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Discussions

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Interactive comment on "Entangled Dynamos and Joule Heating in the Earth's Ionosphere" by Stephan C. Buchert

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The paper "Entangled dynamos and Joule heating in the Earth's ionosphere" provides a model of energy generation and dissipation at mid latitudes, based on interhemispheric asymmetry of neutral winds and on the assumption that magnetic field lines are, essentially, equipotential. A key feature of the model is the use of two reference systems, moving separately with the neutral atmosphere at the two conjugate ends of the magnetic field line. It is pointed out that these two systems are the right choice to investigate energy dissipation, complemented by energy generation in the opposite hemisphere, while any other aether-like system, e.g., a system fixed to the Earth, is arbitrary and not appropriate to address the matter.

I fully agree with this perspective and, altogether, I see the paper as a valuable contribution to the field. I shall be happy to recommend publication, as soon as the issues below are taken care of.

1. Using two reference systems has obvious merits, but it is at the same time challenging, in particular by introducing two instances of the Poynting flux. This is detailed in the Discussion section, though I think that the clarity of the message may benefit from sub-sectioning and some re-arrangement:

1a. More specifically, the three paras from p.12, L17 ("We claim that. . .") up to p.13, L21 (". . .and heating effects") could be moved to p.9, L 26, after the para describing the main features of the model. The first part of Section 5, up to this point, together with the three paras, could make the first sub-section of the Discussion, emphasizing the need for two reference systems.

1b. The rest of the Discussion could be organized in two more sub-sections, one on quantitative estimates of Sq Joule heating (from p.9, L26 up to p.12, L16), and one on applying the model to high latitudes (from p.13, L22 to the end of the Section).

2. Speaking about high latitudes, these are associated in the paper with open field lines, both in the last part of the Discussion and in the Conclusions (e.g., p. 16, L8). As a matter of fact, much of the energy dissipation takes place in the auroral region, which is believed to be threaded (mostly) by closed field lines, that connect the two hemispheres via the plasma sheet in the magnetosphere. However, in this case plasma parameters do not preclude any more parallel electric fields (e.g., much lower density compared to plasmasphere). The open field lines are in general associated with the polar cap, where energy dissipation is limited. As of now, the discussion on high latitudes refers mainly to open field lines / polar cap, while the specific case of the auroral region is just touched a bit, implicitly, in the second last para of the Conclusions. Please complete the Discussion and Conclusions by addressing explicitly the auroral region, where the key feature is the parallel electric field on closed field lines.

3. The mapping between the two hemispheres could be emphasized by adding the two respective reference systems, (x, y, z), N and S, on the side of Figs 3 and 4, with the x axis pointing northward in N and southward in S. This would also clarify the '+' sign in Equation 5. It would help as well to add J_N and J_S explicitly before Eq. (5), $J_N = \Sigma_N \hat{E}_N$ and $J_S = -\Sigma_S \hat{E}_S$.

4. The proxy in Eq. (15) is probably derived by assuming that ion-neutral collision frequency and ion gyro-frequency are roughly equal in the dissipation layer Δz. Please make this clear.

5. I presume the final text will include also the adjustments added in the Author comment – which are not addressed any more here.

6. Minors

p.2, L12: interferE

L15: conductance => conductivity

p.3, Fig. 1: Please increase the figure (zonal wind arrows are not visible) and font size (in particular for the Legend).

L4: Perhaps complete the sentence with: ". . . on the E side, which is the standard form of Lorentz transformation for non-relativistic velocities, u."

Eq. (3): Delete Σ_P in the second term.

p.4, L13: . . .connecting either the latitude lines '1', or the latitude lines '2', or both.

L15: are from of Galilei

p.5, L9: current => FACs

p.6, L3: frame => frame with

L6: surrendered => relaxed (?)

L11: an opportunity => a stronger motivation (?)

p.7, L1: closeS

p.9, L27: and or or

L29: and simulations => nor simulations (?)

p.10, L9: but => therefore

L15: from a with

L22: given => given as well (?)

L32: Delete 'also'. Please explain briefly 'opposite polarity'.

p.11, L30: integrated => integrated over

p.12, L23: to the load => to the load in the opposite hemisphere

L30: as a being

p.13, Eq. (16): According to Eq. (2), I think this should be written as $\hat{E}(z) - u(z)B(z) = const.$ (if mapping is neglected), i.e., electric field in a given, unique reference system, is constant.

L19: the describe . . . confirm Figure 1

L27: It is well accepted => please provide reference.

p.14, Eq. (17): The '+' sign on the r.h.s. should be '-', similar to Eq. (2).

Eq. (18): Both '+'signs on the r.h.s. should be '-': the first, same as above; the second, satellite velocity with respect to neutral atmosphere is $v_{orb} - u$.

L23: Considered => Considered first (?)