Swarm-based empirical models of high-latitude ionospheric electrodynamics

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TL;DR

- **What:** We use Swarm magnetic field and cross-track ion drift measurements to make the Swarm Ionospheric Polar Electrodynamics (Swipe) model. It produces estimates of ionospheric convection (**Fig. 1**), height-integrated electromagnetic work (≠ height-integrated Joule heating) (**Fig. 2**), Hall conductance (**Fig. 3**), Pedersen conductance (**Fig. 4**), and Poynting flux (not shown).
- **Why:** **(i)** No one has tested to what extent these quantities above exhibit hemispheric mirror symmetry with respect to reversal of the signs of IMF By and dipole tilt;
(ii) Conductance is a holy grail in ionosphere-thermosphere electrodynamics.
- **Findings:** **(i)** Hall and Pedersen conductances show hemispherically asymmetric responses to dipole tilt;
(ii) Ionospheric convection and electromagnetic work in each hemisphere mostly exhibit mirror symmetry.
(iii) Distinguishing between electromagnetic work and Joule heating helps determine where conductance estimates are likely to be valid.
- Full description of the Swipe model and results available in **Ref. 1**.
- Want to run Swipe yourself? Installation is as easy as `pip install pyswipe` at the command line!

The Swipe Model: Some Design Choices

The Swipe model itself depends on two other models: the Swarm High-latitude Convection (Swarm Hi-C) model [**Ref. 1**], and the Average Magnetic field and Polar current System (AMPS) model [**Ref. 2**]. The former provides ionospheric convection and the ionospheric electric field, and handles the "Heppner-Maynard boundary" by forcing the ionospheric potential to be zero at ±47° in Modified Apex coordinates. The latter provides currents and magnetic field measurements. Both models

- Are based on Spherical harmonics in Apex coordinates;
- Are parameterized using the same model parameters (IMF *By*, IMF *Bz*, dipole tilt, F10.7);
- *Treat each hemisphere completely independently (arguably a first!)*

Fig 1. Ionospheric potential for 0° dipole tilt (equinox) in the Northern Hemisphere (colored contours) and Southern Hemisphere (black contour lines) as a function of IMF clock angle. The sign of IMF *By* is reversed for the Southern Hemisphere.

Upshot: Ionospheric potential patterns look very symmetric between hemispheres. This is the case during equinox, *and* for local winter and local summer conditions (not shown here; see **Ref. 1**).

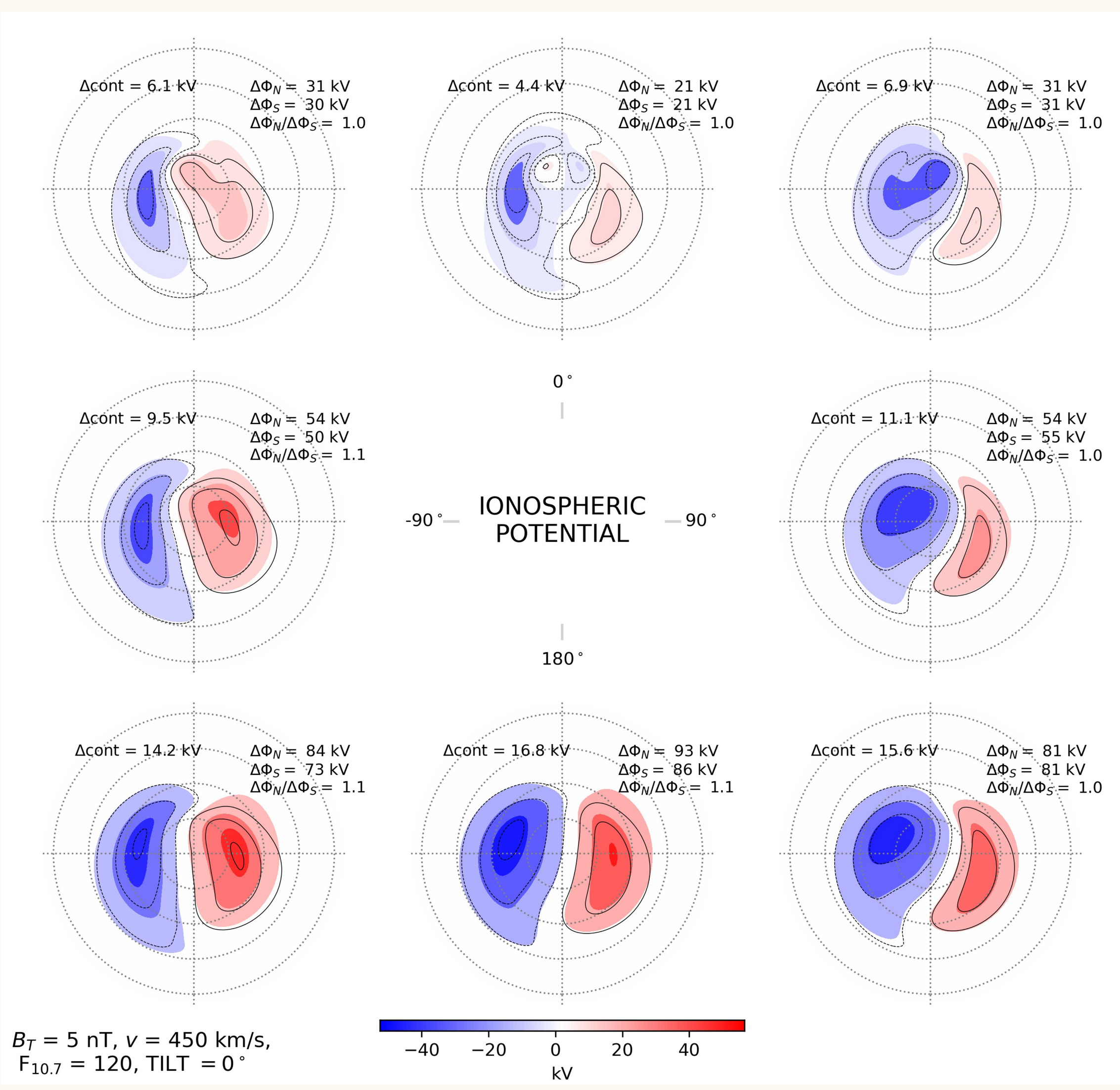


Fig 2. Electromagnetic work W = **J·E** in the same format as Fig. 1 in an Earth-fixed frame, with **J** the perpendicular current from AMPS and **E** the electric field from the Swarm Hi-C model.

Upshot: EM work patterns look very symmetric between hemispheres. We make a fuss about distinguishing between EM work and Joule heating because *we have no information about neutral winds.*

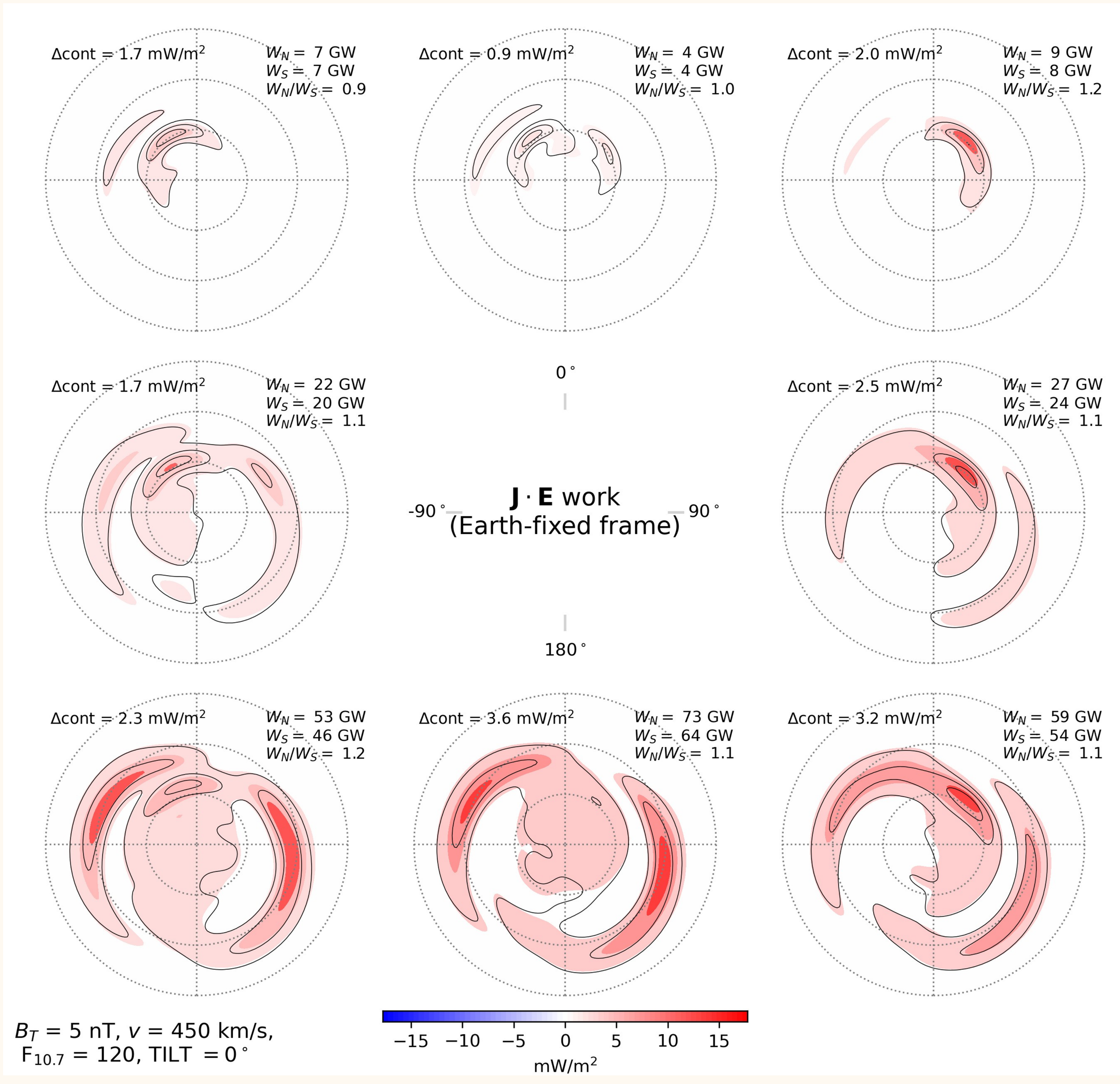


Fig 3. Hall conductance $\Sigma_H = \mp \mathbf{r}\cdot(\mathbf{J}\times\mathbf{E})/|\mathbf{E}|^2$ in the same format as Fig 1. Areas where the reliability criteria $W \geq 0.5$ mW/m² and $\Sigma_H \geq 0$ mho are not met are shown in gray. Note: the outermost contours in both NH and SH distributions mainly indicate the boundary of where the criteria are met, so these contours are not useful for assessing hemispheric differences.

Upshot (not shown!): Hall conductance patterns are semi-symmetric between hemispheres. From local winter to local summer Hall conductances tend to *decrease* in the NH, but do not change in the SH.

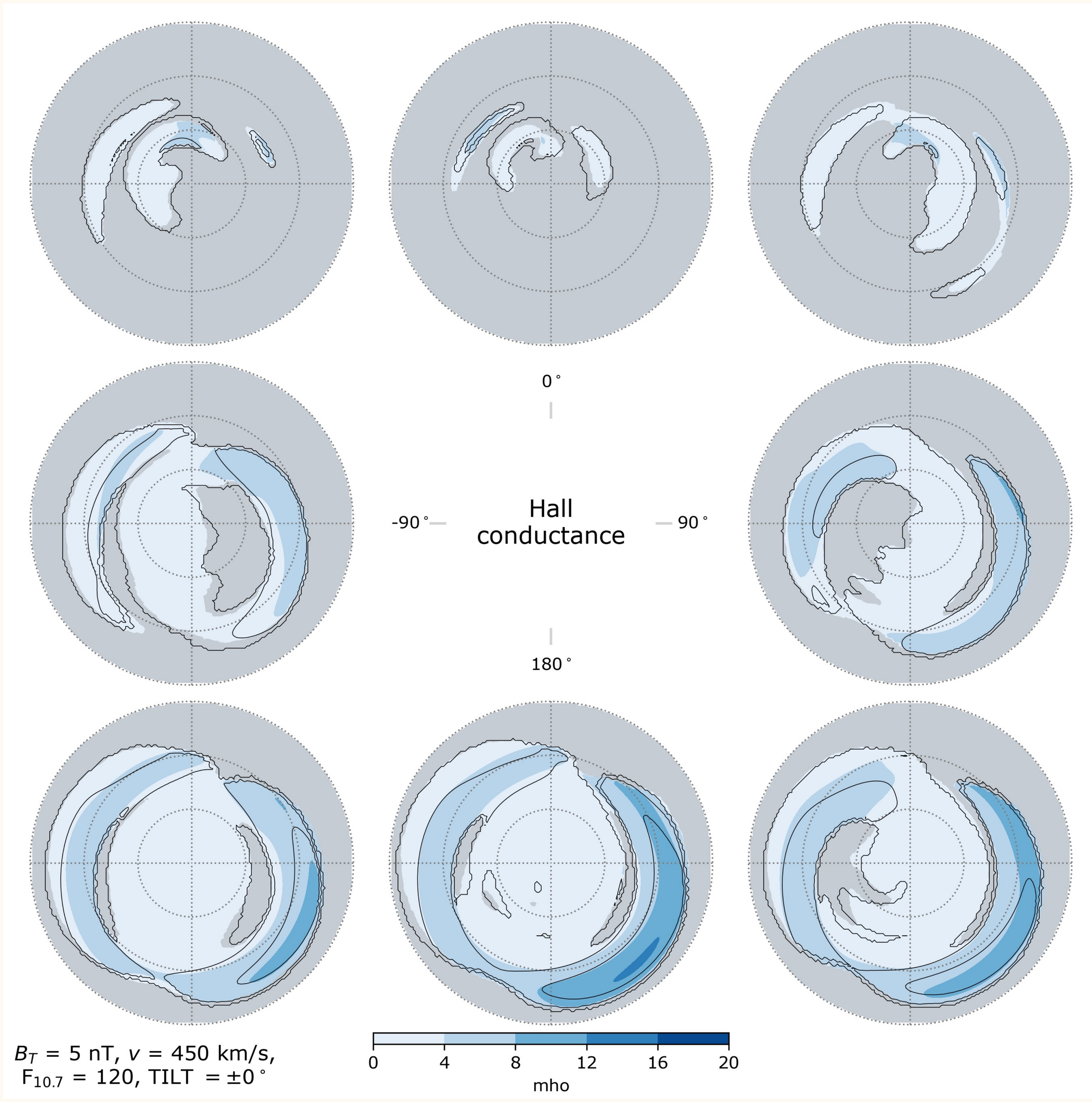
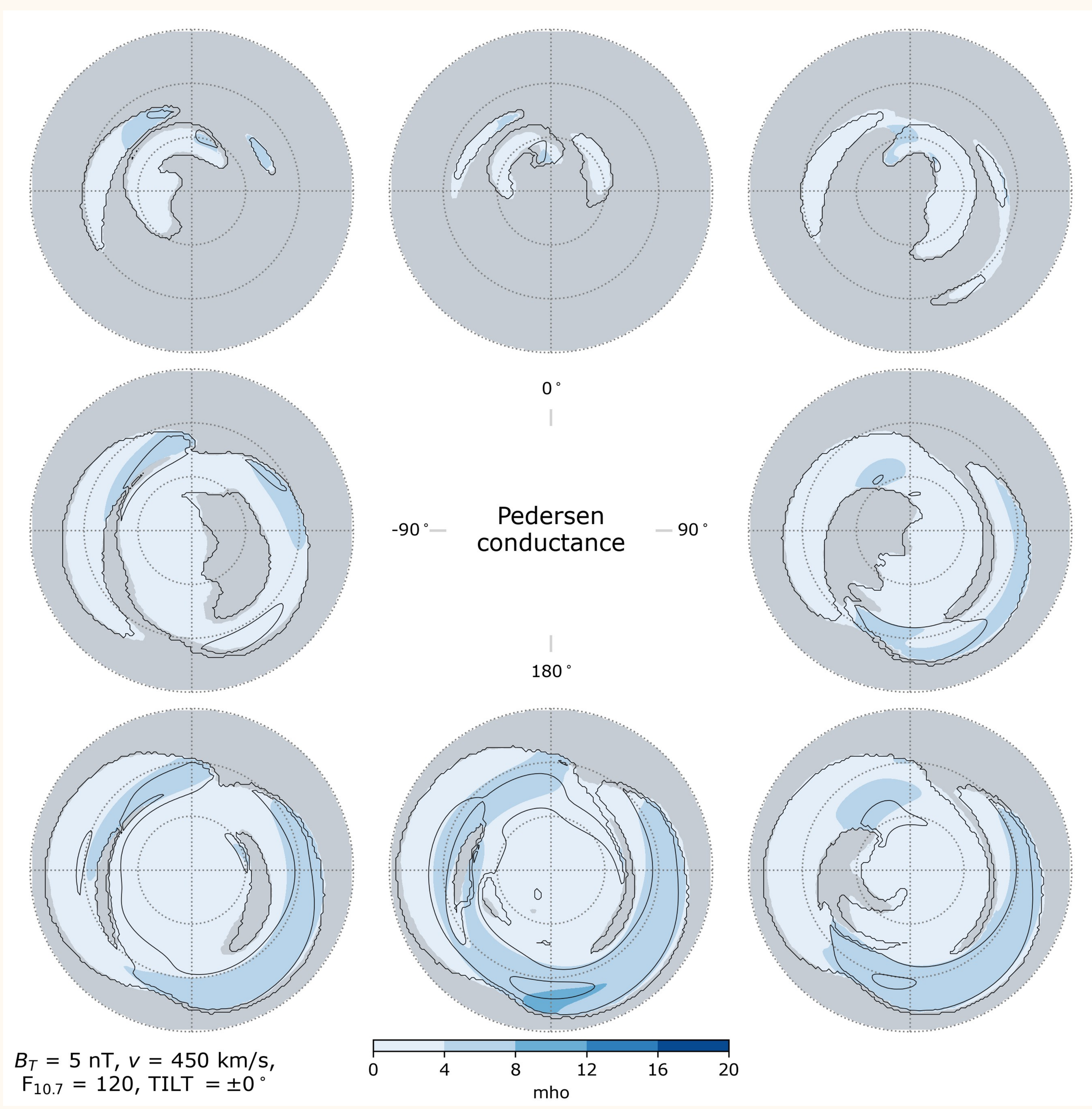


Fig 4. Pedersen conductance $\Sigma_P = \mathbf{J}\cdot\mathbf{E}/|\mathbf{E}|^2$ in the same format as Fig 1. Areas where the reliability criteria mentioned in Fig. 3 caption are not met are shown in gray.

Upshot (not shown!): Pedersen conductance patterns are semi-symmetric between the two hemispheres. From local winter to local summer Pedersen conductances on the nightside tend to *decrease* in the NH, but do not change much in the SH.



What's next?

We'll soon publish a paper showing why it is unlikely that anyone will be able to realistically represent the neutral winds in 2D models of ionosphere-thermosphere electrodynamics (like the Swipe model) in the near future. Ask for details!

REFERENCES

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ACKNOWLEDGEMENTS

This study is supported as part of Swarm Data, Innovation, and Science Cluster (DISC) activities, and is funded by ESA contract no. 4000109587/13/I-NB as well as the Trond Mohn Foundation, Research Council of Norway Contracts 300844 and 223252/F50.

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