Author comment on
Entangled Dynamos and Joule Heating in the Earth's Ionosphere

Stephan C. Buchert[1]

[1]Swedish Institute of Space Physics, Uppsala, Sweden

Correspondence: Stephan Buchert (scb@irfu.se)

Abstract.

In this commment I would like to point out a few errors in the manuscript, that in my opinion are minor and do not affect the overall content and conclusions. I apologize for not having noticed all errors and removed them before submission.

Secondly I provide clarifications and statements which are hopefully helpful. They are not additional new conclusions and do not substantially change the conclusions of the manuscript.

1 Correction of Errors and Other Amendments

- Page 3, line 8: "..., and also the cross-B current." will be erased. Currents across field lines in the topside ionosphere and plasmasphere are not relevant in this context, they cannot be excluded, and adding this statement was not justified.

- Page 5, line 7: "... in an westward ..." should be "... in a westward ..."

- In Figure 6 of the manuscript the Poynting flux is erraneously plotted with the wrong polarity. In the reference frame of the southern neutral gas the Poynting flux is into S and out of N. The corrected Figure is shown below.

- the work by Fukushima (1979) is misrepresented in the manuscript. Fukushima theoretically estimated the field-aligned conductivity and so calculated potential differences of a few volts between hemispheres for Sq FACs that had been observed with satellites. Such low voltages are consistent with entangled dynamos. The potential differences arising from uncompensated $\boldsymbol{u} \times \boldsymbol{B}$ fields would be several kilovolts (kV) for a typical Sq vortex. We can get to this estimate in a similar manner as the estimate of the 0.5–2 GW Joule heating by Sq was done in the manuscript: For a total Hall current I_H of ≈ 100 kAa $\langle \Sigma_H \rangle \approx 12$ S the potential drop $I_H / \langle \Sigma_H \rangle$ across the Sq vortex becomes about 8 kV. Without the compensating E^* the potential difference between hemispheres would reach up to twice this value, about 16 kV! The plasma sets up the electrostatic E^*

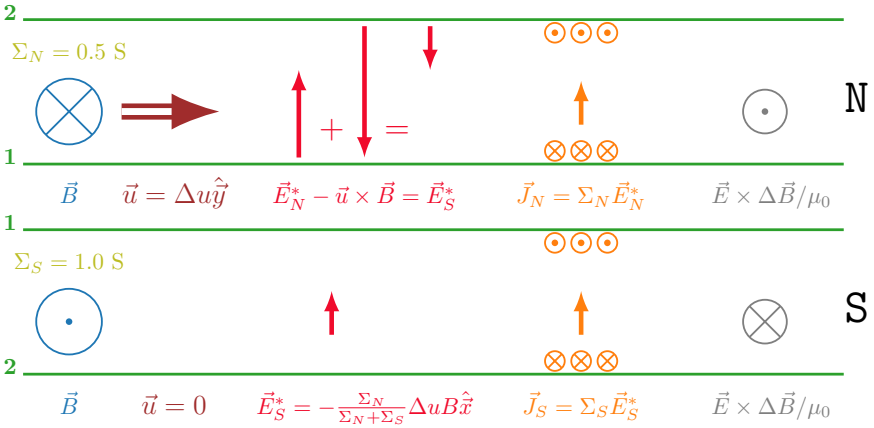

Figure 1. 2-d view like in Figure 5, in the reference of the southern neutral gas. The electric fields are such that for asymmetric conductances $\Sigma_N = 0.5$ and $\Sigma_S = 1.0$ the same current $\boldsymbol{J}$ is obtained. $\boldsymbol{J} \times \boldsymbol{B}$ force and magnetic stress $\Delta \boldsymbol{B}$ are omitted in this Figure. The sizes of the symbols for Poynting flux in Figure 5 and this Figure are according to the flux magnitudes having the same scale.

and so short-circuits potential drops along B. This causes FACs. This means that small remaining voltage drops along B of the order of Volts cannot be avoided. The magnitude of these remaining voltages were estimated already by Fukushima (1979).

I thank again Prof. Fujii for the discussion on this subject.

– the analogy with quantum mechanics is perhaps overemphasized, particularly the reference Greenberger, Horne, and Zeilinger (1989) is only little relevant and can be removed. The analogy is meant purely linguistically in the sense that a system having two components is described using the adjective “entangled.” My intention is to distinguish from “coupled” dynamos, which would exist independently, but interact because they happen to be on the same field-line. The described dynamos cannot exist independently without any “entanglement”. But for future work the “entanglement” concept can be generalized to three and more dynamo layers in the ionosphere.