Review report on “Using the Galilean Relativity Principle to understand the physical basis for magnetosphere-ionosphere coupling processes” by Anthony J. Mannucci et al.

General comments

The authors discuss the problematic interpretation of the electric field in ionospheric electrodynamics, using the “Galilean Relativity Principle” which is a limiting case of the theory of special relativity. While this assertion seems reasonable, the paper includes unacceptable reasoning as I comment below. Also the content of the paper is generally “reinterpretation” of the previous work, without much of scientifically new. However, I think the problem presentation by the authors is useful to the space science community, because such discussion cannot be found in textbooks nor in journal papers. I would like to recommend publication after revision in response to the following comments.

Specific comments

(1) Although I agree with the authors on the conventional problematic interpretation of ionospheric electrodynamics in terms of the electric field, I disagree with the authors’ conclusion that the magnetospheric currents that close in the ionosphere play no role in the magnetosphere-ionosphere coupling (on lines 25-27, lines 414-415, lines 438-440, lines 454-490, lines 522-524). This conclusion is drawn on lines 452-490 by comparing the kinetic momentum of current-carrying electrons with the kinetic momentum of neutrals. I cannot understand the authors’ logic employed. The density of electromagnetic momentum carried by the field-aligned currents is given by

$$\mathbf{p}_m = \frac{\mp\frac{1}{\mu_0} B_0 \Delta\mathbf{B}_\perp}{V_A} = \mp\sqrt{\frac{m_i n_i}{\mu_0}}\Delta\mathbf{B}_\perp \quad \begin{pmatrix} \text{the upper minus sign applies to the northern ionosphere} \\ \text{the lower plus sign applies to the southern ionosphere} \end{pmatrix}$$

and can be comparable to the momentum density of neutrals ($\Delta\mathbf{p}_n$). In fact, in the case of a magnetospheric dynamo, what causes a nonzero relative velocity between ions and neutrals ($\mathbf{u}_i - \mathbf{u}_n$, which is initially zero) is the ion acceleration by the $\mathbf{j}\times\mathbf{B}$ force in the ionosphere. The ions are accelerated until the $\mathbf{j}\times\mathbf{B}$ force balances the collisional force $-m_i n_i \nu_{in}\left(\mathbf{u}_i - \mathbf{u}_n\right)$.

(2) In all descriptions in this paper, an initial finite $\mathbf{u}_i - \mathbf{u}_n$ with $\mathbf{j} = \mathbf{0}$ seems assumed. This is the case of ionospheric dynamo (neutral dynamo). At the same time, however, the case of magnetospheric dynamo (magnetospheric flow increases suddenly while $\mathbf{u}_i - \mathbf{u}_n = \mathbf{0}$ and $\mathbf{j} = \mathbf{0}$ in the ionosphere) is often discussed in parallel or in mixture. This is very confusing, and sometimes the reasoning is incorrect. Examples are on lines 291-292, lines 419-421, lines 429-436, and lines 451-452. The authors should separate the discussion.

(3) (Minor comment) On line 431, “Through flux conservation”: What kind of flux do the authors mean?

(4) (Minor comment) I cannot understand the statement on lines 506-507. In what context did the authors add this statement?

Technical comments

None. The manuscript is well written.