Sources of Auroral Conductance - Balance and Impacts

Agnit Mukhopadhyay[1], Daniel Welling[2], Meghan Burleigh[3], Michael Liemohn[4], Aaron Ridley[5], Elizabeth Vandegriff[2], Shasha Zou[4], Hyunju Connor[6], and Brian Anderson[7]

[1]University of Michigan Ann Arbor
[2]University of Texas at Arlington
[3]US Naval Research Laboratory
[4]University of Michigan
[5]Univ Michigan
[6]University of Alaska Fairbanks
[7]Johns Hopkins Univ

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Abstract

Despite significant developments in global modeling, the determination of ionospheric conductance in the auroral region remains a challenge in the space science community. With advances in adiabatic kinetic theory and numerical couplings between global magnetohydrodynamic models and ring current models, the dynamic prediction of individual sources of auroral conductance have improved significantly. However, the individual impact of these sources on the total conductance and ionospheric electrodynamics remains understudied. In this study, we have investigated individual contributions from four types of auroral precipitation - electron & ion diffuse, monoenergetic & Alfven wave-driven - on ionospheric electrodynamics using a novel modeling setup. The setup encompasses recent developments within the University of Michigan's Space Weather Modeling Framework (SWMF), specifically through the use of the MAGNetosphere - Ionosphere - Thermosphere auroral precipitation model and dynamic two-way coupling with the Global Ionosphere-Thermosphere Model. This modeling setup replaces the empirical idealizations traditionally used to estimate conductance in SWMF, with a physics-based approach capable of resolving 3-D high-resolution mesoscale features in the ionosphere-thermosphere system. Using this setup, we have simulated an idealized case of southward Bz 5nT & the April 5-7 "Galaxy15" Event. Contributions from each source of precipitation are compared against the OVATION Prime Model, while auroral patterns and hemispheric power during Galaxy15 are compared against observations from DMSP SSUSI and the AE-based FTA model. Additionally, comparison of field aligned currents (FACs) and potential patterns are also conducted against AMPERE, SuperDARN & AMIE estimations. Progressively applying conductance sources, we find that diffuse contributions from ions and electrons provide ˜75% of the total energy flux and Hall conductance in the auroral region. Despite this, we find that Region 2 FACs increase by ˜11% & cross-polar potential reduces by ˜8.5% with the addition of monoenergetic and broadband sources, compared to <1% change in potential for diffuse additions to the conductance. Results also indicate a dominant impact of ring current on the strength and morphology of the precipitation pattern.

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[1] Climate and Space Sciences and Engineering, University of Michigan; [2] Naval Research Laboratory; [3] Department of Physics, University of Texas at Arlington; [4] Department of Physics, University of Alaska Fairbanks; [5] Applied Physics Lab, Johns Hopkins University

agnitm@umich.edu

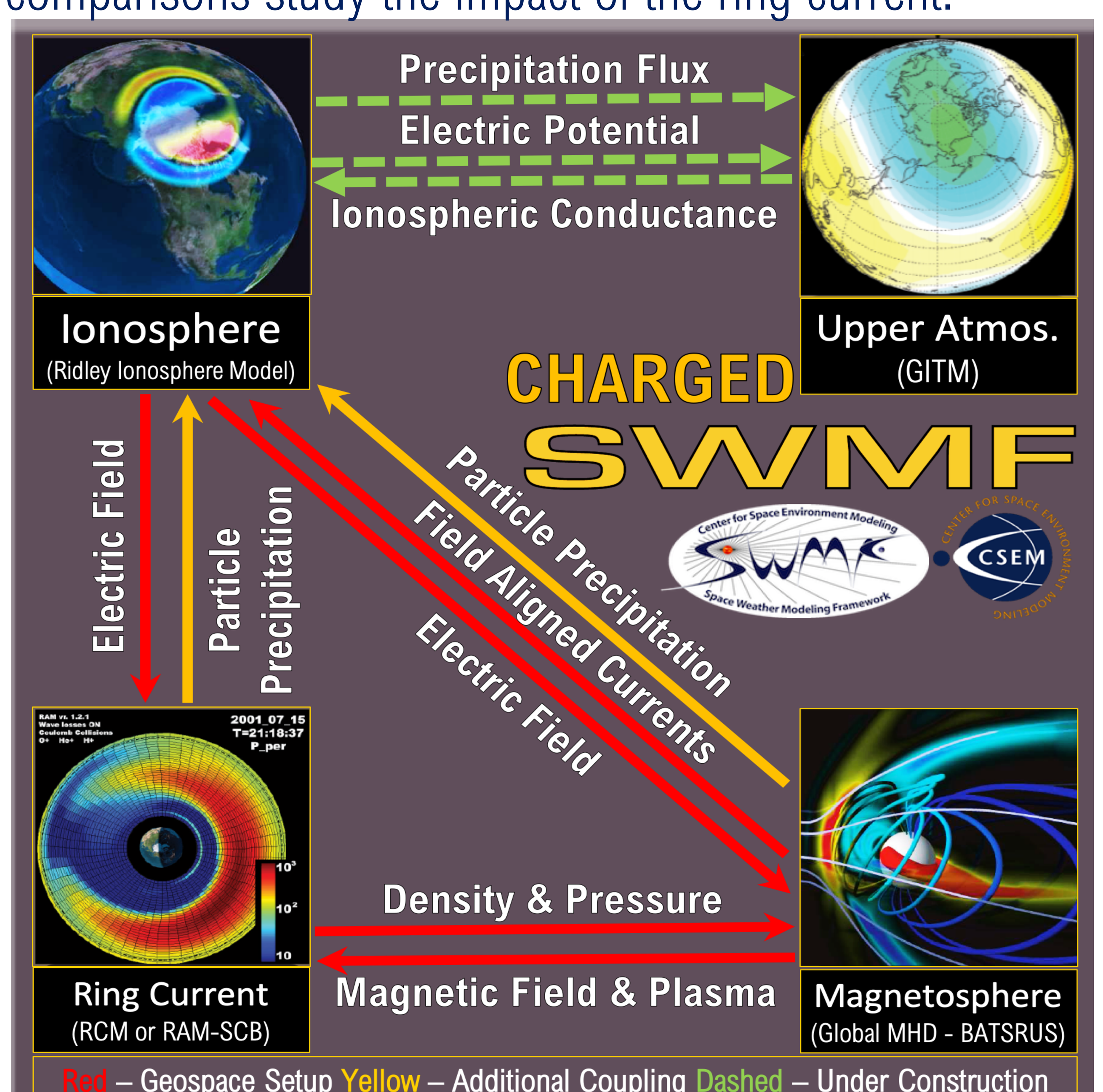
MOTIVATION

Ionospheric Conductance is a precarious quantity to predict in global space weather models. This is especially challenging in the auroral regions, where charged particle precipitation is driven by multiple sources. In this poster, we show results from a novel modeling approach that quantifies the sources of aurora.

METHODOLOGY

We have developed a new MAGNetosphere-Ionosphere-Thermosphere (MAGNIT) auroral model within the Space Weather Modeling Framework that uses adiabatic kinetic theory to estimate auroral conductance from MHD variables (see framework in figure below).

Multiple configurations of this model have been used to simulate the April 5-7, 2010 *Galaxy15* Event to study the balance of different sources & understand its impact on ionospheric electrodynamics. Additional comparisons study the impact of the ring current.



RESULTS - BALANCE OF SOURCES

Figure 1. MAGNIT vs OVATION Prime : Flux Patterns & Contributions

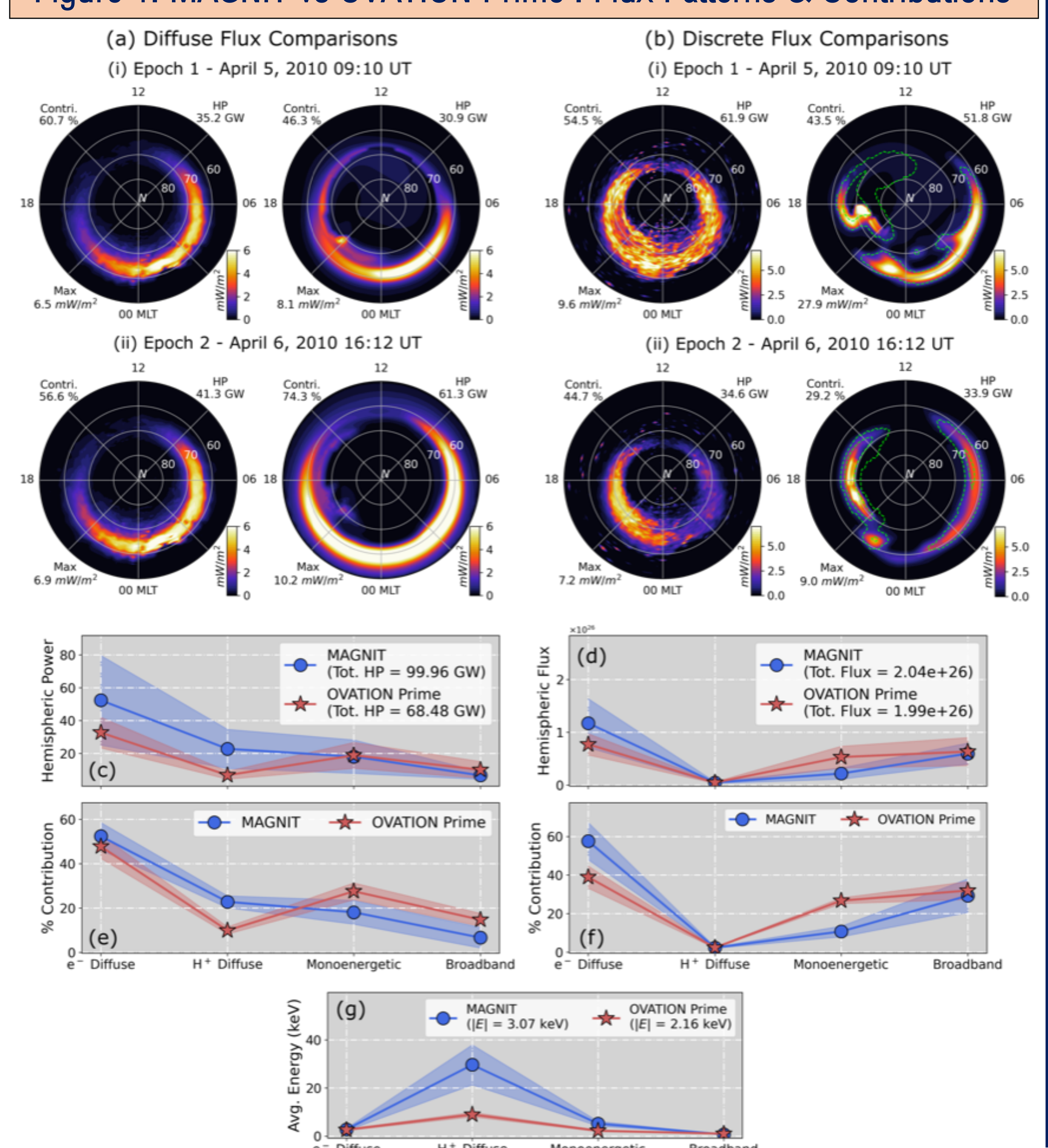


Figure 2. MAGNIT Comparisons : Hemispheric Power Contributions

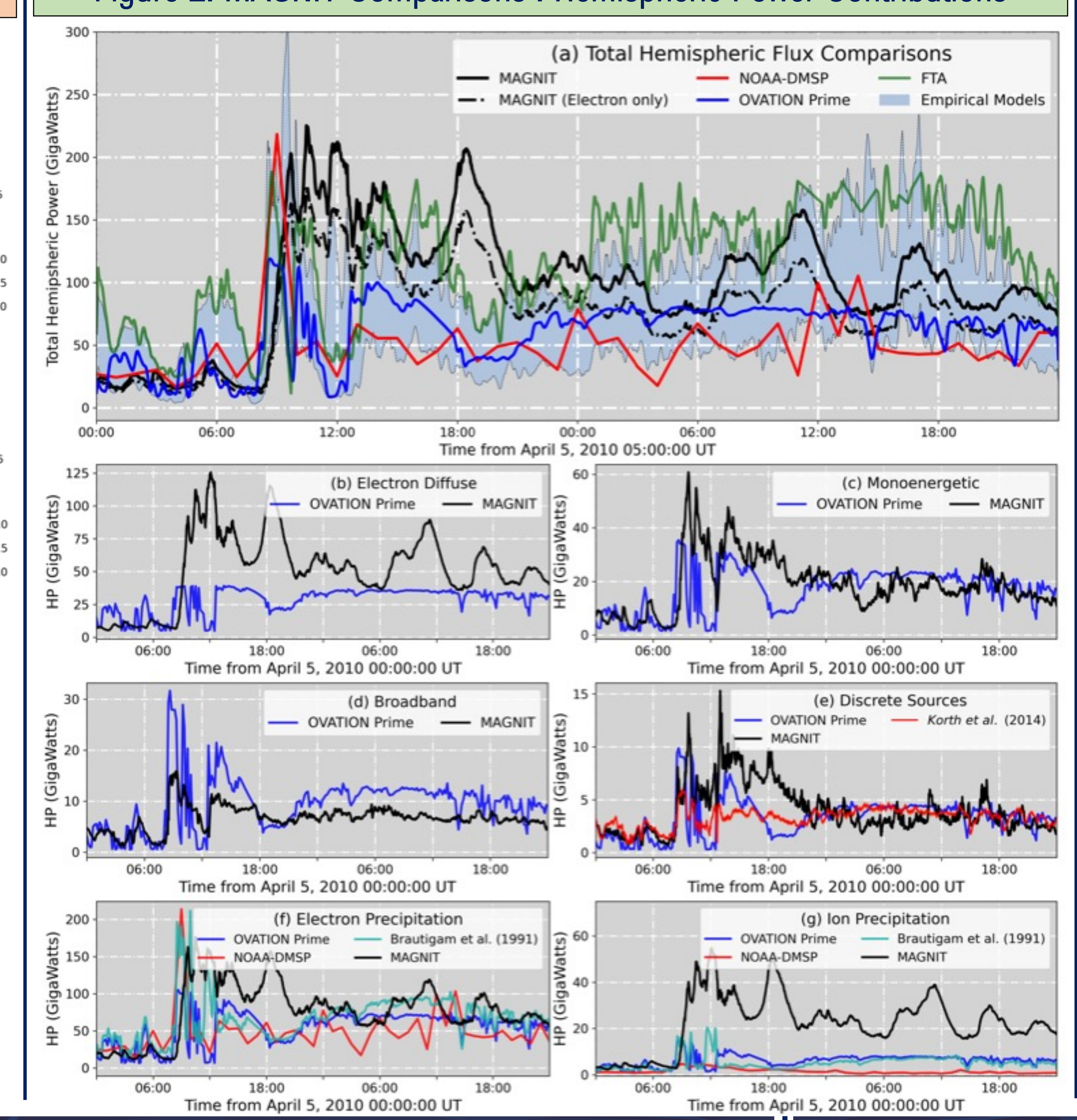


Figure 3. Source-wise distribution of Auroral Conductance

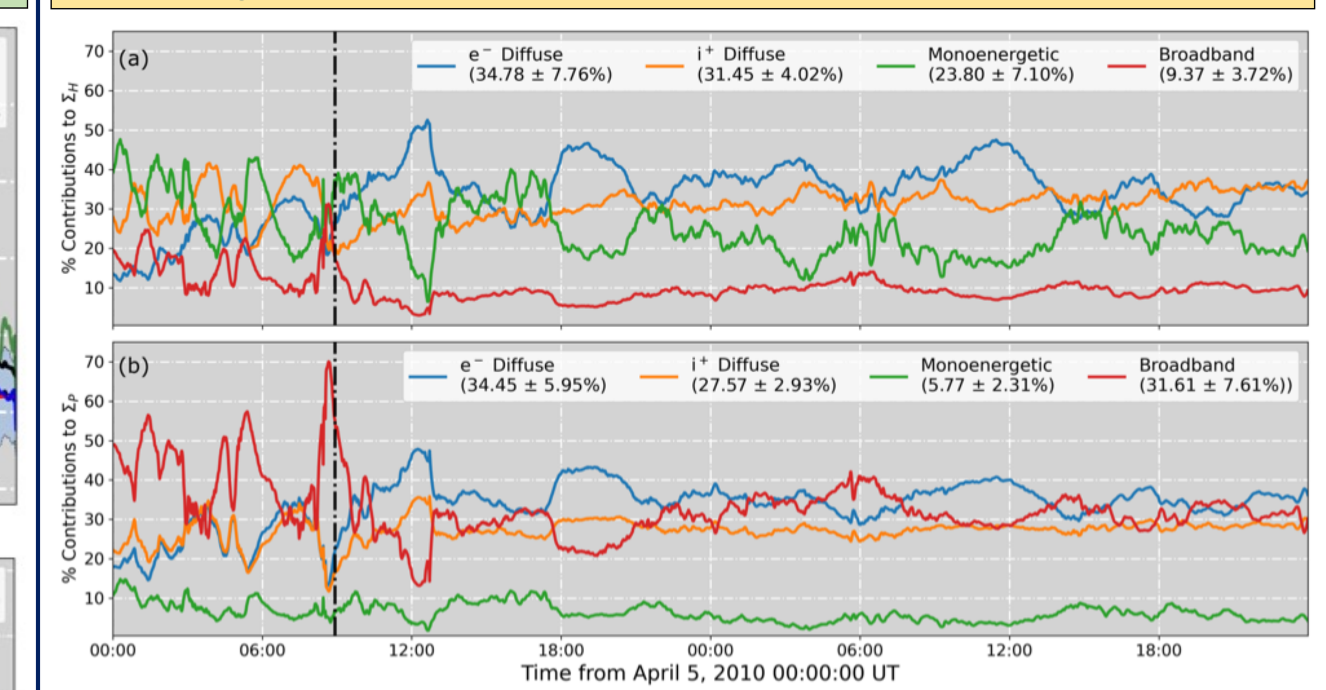


Figure 1. Comparison of SWMF-MAGNIT results against OVATION Prime. (Top dial plots) Comparison of energy flux patterns for diffuse (electron + ion) and discrete (monoenergetic + broadband) fluxes for two epochs – 09:10 UT on April 5 and 16:12 UT on April 6 - during the *Galaxy15* Event. (Bottom Subplots) Median contributions by each source to the total hemispheric power, number flux and average energy.

Figure 2. Comparison of Hemispheric Power during *Galaxy15* Event. (a) Comparison of MAGNIT HP against NOAA-DMSP, OV Prime, FTA and empirical models by Brautigam et al. (1991), Ahn et al. (1983), Lu et al. (1991), and Ostgaard et al. (2002). (b - g) Comparison of (b) electron diffuse, (c) monoenergetic, (d) broadband, (e) discrete sources in the dusk-noon sector, (f) total electron, and (g) total ion precipitation HP against observations and derived estimates.

Figure 3. Distribution of ionospheric conductance from each auroral source. Comparison of electron diffuse, ion diffuse, monoenergetic and broadband (a) Hall and (b) Pedersen conductance. Modeled results show a much higher contribution from broadband precipitation .

IMPACT ON IONOSPHERIC ELECTRODYNAMICS

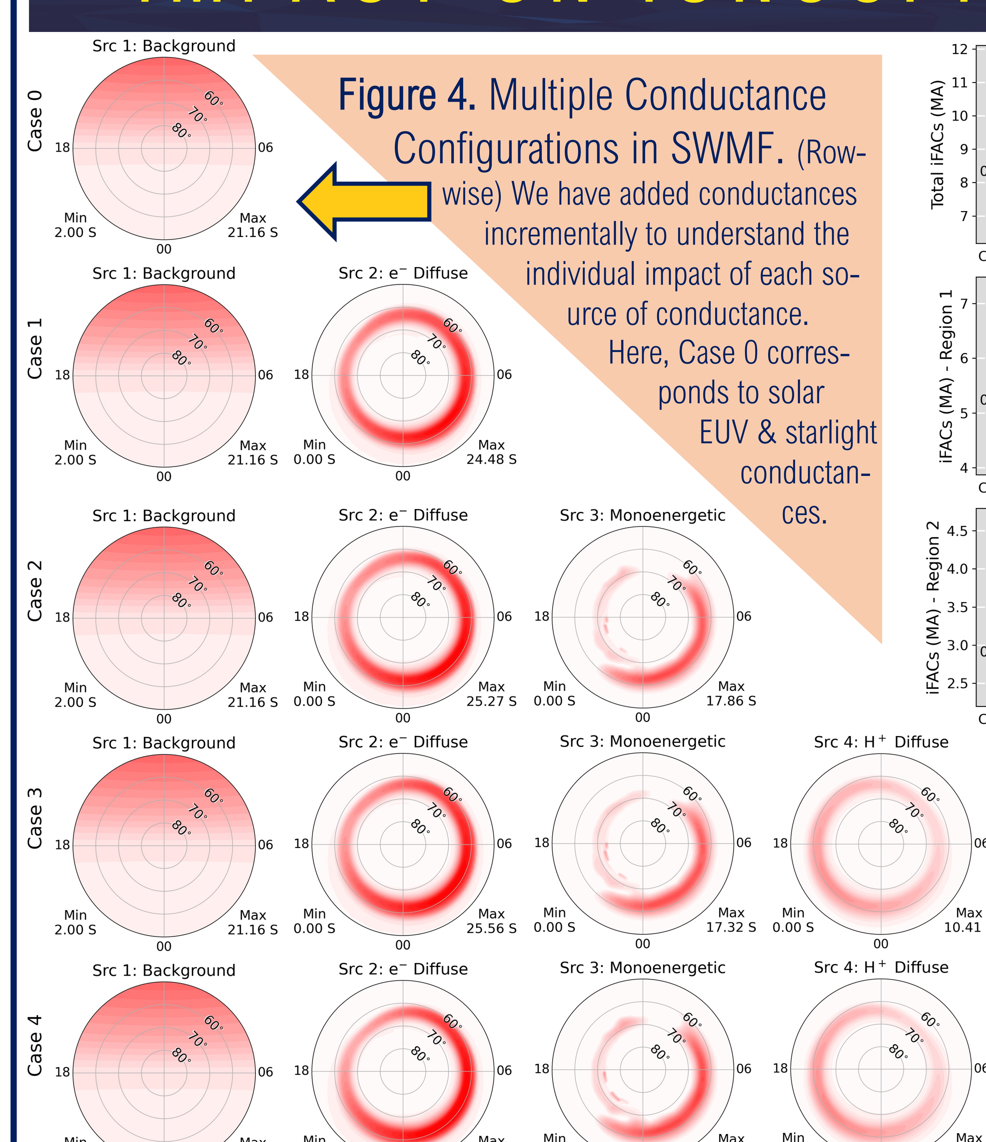


Figure 4. Multiple Conductance Configurations in SWMF. (Row-wise) We have added conductances incrementally to understand the individual impact of each source of conductance. Here, Case 0 corresponds to solar EUV & starlight conductances.

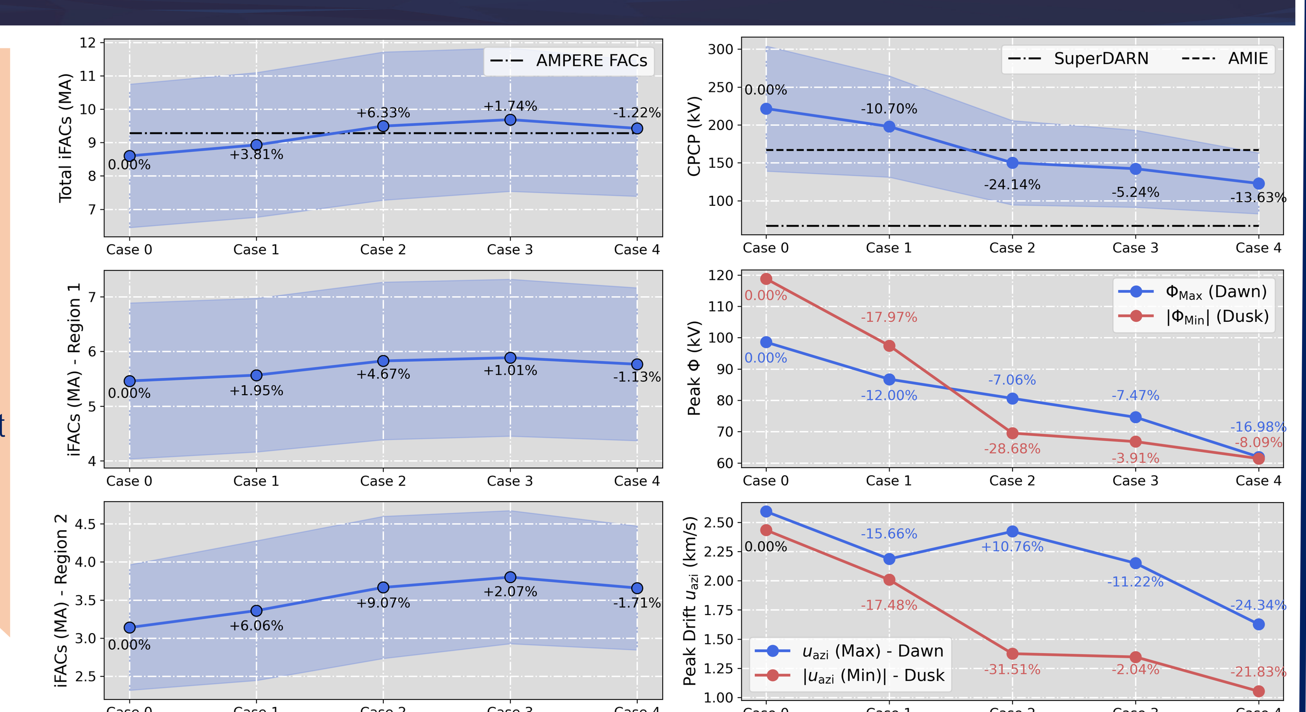


Figure 5. Comparison of median values of ionospheric parameters during the Galaxy15 event. (Left) Comparison of (top) total, (middle) Region 1, and (bottom) Region 2 integrated FACs. Dotted black line is median iFAC value observed by AMPERE. Light-blue range indicates the standard deviation in modeled data. (Right) Comparison of (top) cross polar cap potentail, (middle) peak potentials in each cell, and (bottom) peak electrojet velocity peaks in the dawnward and duskward sectors. Our comparisons show that monoenergetic precipitation plays a significant role in driving an asymmetric electric field.

IMPACT OF RING CURRENT STRENGTH

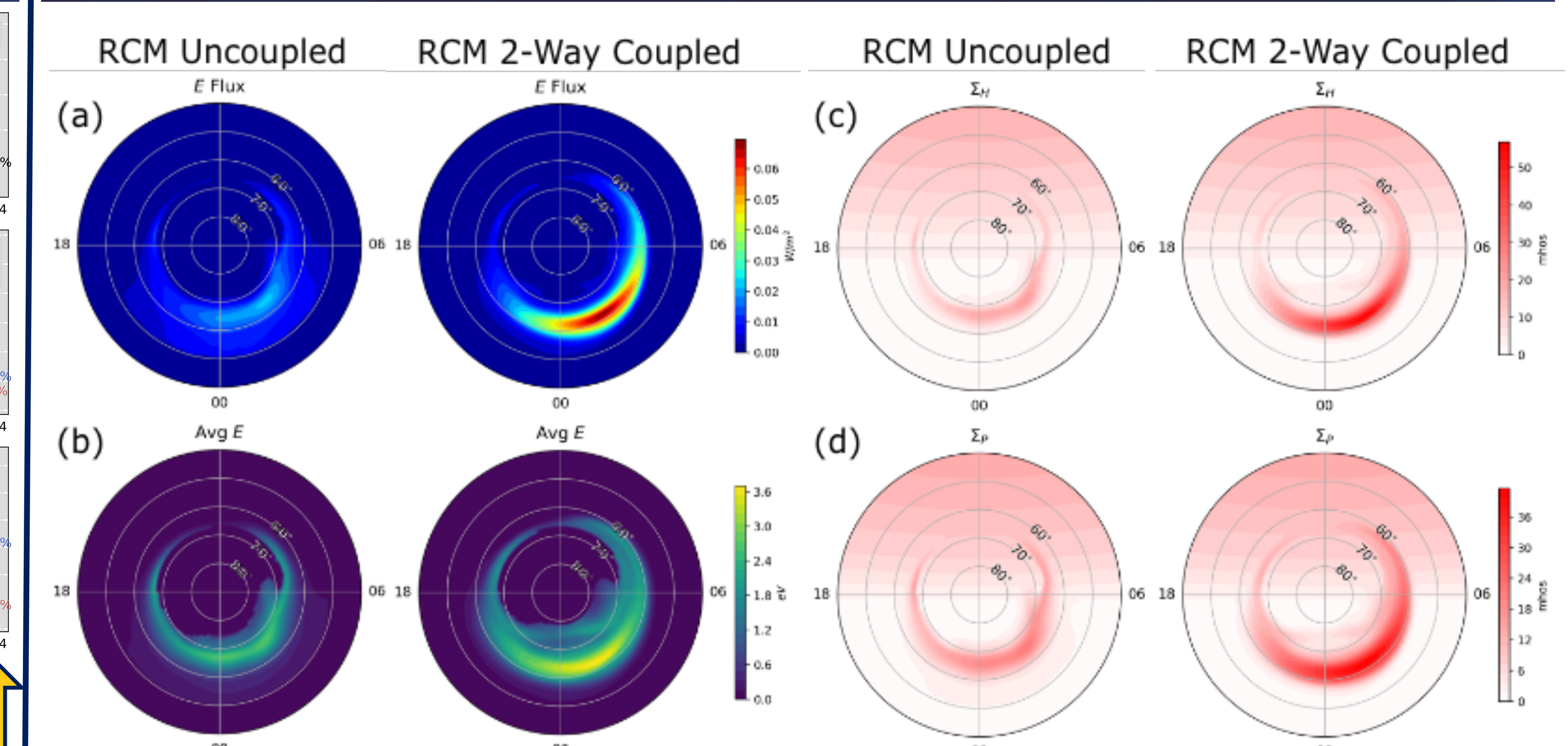


Figure 6. Comparison of Ionospheric Precipitation with and without a dedicated inner magnetosphere solver. Dial plots compare (a) energy flux, (b) average energy, (c) Hall conductance and (d) Pedersen conductance for two configurations of the SWMF. In leftward dial plots, the dedicated coupling to the Rice Convection Model (RCM) is not used, while in the rightward plots, this coupling is used to strengthen the nightside pressure and Region 2 FACs. Our comparisons show that not only are fluxes lower for the non-RCM case (leading to a weaker auroral oval), but they also cause the energy flux to have a wider equatorward spread, in contrast to the RCM case, where a distinct midnight-dawnward peak is established.

CONCLUSIONS

Diffuse sources of precipitation contribute to 71% of the total aurora. Despite this, during active times, discrete sources can contribute upto 61% of the total precipitation. Broadband contributes significantly to iono. conductance.

Monoenergetic precipitation adds underneath upward FACs, which matches the location of the duskward electric field peak. This reduces the E-field and potential and drives asym-metry. This further increases nightside pressure & R2 FACs.

Addition of a ring current model strengthens the pressure peaks in the nightside, that results in a stronger and well-defined auroral oval, resulting in stronger auroral conductances.

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