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

Anonymous Referee #2

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Review comments on the manuscript MS angeo-2019-71: "Entangled Dynamos and Joule Heating in the Earth's Ionosphere" by S. Buchert

The author has provided a detailed description of current generation and dissipation processes in the mid-latitude ionosphere. An important message is the fact that a correct picture only emerges when the processes at conjugate locations in the hemispheres are considered simultaneously. Even though this is a valid claim, the way it is presented is not intuitive and obviously difficult to digest for readers. An indication for that is the long time (about 8 months) and many rejections it took to find referees for the paper. It definitely needs improvement. Otherwise one may ask, what is the purpose of a paper that nobody understands and not taken notice of.

General comments

The presentation of examples could be a little bit more constructive and easier understandable of the readers. It is good that scenarios in different reference frames are outlined, but it would be helpful to focus more on the frame independent quantities. These are, e.g. B-fields, currents, energy dissipation, and velocity difference between plasma drift and wind velocity. I find it not helpful when you state that in the case of Fig. 3 the NH is the sink and SH the dynamo and in case of Fig.4, where you just have changed the reference frame, NH is the dynamo and SH the dynamo. You should have described what actually happens, it is the competing wind-generated E-fields in the two hemispheres that prevents the plasma from moving thus gives equal frictional heating in both hemispheres.

In the case of different conductances (Figs. 5 and 6) you correctly state that power dissipation is higher in the low conductivity hemisphere. Both these examples had been much easier to be understood if you had added also the plasma drift and calculated the frictional heating in the hemispheres.

Specific comments

Abstract: The dynamo effect is not limited to different winds in the two hemispheres. Also differences in conductivity, B-field strength, field configuration, etc. can be responsible generating currents.

Pg. 9, line 7: In the past versions of first-principle ionospheric electrodynamic models the relation E + u x B = 0 was actually maintained by adjusting the wind velocity u. In the latest version of TIEGCM also other currents such as gravity-driven or plasma pressure gradient currents are considered. Therefore, these models now have a 3D electrodynamic solver that maintains current continuity and equal potentials at conjugate locations. For more details see Richmond and Maute (2014) doi:10.1002/9781118704417.ch6

Line 25: I would suggest to change to "…dependence only on relative motion between plasma and neutral gas, no reference to absolute frames."

Lines 26-29: It is not clear to me what these sentences want to state.

Pg. 10, lines 24-28: Here again, it would be instructive to address also the difference between plasma drift and wind. In particular, since the local plasma drift is the prime measurement of satellites in the ionosphere, not E-field.

Pg. 11, line 5: Concerning inter-hemispheric field-aligned currents (IHFAC) there are more recent results of their mean properties, e.g. Lühr et al. (2020) doi:10.1002/2019JA027419. Furthermore, it has been noticed that these IHFACs do not originate from the Sq focus but there is a group of IHFACs located equatorward of the focus, and another group of IHFACs with mainly opposite current directions is emanating from mid-latitudes above the focus (see Park et al., 2020, accepted, doi:10.1002/2019JA027694)

Line 10: The sentence correctly states that wind energy is extracted from one hemisphere and dissipated as Joule heating in the other. But unfortunately, no estimate of the energy transfer from the summer to the winter hemisphere, relative to the total energy, is given. Only the total energy is estimated. Here again we like to stress the very different IHFAC configurations for June and December solstices although no such seasonal differences are obvious from ground-based maps of Sq patterns.

Pg. 12, lines 19ff: You start again stressing the frame dependence of Poynting flux. This is for me the wrong definition. Poynting flux as such is frame independent. Here again the velocity differences between plasma and neutral in both hemispheres would give a unique picture.

Pg. 15, line 2: It is not clear what is meant by "an isolated neutral wind in a plasma would not result in any steady state dynamo effect."

Lines 4-9: I cannot agree with the suggested principle of Sq generation. The mid-latitude winds are only marginally affected by the plasma dynamics. Therefore, it is the difference in plasma drift response to the winds in conjugate points (depending

on conductivity, B-field strength, wind velocity, etc.) that is communicated along field lines between the hemispheres. Again, the resulting local velocity difference between plasma and neutrals drives the electrodynamic processes. The 12-hour period of the Sq signal is mainly dictated by the atmospheric semidiurnal tide, which is clearly dominating at mid latitudes. Longitudinal variations of the various involved quantities play only a minor role.

Last line: As mentioned above, the 3D electrodynamic solver in TIEGCM avoids potential drops between conjugate points.

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