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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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Our replies to Referee #1 are summarized as follows.

The poleward expansion of auroras was an auroral event observed in the initial pulse of Pi2 pulsations [Saka et al., JASTP, 80, 285-295, 2012]. The dipolarization of geomagnetic fields would have ended by the time of the Pi2 onset because Pi2 pulsations were triggered by the bifurcation of the fast earthward flows [Saka et al., JASTP, 72, 1100-1109, 2010]. The convection surge was produced by dawn-dusk stretching of flux tubes associated with longitudinal expansion of dipolarization [Saka and Hayashi, 2017].

We assumed that electron precipitations associated with the upward field-aligned currents lead to a temporal production of electron density in negative potential region. Quasi-neutrality is maintained because the Pedersen currents transported ions into this negative potential region. These effects enhance the ionospheric conductivities at the negative potential region. This may result in the ionospheric screening of the incident westward electric fields which was strengthened at the density peak. As a result, the ionosphere itself suppressed the further increase of the density at the peak by slowing down the directed flows. The flow velocity (U) is a function of ionospheric density (n) in such a way that U decreases with increasing n. This relation is consistent with the flux-density curve in traffic flow. Density accumulation may evolve nonlinearly following this curve.

In the E region, a large density gap occurred between ions and electrons by a mobility difference. These gaps were reduced by the Pedersen currents and retain quasi-neutrality. Figure 1 depicts an example of electrostatic potential pattern at T=4 (prior to the onset of poleward expansion) caused by ExB drift. Westward electric fields transmitted from the magnetosphere are assumed to extend in east-west directions by the form, Ey=Exp[-(x/20)ˆ2 - (y/40)ˆ2]. Here, x is in north-south and y is in east-west directions. Longitudinal scale is two times larger than that in latitudes. The ionospheric currents close to the field-aligned currents (upward from the negative potential region and downward towards the positive potential region) thereby sustaining these potential structures and retaining a quasi-neutral condition. The convergent electric fields in negative potential regions in the equatorward part expand poleward by the nonlinear evolution (T5 in Figure 2B). Though not shown in Figure 1, the transmitted westward electric fields skew potential contours in positive potential regions by moving the center towards the west. This skewing could be insignificant in the negative potential regions because electric fields from the magnetosphere were weakened.

A nonlinear evolution of the density accumulation with time is illustrated in Figure 2B using flux-density curve in Figure 2A. Density increased in a step-like manner, from T1 to T5. The shock formation started when the density increased over the critical density.

The velocity of the shock is the same as the flow velocity towards downstream, namely 2.0 km/s for 100mV/m of the westward electric field amplitudes, which is a typical value of the expansion velocity associated with Pi2 pulsations [Saka et al., JASTP, 80, 285-295, 2012]. The critical density separates free flows (lower density than the critical density) and congested flows (higher density than the critical density). It is supposed that the free flows dominated in the westward electric field region when they propagated equatorward, while congested flows dominated when they stopped or even reversed its propagation direction. The shock formation delayed in the former case while it starts quickly for the latter case.

Major losses along the field lines may be caused by steady-state plasma motions existing up to 800km in altitudes, where ion velocity exceeded the phase velocity of ion acoustic wave. Field-aligned velocities of the steady-state ion flows varied from 15m/s at 400km to 1367 m/s at 800km in altitudes. The upward ion flux carried by the flow also varied from 5.9x10ˆ12mˆ-2sˆ-1 at 400km to 8.2x10ˆ13mˆ-2sˆ-1 at 800km in altitudes. This means that the steady-state flows evacuated the accumulated density in 250 s (4.2 min) at 750 km, while ions at 450 km were slowly evacuated to the higher altitudes in 3300 s (55 min). If we consider a transient event of few minutes, field-aligned loss may become negligible below 500 km. In ten seconds, losses may be negligible throughout the topside ionosphere.

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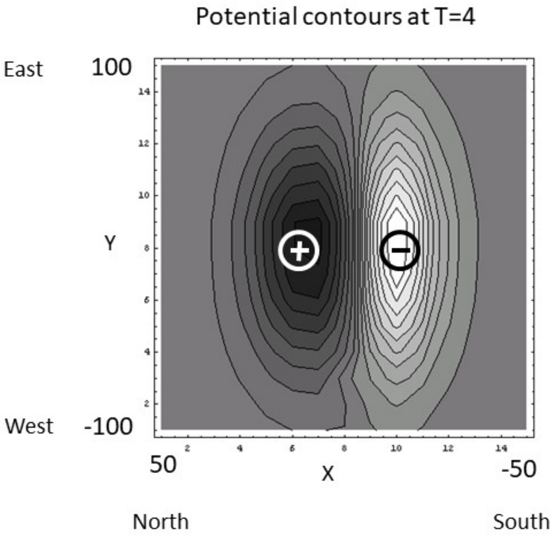

Fig. 1. Contour plots of electrostatic potential at T=4 (before onset) in the E region produced by the two-dimensional westward electric fields.

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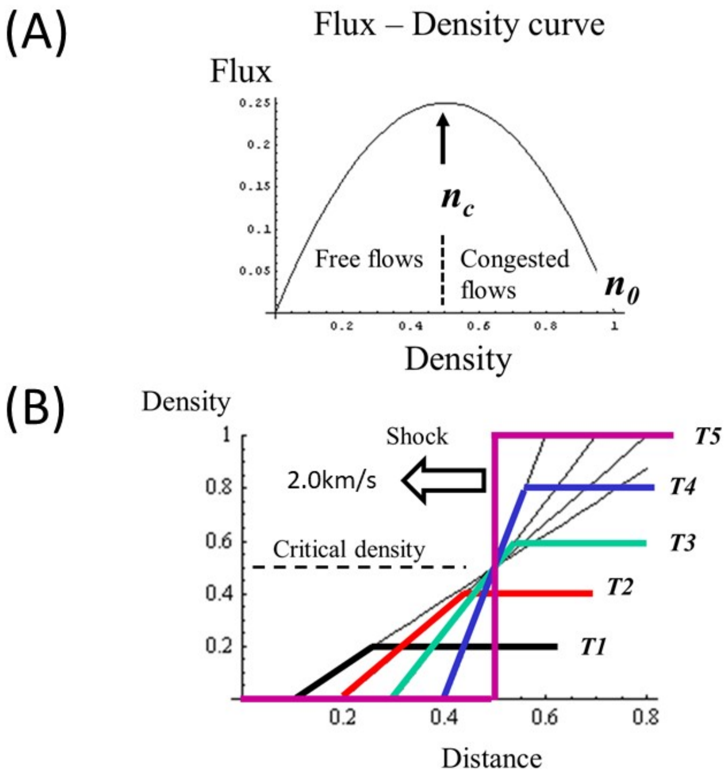

Fig. 2. (A) flux (q)-density (n) curve represented by q=n(1-n). (B) Plots of nonlinear evolution of density accumulation.