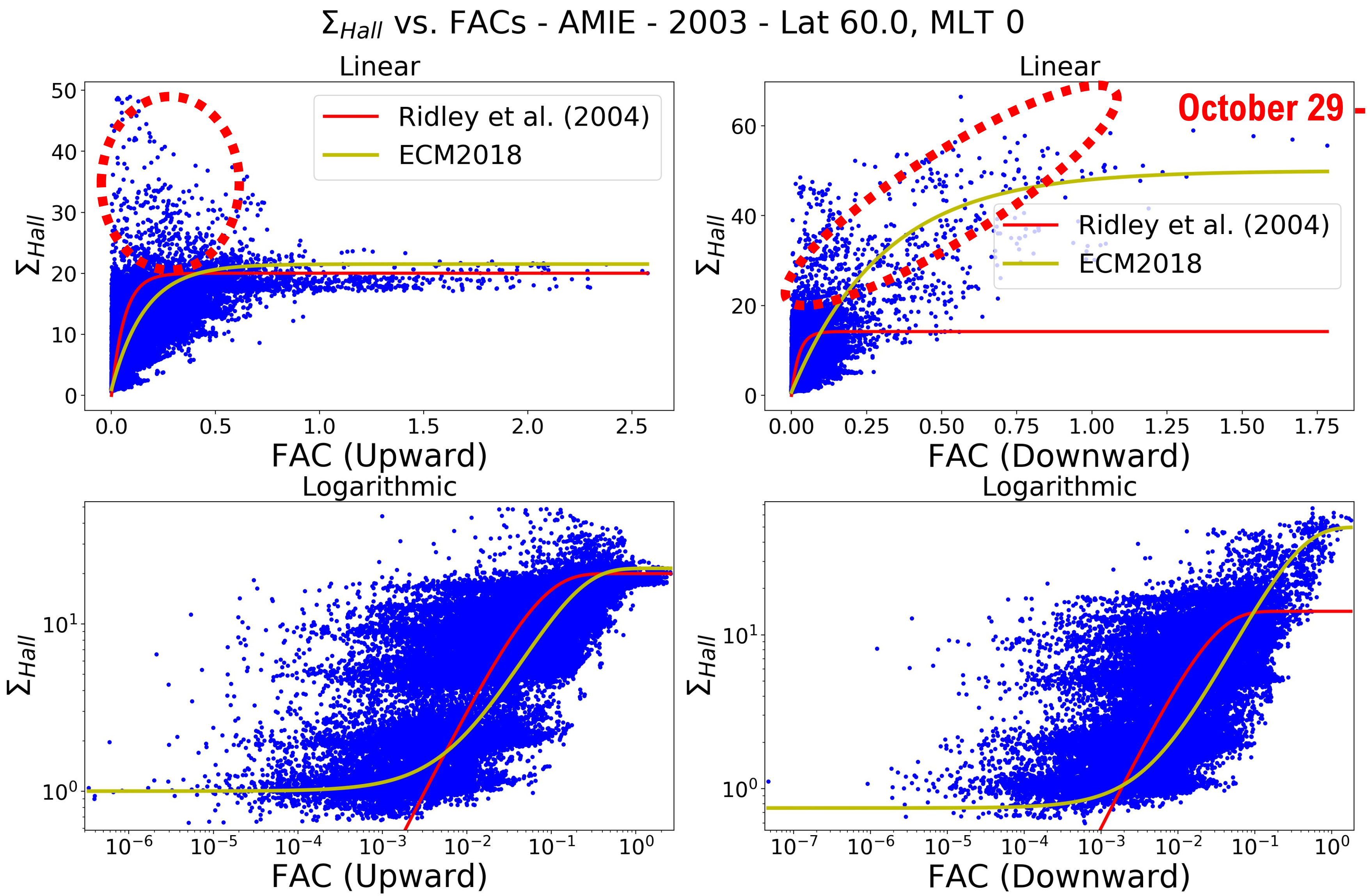
November 1, 2003



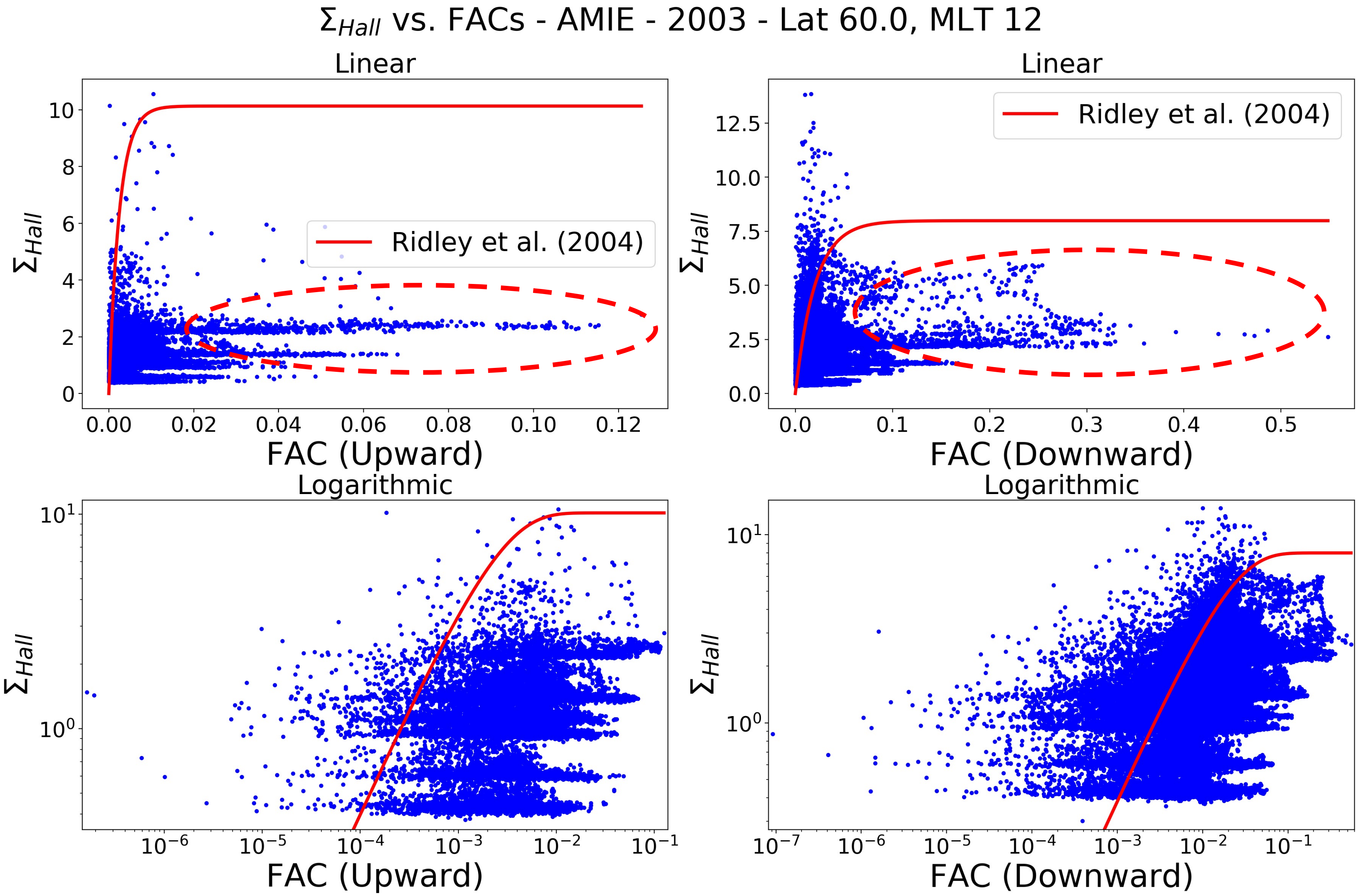
Conductance Model – Towards Improvement

November 1, 2003

October 29 - 31, 2003



New Conductance Model – *Noon Sector*



New Conductance Model – *Noon Sector*