Modeling Earth's Magnetosphere as a Current Circuit

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SUMMARY: Multiple plasma model framework simulation compared with circuit representation of plasma in earth's magnetosphere. Individual components show strong discrepancies from high fidelity simulation without losing overall predictive capability. Illustrates unequal weighting of plasma phenomena and opportunity for revisiting circuit type models.

A: SPACE WEATHER MODELING FRAMEWORK

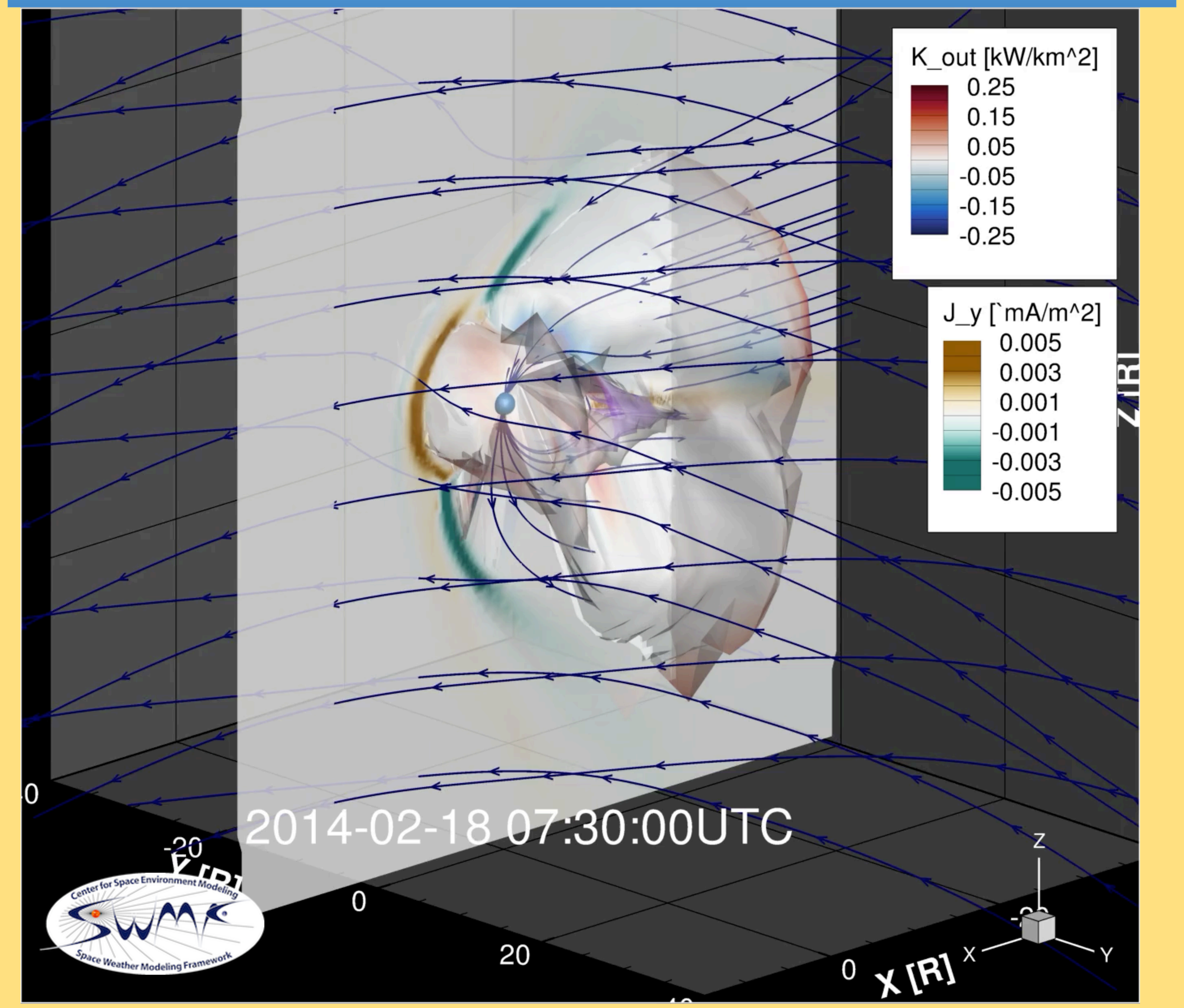

Fig A1: Surfaces/Volumes of Integration Computed visualized in Tecplot

Surface construction 3D surfaces are constructed by field line tracing via Tecplot, then the datapoints are processed using Python scripts and fed back for visualization and integration.

SWMF The Space Weather Modeling Framework[2] couples several plasma models for spatial regions. What is shown in Figure A1 is visualization of the BATS-US MHD field data. This MHD formulation is "ideal" with only numerical contributions to resistivity.

C: RESULTS

2014 Feb 18, 06:00UT- Feb 20, 00:00UT

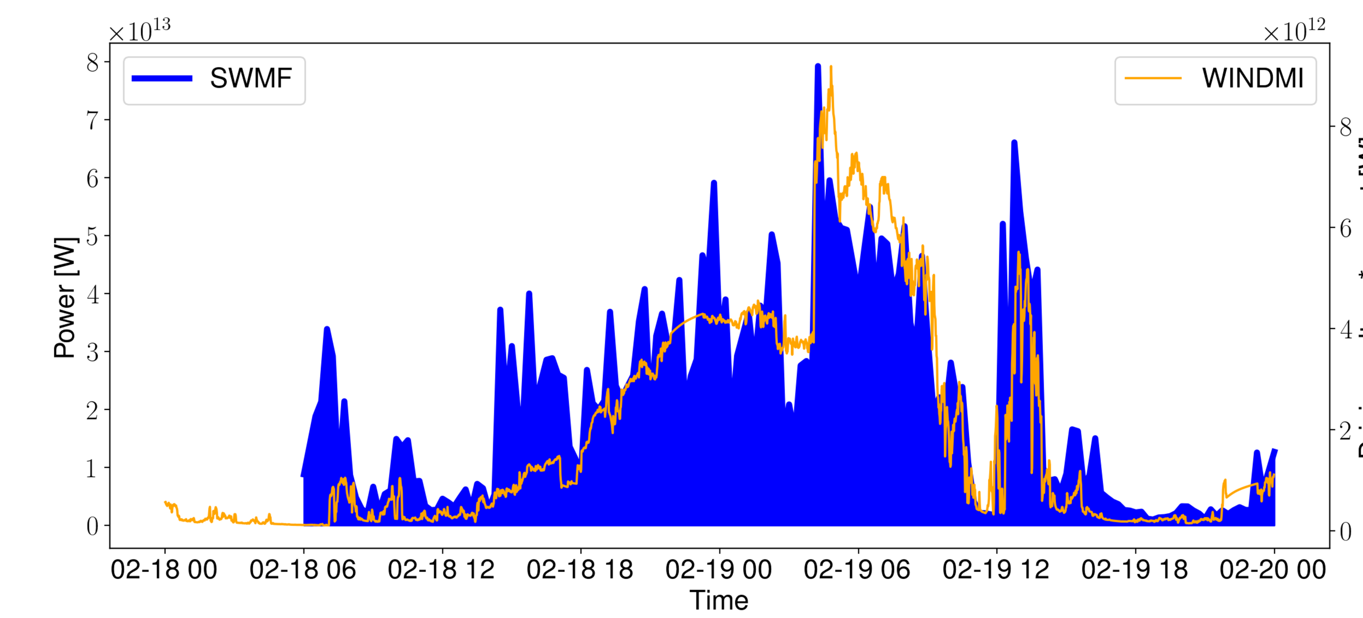

Fig C1: Driving Energy Input

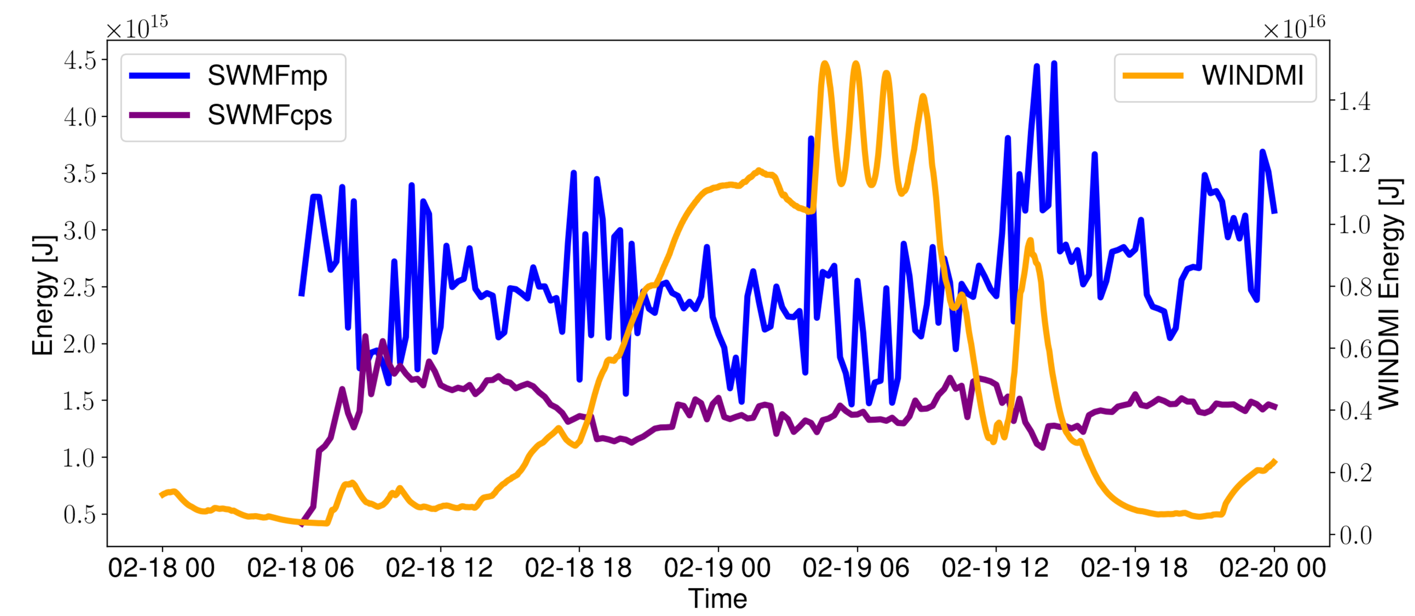

Fig C2: Magnetic Energy

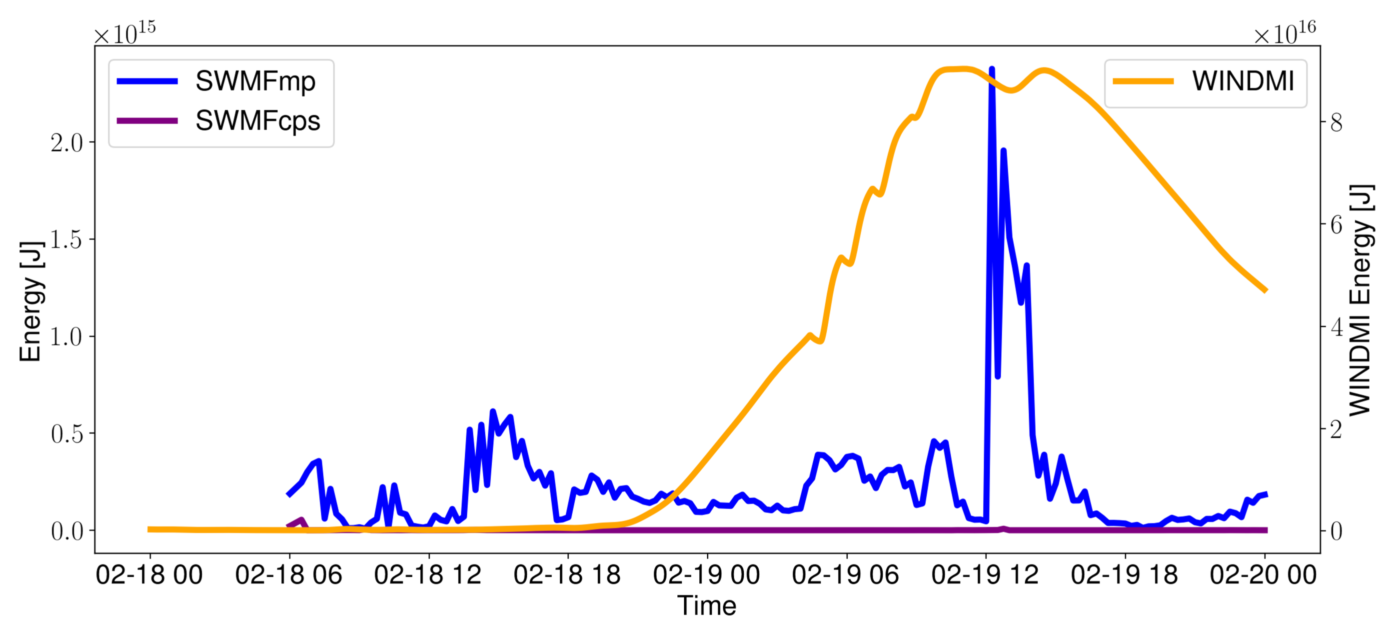

Fig C3: Parallel Kinetic Energy

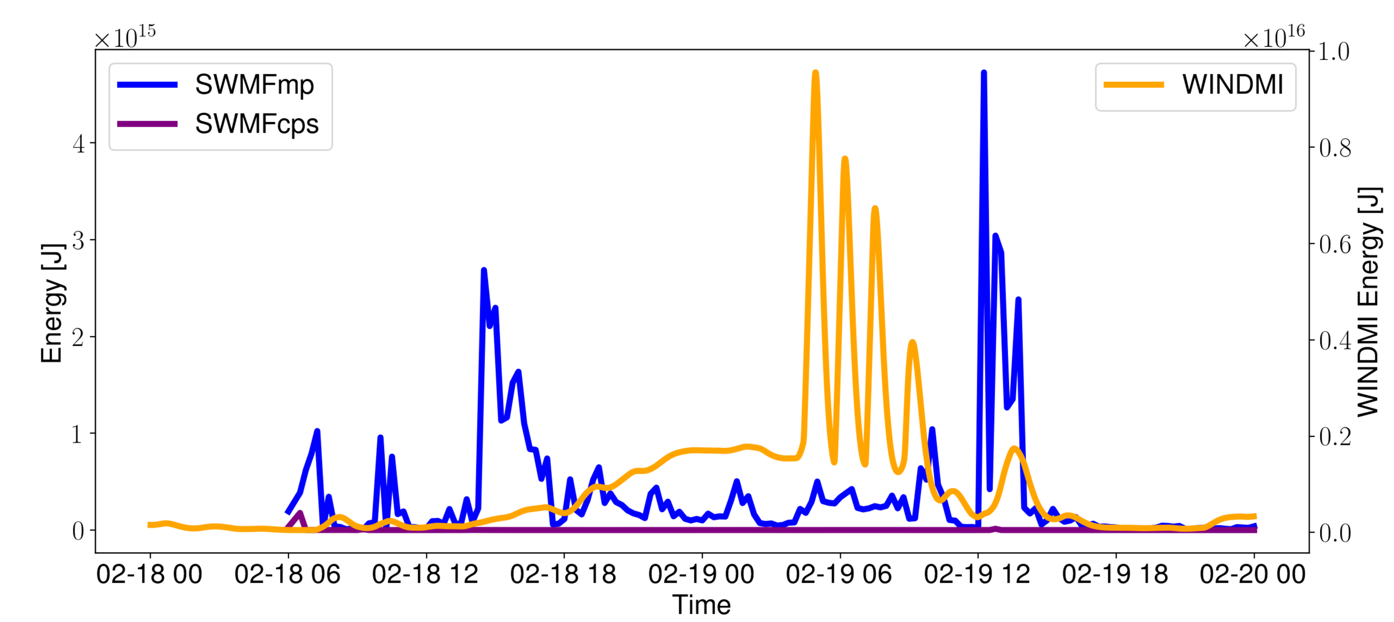

Fig C4: Perpendicular Kinetic Energy

B: WINDMI

Table B1: WINDMI Fixed Parameters

Parameter	Unit	Value
L	Henry	90
M	Henry	1
C	Farads	50000
α	-	8E11
σ	mΩ	8
Ω_{CPS}	Re^3	10000
μ_0	$m^-1, kg^{-0.5}$	4E-09
I_c	A	17800000
$\triangle I$	A	125000
A_{eff}	Re^2	2
B_{tr}	T	5E-09
L_y	Re	5
τ_E	hr	0.5
τ_P	hr	0.167
L_1	Henry	20
C_1	Farads	800
Σ_1	mΩ	3
L_2	Henry	8
R_{PRC}	Ω	0.1
R_{A2}	Ω	0.3
τ_{RC}	hr	12
β	-	1

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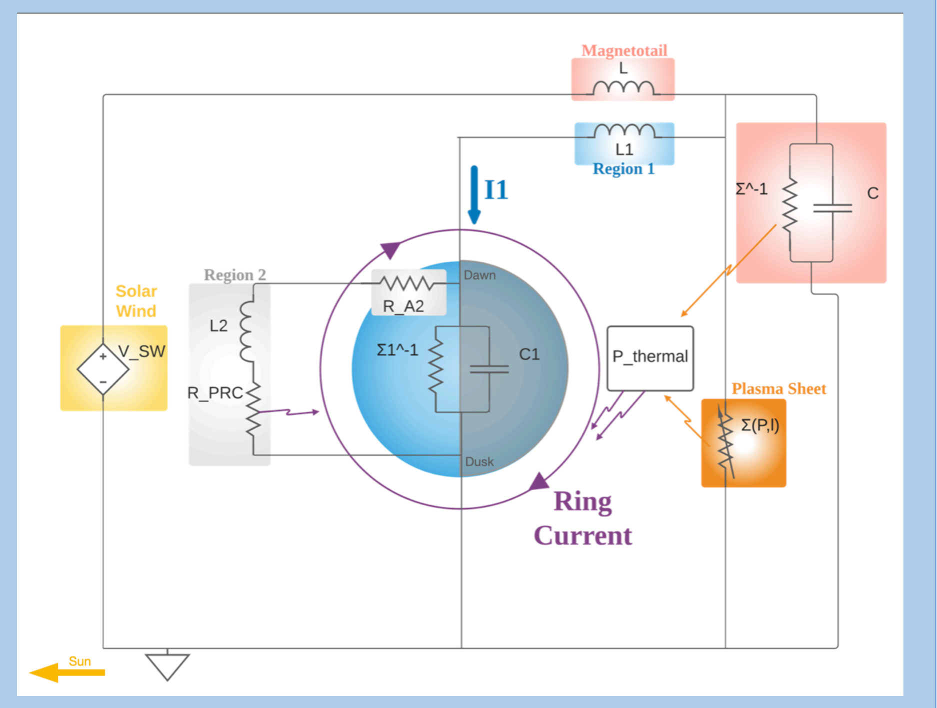

Fig B1: WINDMI Circuit Diagram

eq1) $$U_{magnetic} = \int_{\text{lobe}} \frac{B^2}{2\mu_0} d^3x = \frac{1}{2}\mathscr{L}_{Kp} I^2$$

eq2) $$U_{electric} = \int_{\text{CPS}} \frac{1}{2}\rho_m u_\perp^2 d^3x = \frac{1}{2} C_{Kp} V^2$$

eq3) $$U_{kinetic} = \int_{\text{CPS+PSBL}} \frac{1}{2}\rho_m u_\parallel^2 d^3x = K_\parallel$$

WINDMI Circuit Model The WINDMI[1] model treats plasma populations as circuit elements which carry and transfer electric, magnetic and thermal energy. The advantage of this approach is near instant run time for space weather prediction.

E: FUTURE WORK: IONOSPHERE ELECTRODYNAMICS

Current Accounting EM energy contributions from the ionospheric region are separated by type (Electric, Magnetic, Thermal). The location is determined by the signs of the potential and field aligned currents.

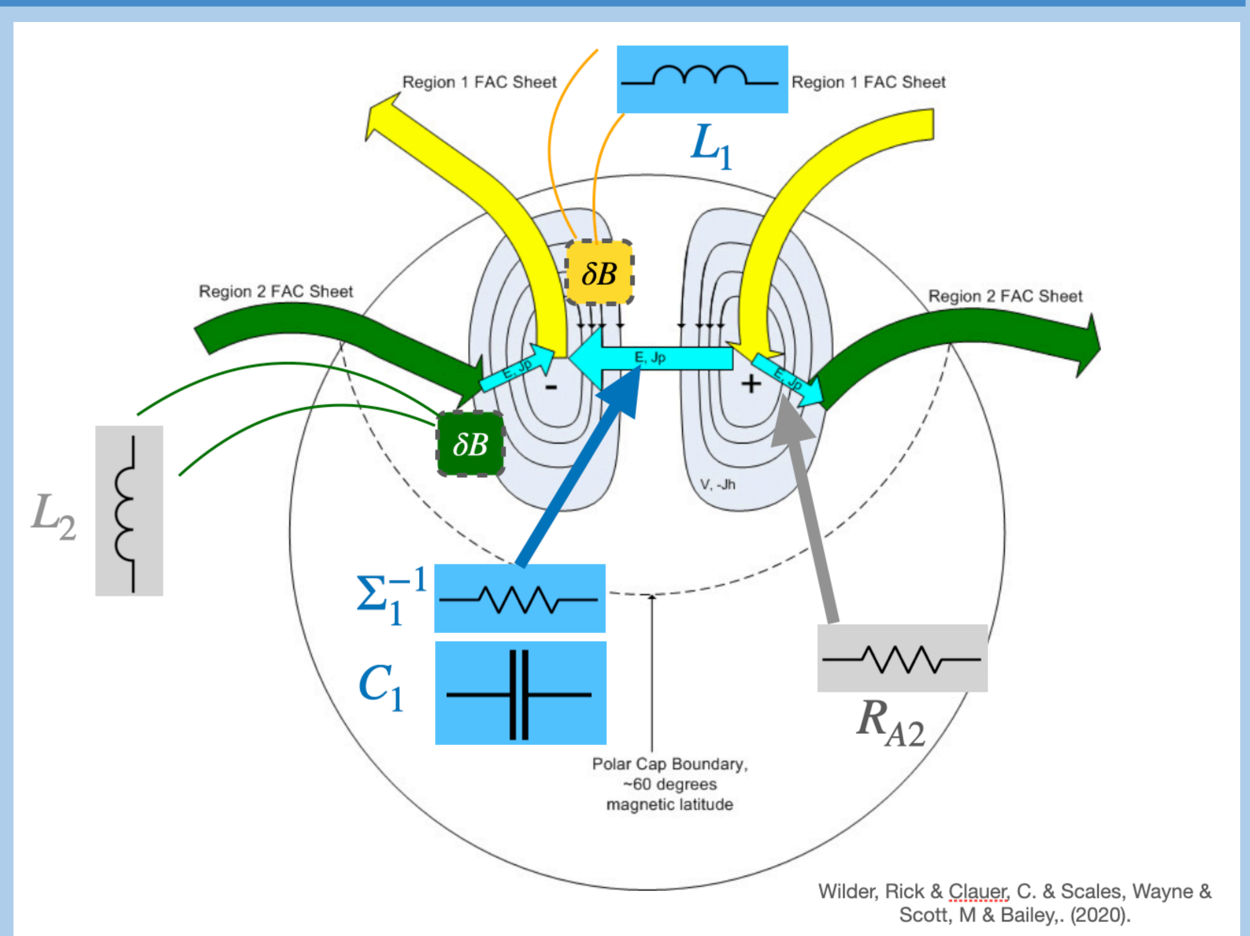

Fig E1: Ionosphere current systems as circuit elements

D: CONCLUSIONS

Component comparison Circuit models like WINDMI have the capacity to predict important plasma dynamics which can be beneficial for space weather forecast as seen in Figure D1. Improvements to the WINDMI component modeling could improve predictive capability at little extra cost.

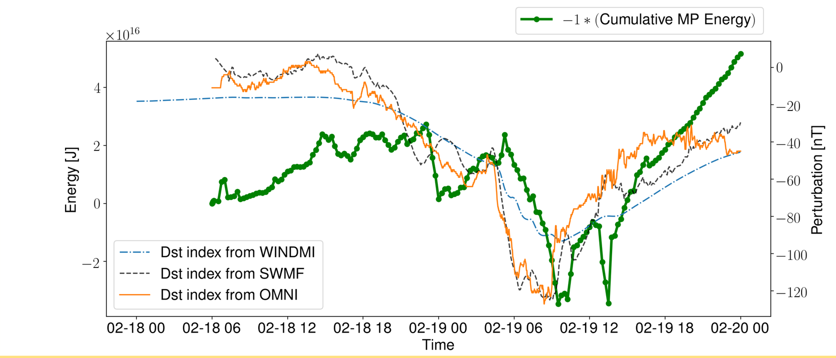

Fig D1: Space Weather Index and Energy

REFERENCES

[1] Spencer, E., Horton, W., Mays, M. L., Doxas, I., and Kozyra, J. (2007), Analysis of the 3–7 October 2000 and 15–24 April 2002 geomagnetic storms with an optimized nonlinear dynamical model, *J. Geophys. Res.*, 112, A04S90, doi:10.1029/2006JA012019.

[2] Tóth, G., et al. (2005), Space Weather Modeling Framework: A new tool for the space science community, *J. Geophys. Res.*, 110, A12226, doi:10.1029/2005JA011126.[2] S. Taylor and P. Pix, J. Appl. Phys. **101**, 2389 (2009).