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Interactive comment on "A new scenario applying traffic flow analogy to poleward expansion of auroras" *by* Osuke Saka

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In the current manuscript, a new scenario is proposed to explain how the ionospheric drift directions can be equatorward within the activated expansion-phase auroras while the poleward regions expand poleward. The main idea proposed is that if one takes into account compressibility effects in the ionosphere, a sequence of events can potentially occur in which density accumulations in the ionosphere end up producing field aligned currents that propagate poleward. While the concept is interesting and is described in some detail, the manuscript does not present a self-consistent treatment in terms of real MI-coupling processes (no model really does this properly yet) and does not simulate any events that can be validated against observations. The simulations are fairly simplistic with questionable assumptions. For example, the evolution of density in equation (2) is treated as a 1D problem based on the assumption that the imposed

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convection surge spreads more widely in longitude than in latitude. In addition, there is no model for how the "convection surge" is created or what might be going on in the tail that led to its creation. In real substorms, the magnetic field is highly variable including a slower stretching of the field during the growth phase followed by a more rapid and typically complex dipolarization phase. These B-field variations will change the mapping in a time-dependent manner and produce a complex transient reponse in the form of MI-coupling which is not accounted for here. It is therefore difficult to gauge how successful the model really is in terms of describing real substorms.

A major motivation of the manuscript appears to be the assumption that the direction of plasma drifts in the ionosphere during substorms is not understood. The author points out that the poleward expansion of the auroras [associated with substorms] is opposite to the general motion of plasma drift (or auroral forms?) within the expanding [bulge] (e.g. Lines 30-36 of the manuscript). As the author notes, this has been known for a very long time. Although it was not really discussed in the original phenomenological model of Akasofu [1964], it was certainly known early on. See, for example, Figure 3 of Akasofu et al. [1966]. That said, the author probably should not claim that this "discrepancy" has been a source of ongoing debate since that time.

Global auroral observations and ground-based all sky imagery clearly shows that while the envelope of activity expands poleward during the expansion phase, forms within the bulge tend to move equatorward. The Earthward motion (often in the form of streamers) is completely consistent with the virtually universally-accepted idea that convection in the nightside magnetotail is Earthward (on the sunward side of reconnection sites) and that it is typically bursty in nature (i.e. bursty bulk flows described by Baumjohan, Angelopolous, etc..). The poleward motion of the expanding envelope is also completely consistent with the progression of the substorm x-line toward the lobe field lines in the tail (and associated plasmoid release).

The controversy addressed by THEMIS was not really about which direction auroral forms (or ionospheric plasma drifts) move during the expansion phase, but rather which

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region activates first (i.e. inside-out or outside-in) around a much narrower time period near the onset of a substorm. The controversies revolve around: (1) why in the outside-in model, auroral signatures of a higher latitude reconnection process are not clearly observed prior to the lower-latitude activation and subsequent poleward-expanding envelope, and (2) how in the inside-out model, a near-Earth disturbance is related to activation of mid-tail reconnection that is known to develop during substorms (and whose signatures have sometimes been reported to precede the lower latitude activation.)

Some major issues with the manuscript are:

(1) It appears to ignore mechanisms in the magnetotail that are already fairly well understood. For example, it is known that a new x-line is formed in the magnetotail sometime early on during substorms. In addition, it is known that convection from both the pre-existing x-line and the new substorm x-line proceeds in a bursty manner which produces Earthward-directed bursty bulk flows (BBFs). There has also been considerable work done in showing how such localized flows relate to equatorward-moving auroral forms in the ionosphere (i.e. streamers) and particle energization in the magnetosphere.

(2) Intensifications of the poleward expanding edge of the bulge are often accompanied by equatorward ejection of streamer forms. How does the current model account for this type of activity? This is very easy to explain in the context of reconnection, but it is not clear how the current scenario would acount for such observations.

(3) Low-altitude observations have shown that the auroras at the poleward edge of the expanding disturbance are Alfvenic in nature (i.e. due to wave-accelerated electrons) (e.g. see Mende, (2016)). This is in contrast to more equatorward auroral arcs that are often associated with inverted-V type potential structures (acceleration of electrons through a field-aligned potential drop). It is not clear how the current model fits these observations. How does the model produce broadband wave acceleration of auroral particles at the poleward edge and inverted-V type structure in the more equatorward

regions? The current scenario discusses ion acoustic waves travelling upward and downward along field lines in the ionosphere. Are these observed? How do they relate to observations of Alvfenic auroras already published?

(4) The poleward-expanding bulge during a substorm eventually grows to coalesce with the open-closed boundary, while at the same time plasmoids are known to be released in the more distant tail. This is exceptionally strong evidence that new reconnection at a mid-tail site is a dominant driver during the expansion phase. It is not clear how the current model is consistent with these observations.

(5) The model assumes the imposition of physical processes and dynamics from the magnetotail in the form of a substorm "convection surge" at the dipolarization onset, but then argues that the ionosphere ends up directly driving processes in the tail (e.g. lines 199-202). It is probably more appropriate to think of the entire process via a more unified MI-coupling approach, but the fact that magnetotail processes appear to be required to drive the effects considered in the current model, indicates that the magnetosphere is really the source of driving in the model.

(6) The manuscript should have described other models for poleward expansion of the aurora (as described in some of the points above), but one in particular has a very similar analogy to propagation of brake lights on cars in traffic. Specifically, the flow-braking model postulates a very similar tailward-propagating distrubance that could be related to poleward propagation in the ionosphere. Especially since the language used for these models is quite similar, the author should really have provided some discussion of it here.

In summary, the proposed model may be valuable in understanding some of the details of MI-coupling that occurs near onset, but it is very unlikely to be able to explain the full wealth of observations that are known to exist in the ionosphere and in the tail during expansion phase. In this view, the proposed scenario should not really be considered as an alternative to other models, but rather as a refinement on them. Otherwise, the author should be able to explain why all of the other mechanisms proposed in the past somehow cease to operate as a result of the currently proposed concept. For example, we know that near-Earth reconnection occurs during substorms. How does the current model stop this reconnection site from imposing a poleward-propagating envelope of activity in the ionosphere as it progresses toward the lobe field lines in the tail? Similarly, the manuscript does not address how the model is consistent with the vast array of known observations of auroras during substorms (e.g. how does it produce Alfvenic auroras at the poleward edge of the expanding bulge? How are streamers produced? etc.)

I would reccommend that the focus of the paper should not be an all-encompassing alternative model for poleward expansion during the expansion phase in general (this is how the paper currently reads), but rather that it merely point out that some MI-coupling phenomena associated with ionospheric compressibility may be important during the initial onset phase of substorms.

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