Data-Model Comparisons of Updated Auroral Conductance Model in SWMF

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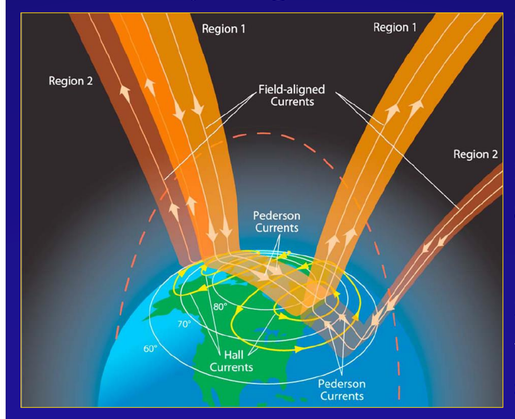
KEY QUESTION:

Can accurate conductance during extreme events better predict high dB/dt on ground?

Scientific Background

- Ionospheric conductance (Σ) is a **key factor** in M-I coupling.
- Predicting auroral (precipitative) conductance is a challenge in global MHD models. Most use an **empirical formulation** based on precipitation [5, 7, 10].
- Recent studies indicate global models to be **under-predicting ground-based dB/dt** due to incorrect conductance predictions during extreme events [4, 9].
- To remedy that, we have **updated the empirical conductance model (ECM)** in the SWMF [8] to include extreme storm-time conductance.

M-I Coupling



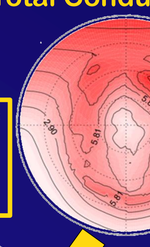
1. Relate FACs to ionospheric potential using **Ohm's Law** [2]:

$$J_{||} = \nabla_{\perp} (\Sigma \cdot \nabla_{\perp} \Phi)$$

2. Conductance is assumed to be known *a priori* [2].

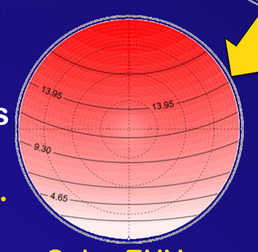
3. Two dominant parts to the conductance: **solar EUV & aurora** [7].

Total Conductance Σ



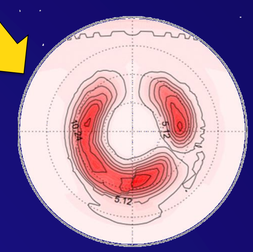
Most models use the *Moen and Brekke (1993)* model to estimate EUV conductance.

OpenGGCM and LFM use the *Robinson et al (1987)* equation, while SWMF uses an exponential formula



Solar EUV

- Added as a function of solar zenith angle.
- Dependent on an absorption function to estimate photoionization.



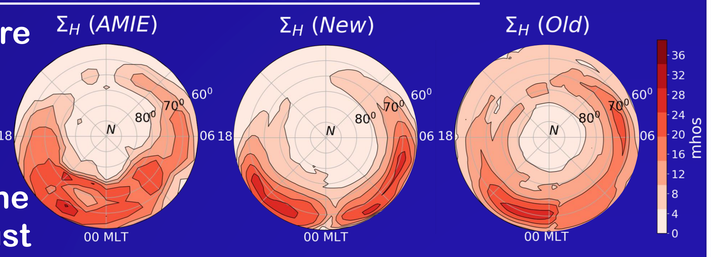
Auroral

- Dependent on particle distribution function and loss cone.
- Added as an empirical function in most models.

Updated Empirical Conductance Model

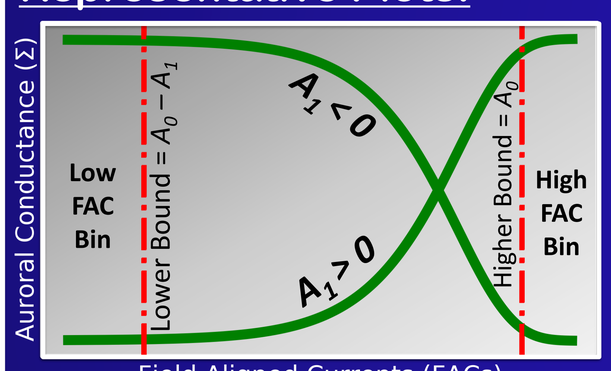
- Auroral Conductance in the SWMF are empirical maps[7] **dependent on FAC distributions** of the following form **derived from AMIE**[6]: $\Sigma = \Sigma_0 e^{-A_2{}^2 |J_{||}|}$
- In the updated model, we changed the above exponential function to a robust **three coefficient** format:

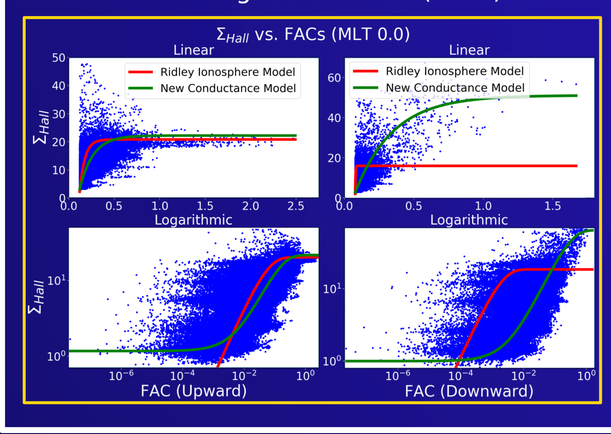
$$\Sigma = A_0 - A_1 e^{-A_2{}^2 |J_{||}|}$$



(Generated using FAC distribution for SWPC Event 1 from SWMF.)

Representative Plots:





How do we calculate the coeffs?

- For A_0 and A_1, a median based method is applied based on the **binning of the FACs**.
- For A_2, an **LM Least Squares method**[3] is used to generate an initial value.
- A **minimized error approach** decides the final coefficient values.
- Using above algorithm **for each grid point (Lat x MLT)**, coefficient **maps** are made.
- Old model is based on minute-resolution AMIE data **from January 1997**. In the new model, data from the **whole year of 2003** has been used.

GOOD

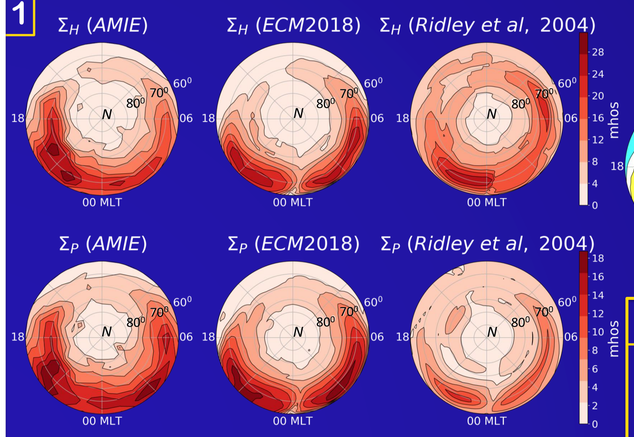
✓ **Easy to build**, easy to remodel
✓ **Computationally, simple!**
✓ **Better predictions during extreme events**

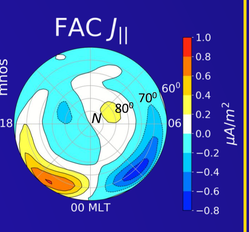
BAD

X **No precipitation** physics included.
X **Accurate conductance** still not achieved.

Data-Model Verification of Conductance Model

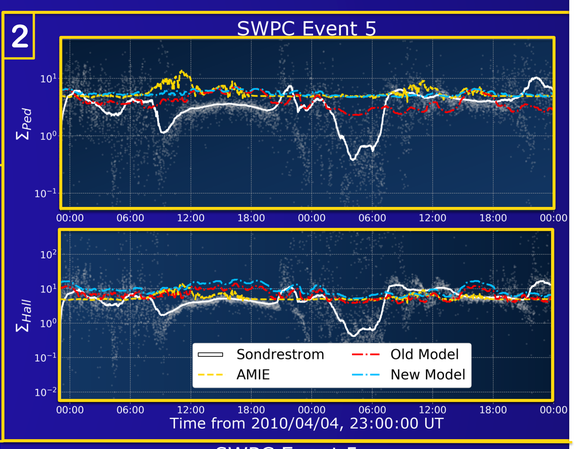
1





Through the new model, we have addressed the question of accurate conductance during extreme events. This is clearly visible on the nightside.

2

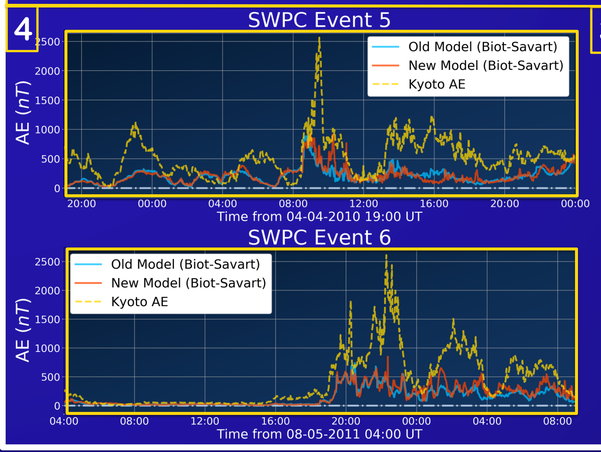


Verification results for the new model

(Clockwise from top left):

(1) Modeled Σ compared with AMIE results **at the peak of Event 1** using SWMF FAC dsitribution.
(2) **Modeled and AMIE Σ** compared with **ISR (Sondestrom) observations** for **Event 5**.
(4) **Modeled CPCP** compared for the old and new model.
(3) Modeled **AE** compared with obs. For **Event 5**.

4



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Preliminary Model Validation through SWMF

1

2

dB/dt threshold	Heidke Skill Score Old	New	Diff
0.3 nT/s	57.1%	59.9%	+2.8%
0.7 nT/s	41.5%	44.4%	+2.9%
1.1 nT/s	29.3%	36.8%	+7.5%
1.5 nT/s	26.9%	32.0%	+5.1%

3

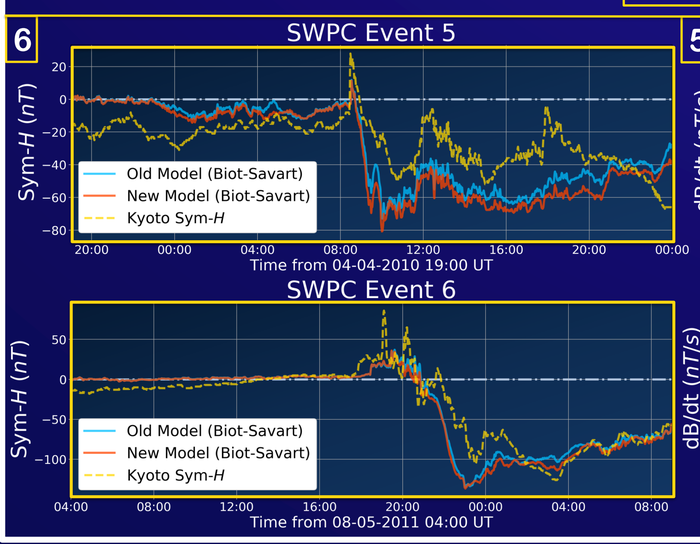
SWPC Event[4]	Date/Time of Event	Min Dst
1	0600 UT 29 Oct, to 0600 UT 30 Oct, 2003	-353 nT
2	1200 UT 14 Dec, to 0000 UT 16 Dec, 2006	-139 nT
3	0000 UT 31 Aug, to 0000 UT 1 Sep, 2001	-40 nT
4	1000 UT 31 Aug, to 1200 UT 1 Sep, 2005	-131 nT
5	0000 UT 5 Apr, to 0000 UT 6 Apr, 2010	-73 nT
6	0900 UT 5 Aug,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

Comparisons between the old and new model

(Clockwise from top left):

(1) Modeled Σ compared with AMIE results **at the peak of Event 5**.
(2) **Heidke Skill Score** for Events 3, 5 and 6 for dB/dt thresholds[4].
(3) List **of SWPC Events**[4] with the event times and strengths.
(4) Modeled **FAC** compared with **AMPERE** [1] for **Events 5 and 6**.
(5) Modeled **dB/dt** compared with obs. for **Event 5** at **varying latitude**
(6) Modeled **Dst** compared with **Kyoto Dst obs.** for **Events 5 and 6**.

6



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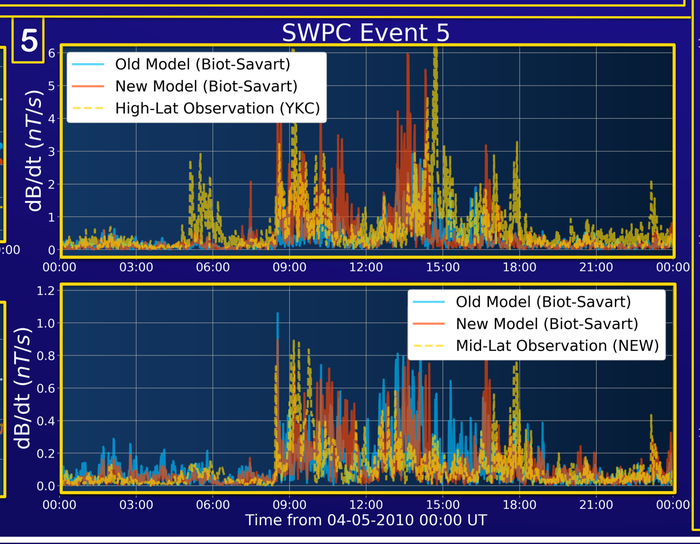

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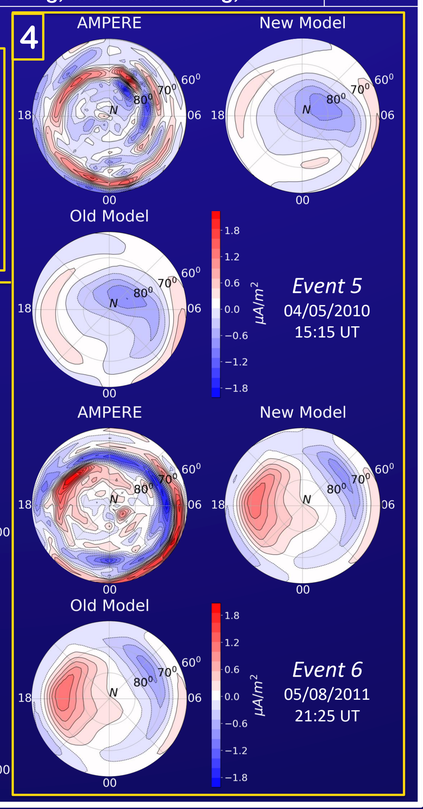

Main Takeaway

Using the updated conductance model, high dB/dt predictions have improved during extreme events.

Future Work

Immediate tasks include a thorough data-model validation for stronger events, followed by the development of a physics-based model to estimate conductance employing the use of I-T and I-M models.

Acknowledgments

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References

[1] Anderson et al (2017), 15(2), 352 – 373, *Space Weather*
[2] Goodman (1995), 13(3), 843 – 853, *Annales Geophysicae*
[3] Pujol et al. (2007), 72(4), W1 – W16, *Geophysics*
[4] Pulkkinen et al. (2013), 11(6), 369 – 385, *Space Weather*
[5] Raeder et al. (2001), 106(A1), *Journal of Geophy. Research – Space Phy.*
[6] Richmond and Kamide (1988), 93(A6), *Journal of Geophy. Research*
[7] Ridley et al. (2004), 22(2), 567 – 584, *Annales Geophysicae*
[8] Toth et al. (2005), 110(A12), *Journal of Geophy. Research*
[9] Welling et al. (2017), 15(1), 192 - 203, *Space Weather*
[10] Wiltberger et al. (2009), 114(1) , *Journal of Geophy. Res. – Space Phy.*