BIRKELAND CENTRE
FOR SPACE SCIENCE

A consistently derived set of empirical models for high-latitude electrodynamics

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UNIS The University Centre in Svalbard
NTNU Det skapende universitet

I. How do we improve estimates of key I-T parameters?

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Five studies in past two years* call for improved estimates of key I-T parameters:

- Joule dissipation
- Ionospheric conductances
- Poynting flux and EM energy deposition

In my view (I recuse coauthors!), **two unnecessary sources of uncertainty** in existing empirical models of high-lat ionospheric electrodynamics:

I. **Assumption of hemispheric mirror symmetry** when sign of dipole tilt, IMF By is reversed
II. **Inconsistent derivation** (e.g., differing coordinate systems and/or assumptions about hemispheric symmetry)

This study asks: **Can we improve estimates of I-T parameters by dumping these two sources of uncertainty?**

*Heelis and Maute (2020); Öztürk et al. (2020); Palmroth et al. (2020); Weimer and Edwards (2021); Richmond (2021)

II. “What uncertainty/error?”

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$\Delta B_{\parallel}$ from AMPS* model is different by nearly 50% at conjugate points between hemispheres!

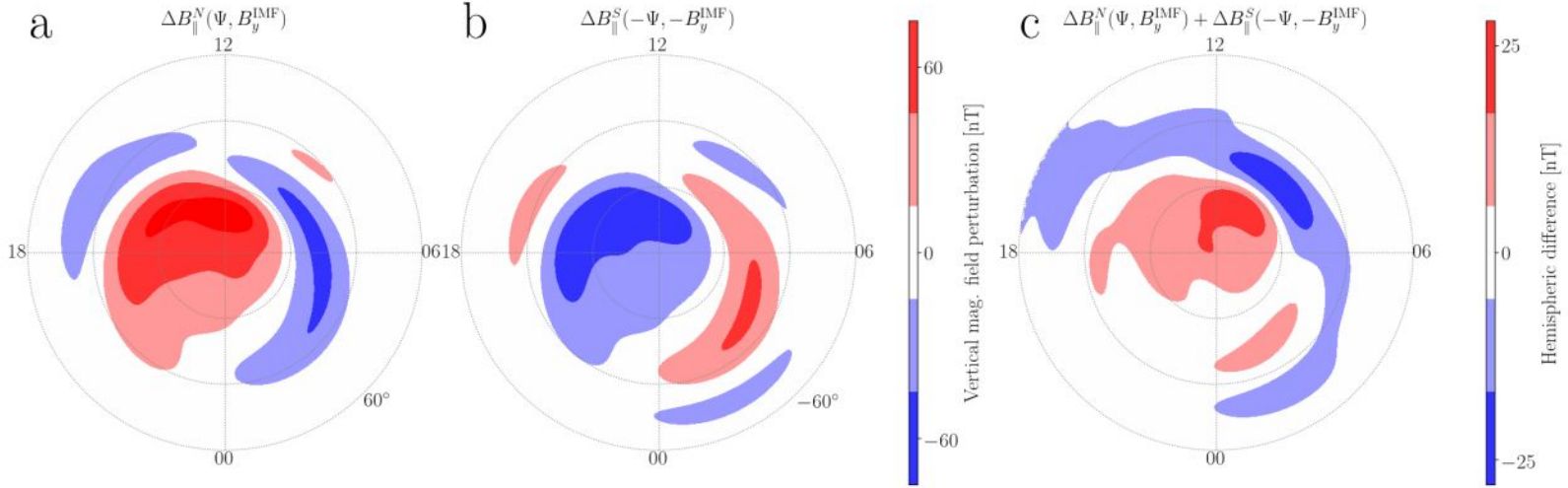

Figure 3: (a) $\Delta B_{\parallel}$ from the AMPS model in the Northern Hemisphere for $\Psi = 20°$ and $B_y^{\mathrm{IMF}} = 4$ nT. (b) $\Delta B_{\parallel}$ in Southern Hemisphere with signs of Ψ and B_y^{IMF} flipped. (c) Sum of $\Delta B_{\parallel}$ in panels a and b, cf. Eq. (2). **It is often assumed that the distribution of $\Delta B_{\parallel}$ in each hemisphere is identical under antisymmetric conditions. Panel c shows that this assumption is false.**

*Laundal et al (2018)

III. Two Swarm models: AMPS + SHEIC

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AMPS (Average Magnetic field and Polar current System; Laundal et al, 2018)
SHEIC (Swarm HEmispherically resolved Ionospheric Convection; **this presentation**)
SWEEP=SHEIC + AMPS (Swarm Electrodynamics and Electric Potential; **this presentation**)

- Swarm B- and E-field measurements
- Spherical harmonics in Apex coordinates (handles non-orthogonality of geomagnetic field!)
- Five inputs: IMF By, Bz; SW speed; Newell coupling function; dipole tilt angle

Conductances

$$\Sigma_H = \frac{\hat{\mathbf{r}} \cdot (\mathbf{J}_\perp \times \mathbf{E}_\perp)}{|\mathbf{E}_\perp|^2}$$

$$\Sigma_P = \frac{\mathbf{J}_\perp \cdot \mathbf{E}_\perp}{|\mathbf{E}_\perp|^2}$$

Joule dissipation

$$W_J = \mathbf{J}_\perp \cdot \left(\mathbf{E}_\perp + \mathbf{U}_n \times \mathbf{B}_0\right)$$

Poynting flux

$$\mathbf{S}_p = \frac{\mathbf{E}_\perp \times \Delta\mathbf{B}}{\mu_0}$$

SWEEP

$\mathbf{E}_\perp$ SHEIC — This presentation!

$\mathbf{J}_\perp, \Delta\mathbf{B}$ AMPS (Laundal et al, 2018)

$\mathbf{U}_n$ HL-TWiM or HWM21 (Dhadly et al, 2019)

$\mathbf{B}_0$ IGRF 12 (Thébault et al, 2015)

IV. Pictorial representation

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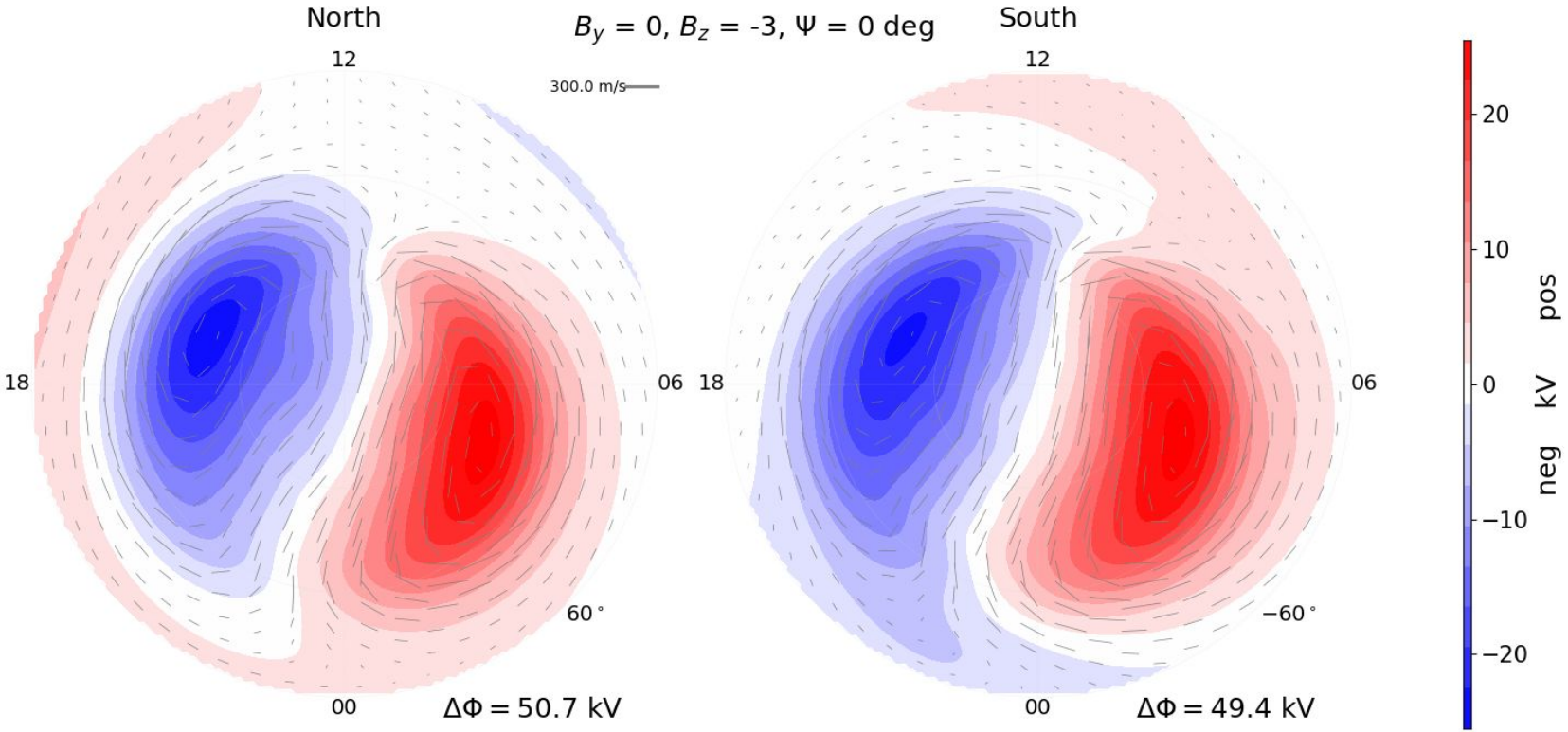
Get **E** from SHEIC …



IV. Pictorial representation

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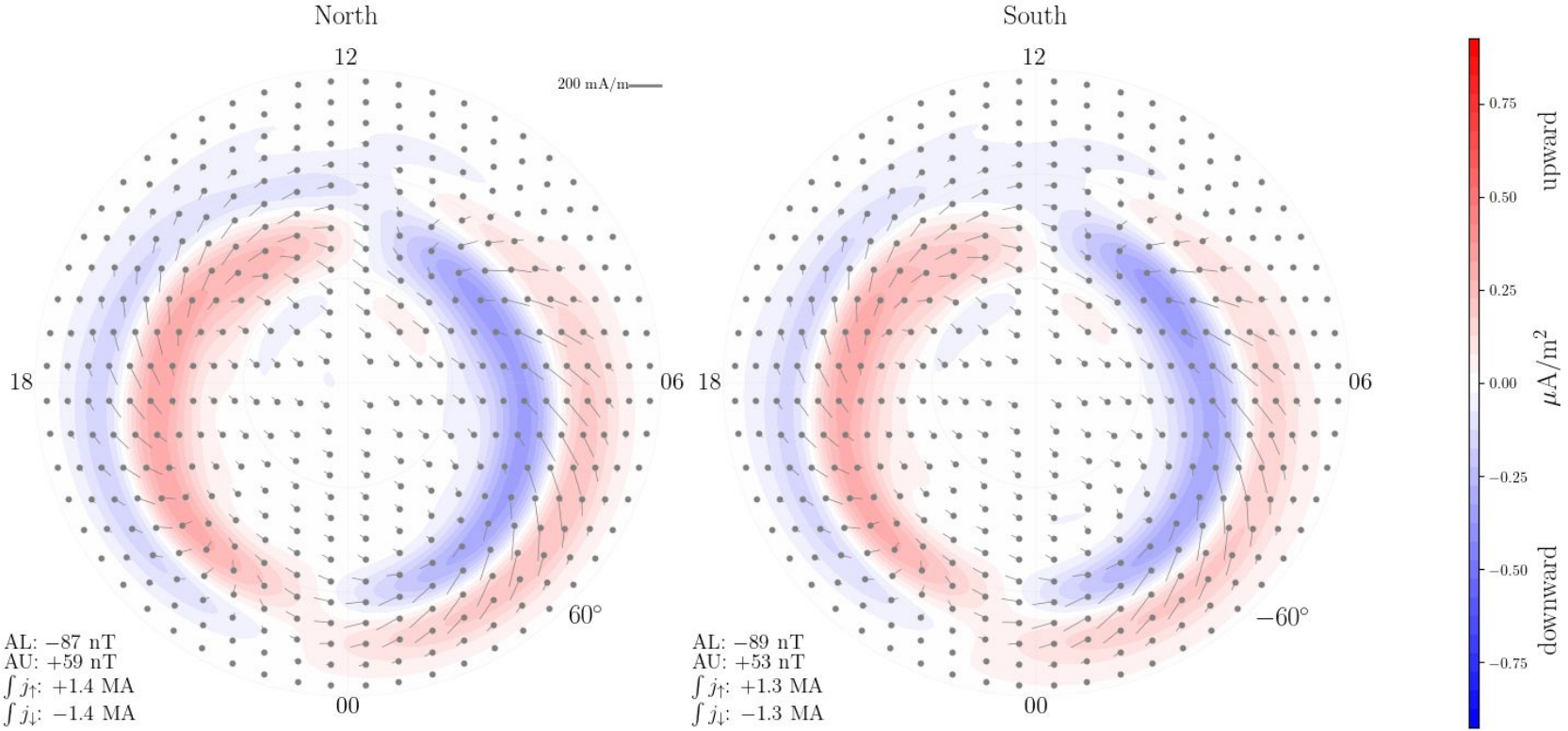
Get ΔB, J from AMPS …



IV. Pictorial representation

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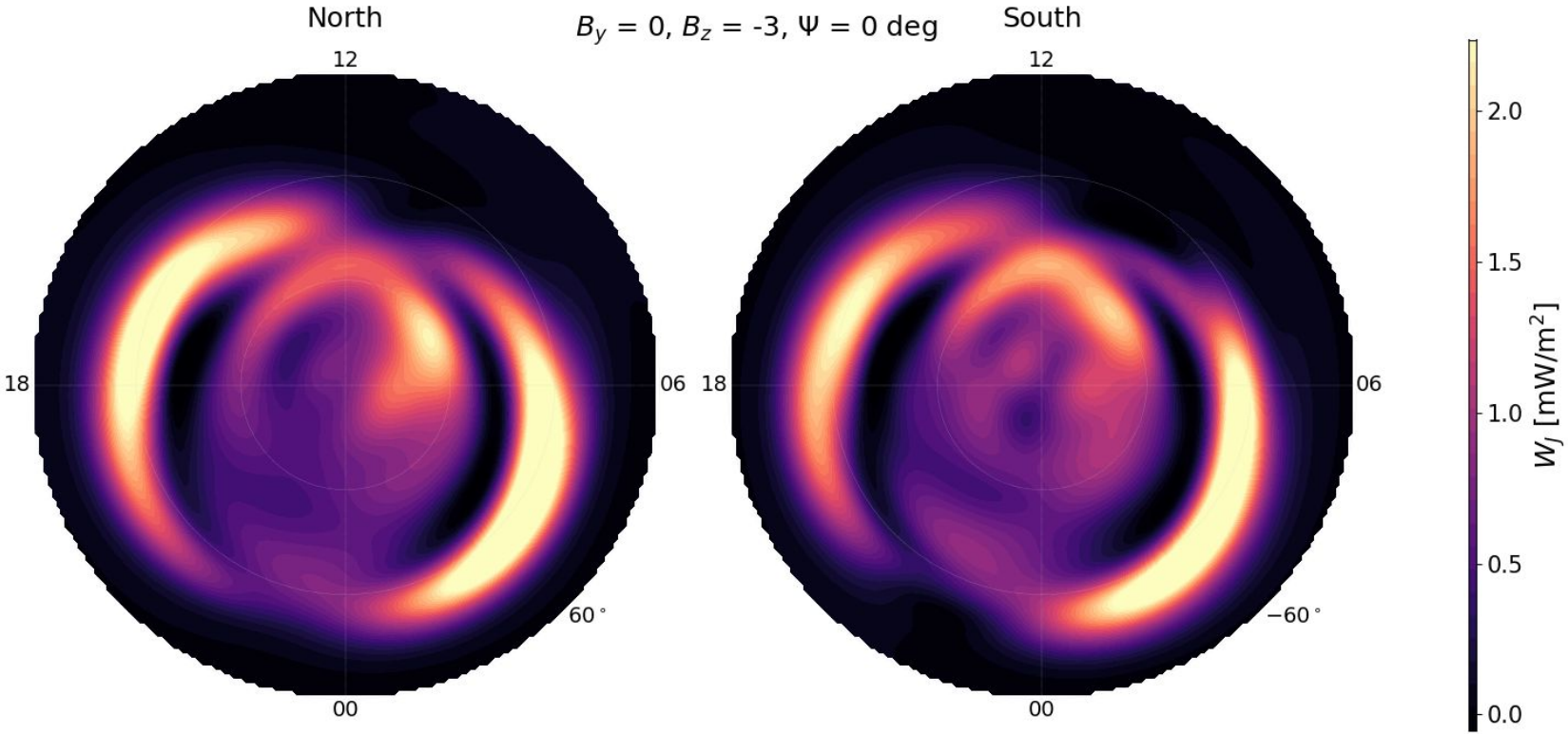
Combine to get Joule Heating:

$$W_J = \mathbf{J}_\perp \cdot \mathbf{E}_\perp$$



IV. Pictorial representation

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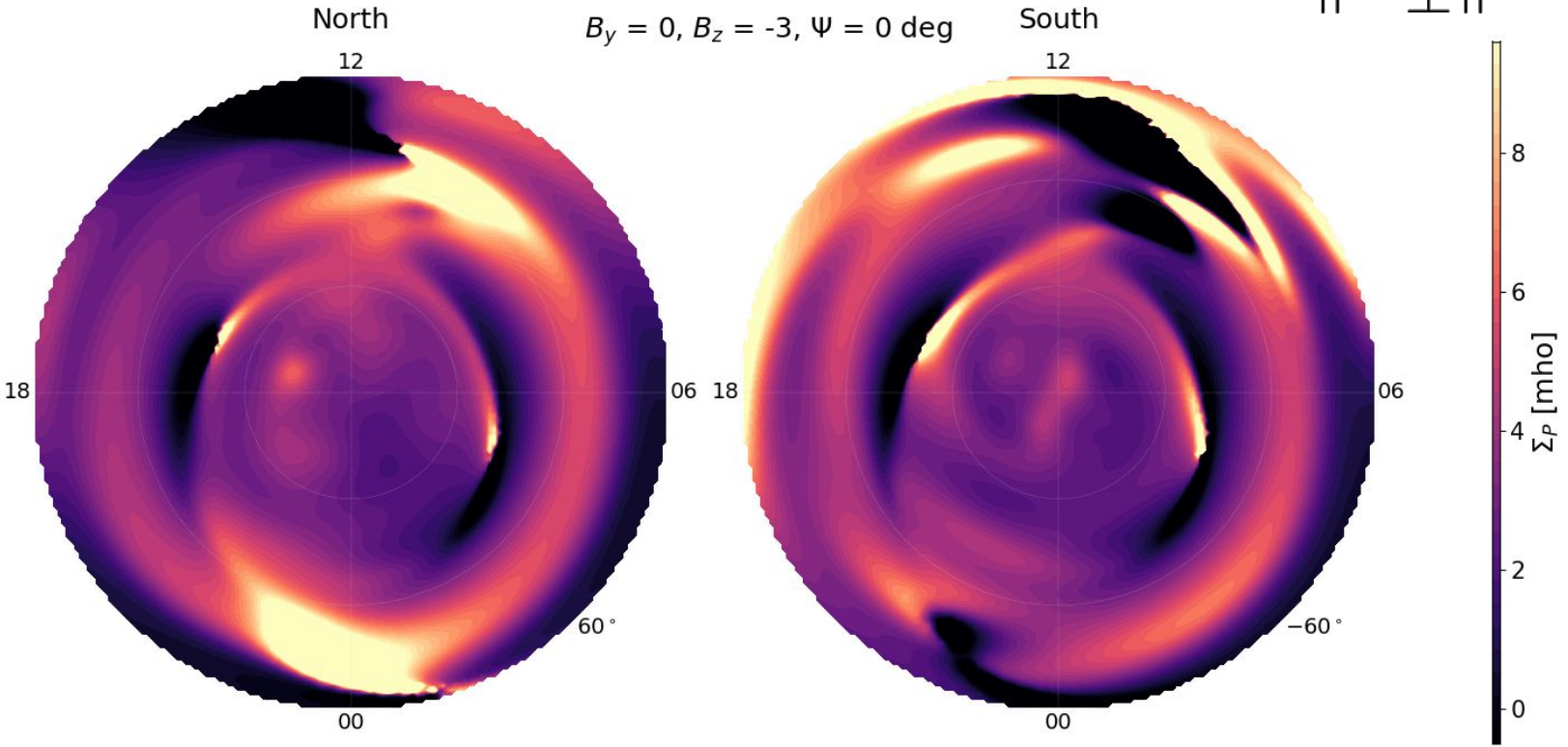
… Or Pedersen conductance:

$$\Sigma_P = \frac{\mathbf{J}_\perp \cdot \mathbf{E}_\perp}{\|\mathbf{E}_\perp\|^2}$$



IV. Pictorial representation

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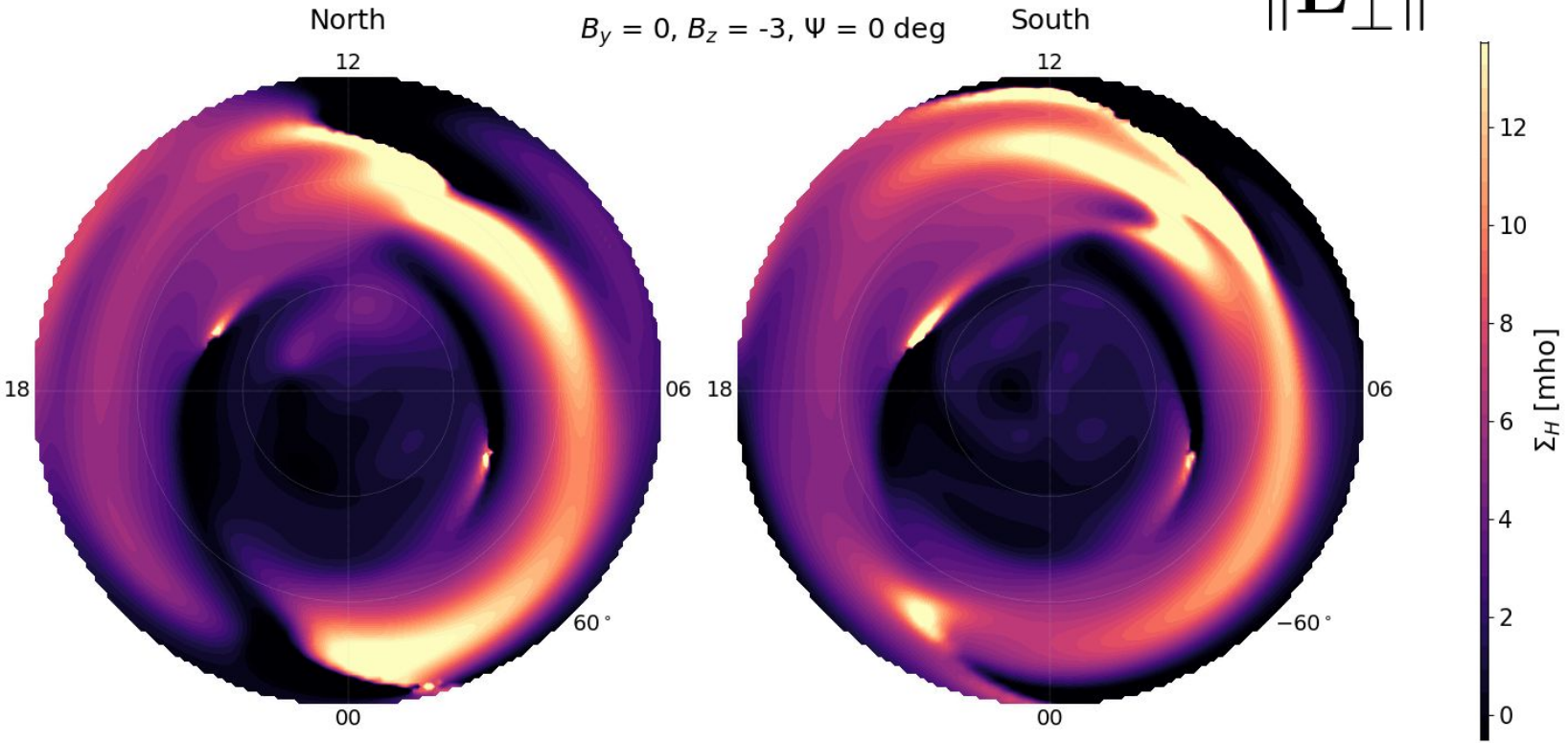
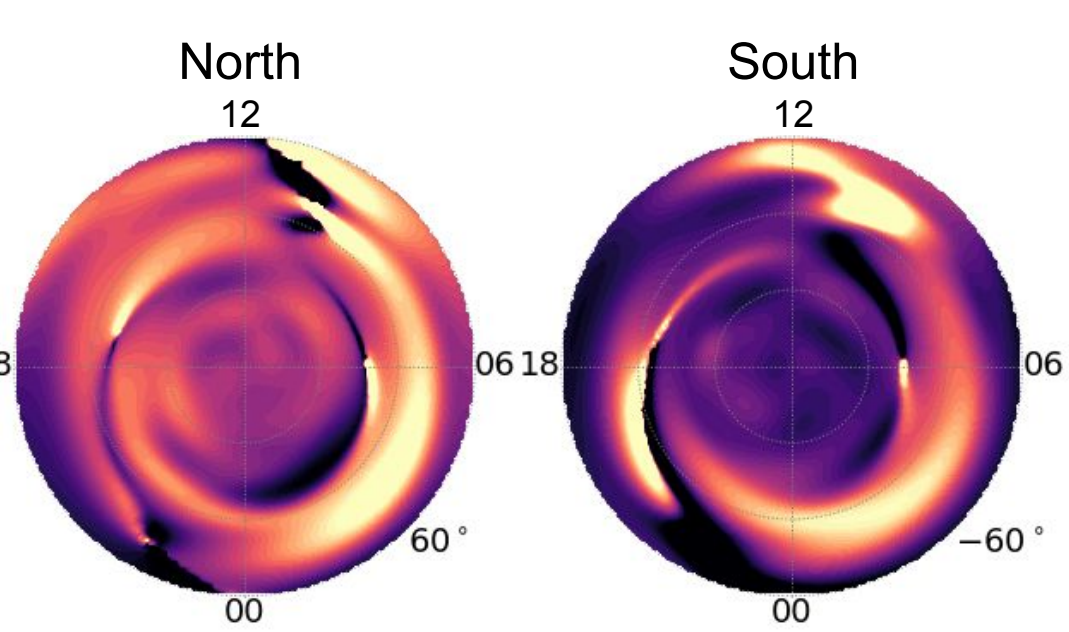
… Or Hall conductance:

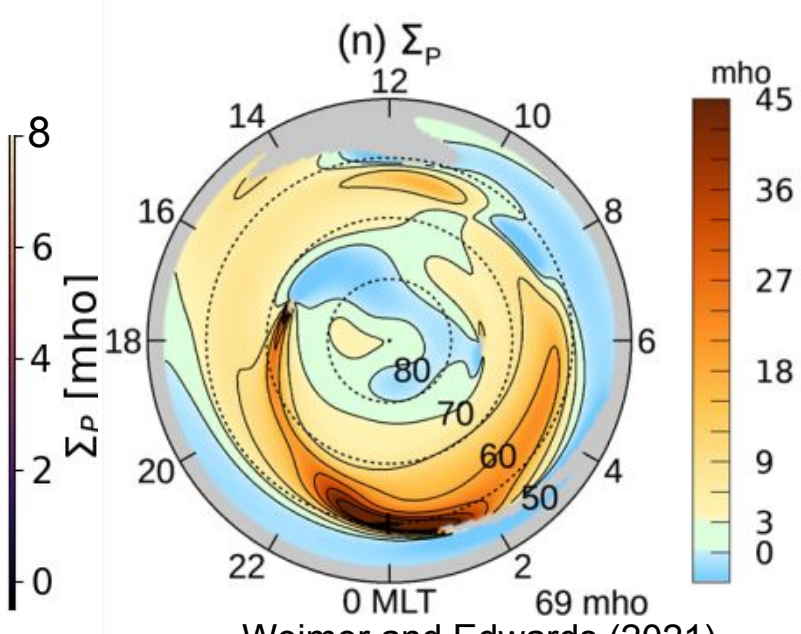
$$\Sigma_H = \frac{\hat{\mathbf{r}} \cdot (\mathbf{J}_\perp \times \mathbf{E}_\perp)}{\|\mathbf{E}_\perp\|^2}$$



V. Questions and problems

Why do we and Weimer+Edwards get negative conductances? Lacking neutral winds …





Weimer and Edwards (2021)
Bz = -10 nT

VI. Conclusions

Many recent calls for better estimates of key I-T parameters

Our new Swarm-based models, SHEIC and SWEEP, eliminate uncertainties related to **coordinate systems**, **assumptions about hemispheric conjugacy,** and **use of different combinations of instruments**

We estimate :

- Joule dissipation and Poynting flux (separately!)
- Pedersen and Hall conductances

Questions:

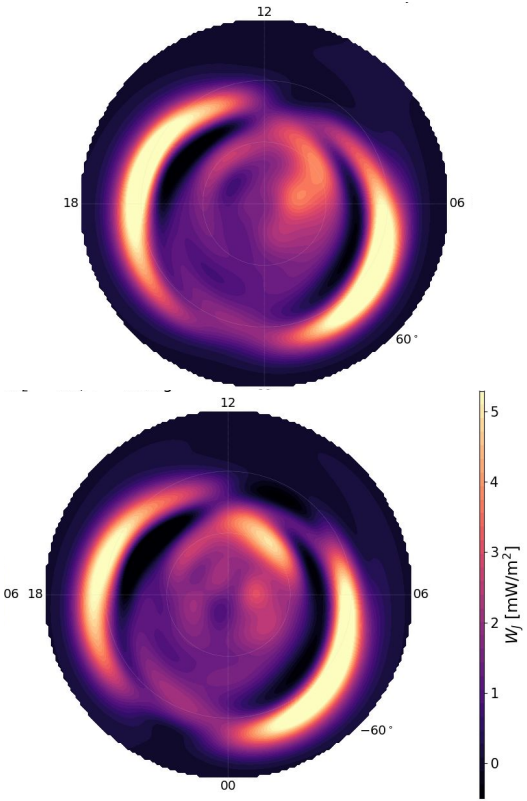
- How do Poynting flux and Joule dissipation differ in each hemisphere?
- How to address negative conductances (must be neutral winds?)? Weak Pflux/Joule diss.?

Plan to publish open-source with Python frontend

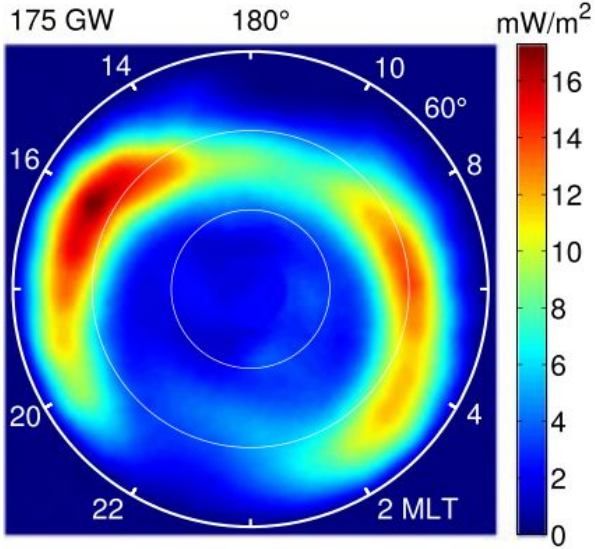
BACKUP SLIDES

Questions

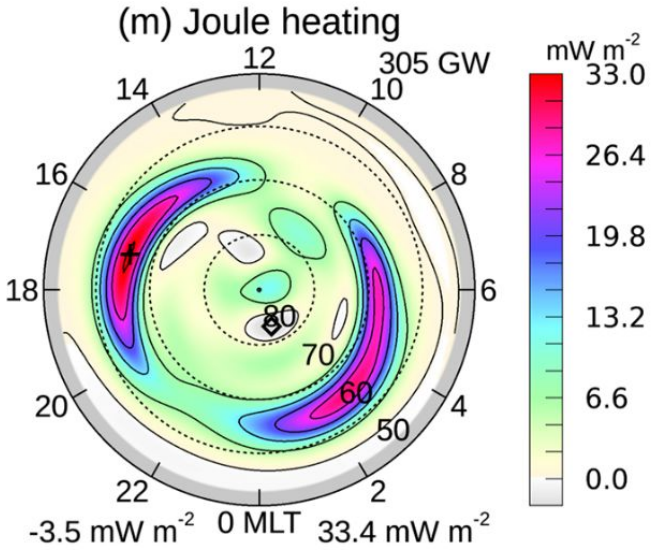
- Why is Joule dissipation so much weaker with SHEIC/SWEEP model?



Poynting flux



Cosgrove et al (2014)
Bz = -5 nT



Weimer and Edwards (2021)
Bz = -10 nT