"Physics of Auroral Phenomena", Proc. XIX Annual Seminar, Apatity, pp.47-49, 1996

Polar Geophysical Institute

JET STRUCTURE OF MAGNETOSPHERIC CONVECTION AND FORMATION OF AURORAL ARCS

Yu.P.Maltsev, and I.V.Golovchanskaya *(Polar Geophysical Institute, Apatity, Russia)*

Abstract. Three models of the magnetospheric convection are discussed: continuous, bubble, and multi-jet ones. It is shown that the multi-jet model allows to avoid the convection crisis and to explain a number of features of discrete auroral arcs.

1. Introduction

The electric field of the magnetospheric convection consists of two parts. The averaged part is rather continuous and smooth (Figure 1a). Being mapped onto the ionosphere (Figure 1b) the average convection has the two-cell structure. The fluctuating part of the field usually exceeds the average part. The characteristic spatial scale of fluctuations is tens and hundreds kilometers in the ionosphere.

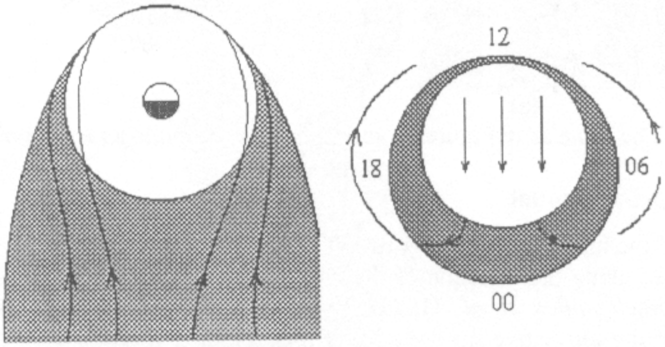


Figure 1. Continuous model of the magnetospheric convection: a) convection in the equatorial plane of the magnetosphere; b) convection in the ionosphere.

Erickson and Wolf [1980] showed that the continuous convection can lead to the so-called crisis when the plasma pressure at the inner edge of the plasma sheet becomes unrealistically large. True, *Kivelson and Spence* [1988] argued that the steady continuous convection is possible in the magnetotail of finite width and for not very large electric potential differences from dawn to dusk ($U < 5\ T_i/e$, where T_i is the ion energy). But even if the continuous convection is possible, it remains ambiguous, why the polar cap boundary determined by precipitations (the soft polar rain in the cap and the harder particles in the auroral oval) is so sharp. It is unclear how the magnetic flux tubes drifting from the cap to the oval become filled with the energetic plasma because this contradicts to the frozen-in condition.

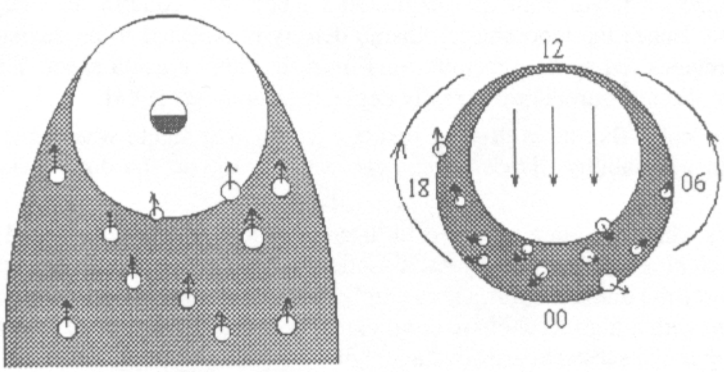
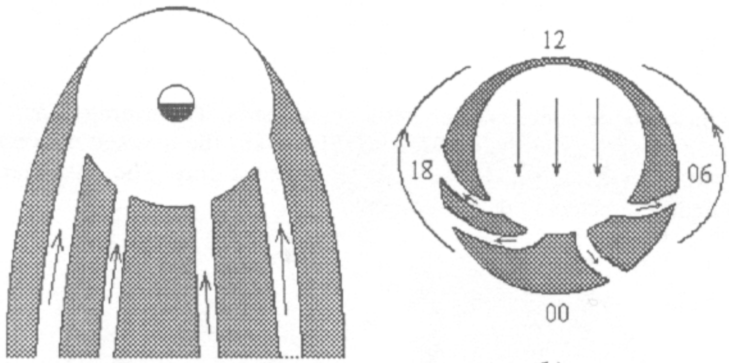


Figure 2. The same as in Figure 1, but for the bubble model of the convection.

Pontius and Wolf [1990] as well as *Chen and Wolf* [1993] suppose that the plasma drift is not continuous. With the background of a comparatively slowly moving hot plasma of the plasma sheet there are cold magnetic flux tubes originating from the magnetotail lobes. Since the plasma pressure in these tubes is smaller than that in the surrounding plasma they move to the Earth much faster due to the interchange effect which is equivalent to the force of buoyancy in hydrodynamics. The tubes look like bubbles in their cross-section (Figures 2a and b).

Plasma and magnetic field measurements in the neutral sheet [*Angelopoulos et al.*, 1992] are consistent with the bubble convection model. Fluctuations in the magnetic z-component appeared to anticorrelate with the plasma pressure. When the pressure is large the z-component is close to zero; when the pressure is small the z- and x-components are comparable to each other, and the earthward drift velocity grows significantly.

Our paper is a further development of the concept by *Pontius and Wolf* [1990].



(a) (b)

Figure 3. The same as in Figures 1 and 2, but for the multi-jet model of the convection.

2. Features of the multi-jet model

Circular cross-section of the tubes shown in Figure 2 is postulated rather arbitrarily. Here we suggest that the tubes may be strongly stretched along the direction of their movement so that their cross-sections look like jets (Figure 3). Observations by *Angelopoulos et al.* [1992] can not distinguish between bubbles and jets. Ionospheric measurements show that the convective jets are adjacent, as a rule, to discrete auroral arcs both at the auroral oval latitudes [*Timofeev et al.*, 1987; *Opgenoorth et al.*, 1990; *Williams et al.*, 1992; *Lewis et al.*, 1994] and at the higher latitudes region typically considered as the polar cap [*Valladares and Carlson*, 1991]. During severe magnetic storms when the discrete auroras shift equatorward the jets are observed at the latitudes which are generally considered to be subauroral [*Galperin et al.*, 1973; *Smiddy et al.*, 1977; *Maynard*, 1978; *Spiro et al.*, 1979; *Shuman et al.*, 1981].

Figure 3a shows that the cross-tail current of hot particles disrupts at the jet edges. Since the total current must be continuous, a part of the current branches off into the ionosphere as field-aligned currents, and the other part is being closed by the inertial currents arising due to the earthward acceleration of plasma in the jets. On the ionospheric level, the field-aligned current at the right-hand edge of the jet flows upward and can form a discrete auroral arc. An arc must appear at the poleward edge of the jet in the dusk sector and at the equatorward edge in the dawn sector. Such location of the jet and arc with respect to each other is confirmed by the EISCAT observations [*Timofeev et al.*, 1987; *Opgenoorth et al.*, 1990; *Williams et al.*, 1992; *Lewis et al.*, 1994].

Since the fast-drifting tubes originate from the magnetotail lobes, they contain no energetic particles, with no precipitation to their base. Hence the ionospheric plasma density is expected to be depleted here as compared to that in the surrounding regions fed by the precipitations from the "hot" plasma sheet. The ionosphere inside the convective jets adjacent to discrete auroral arc is really depleted [*Marklund*, 1984].

The poleward edge of the "cold" flux tubes drifting inside a jet is rather stable whereas their equatorward edge is subjected to the interchange instability. Hence we can see why the arcs in the dusk sector are more regular and long-living.

Curl and vortex structures which are often observed in discrete auroras can be interpreted in terms of the Kelvin-Helmholtz instability developing at edges of the jets. If motion in the jets, relative to the hot background plasma, is driven by the buoyancy force the discrete auroral arcs can be formed only in the region of the closed magnetic field lines. This is in agreement with a high level of arc conjugancy under quiet conditions and the fact of disappearance of the arcs in the polar cap at the substorm growth stage, when the polar cap magnetic field lines turn open.

We suppose that the convective flow is concentrated mainly in the jets whereas the surrounding plasma is nearly motionless (excluding the cases when the polar cap expands forcing the auroral zone plasma to shift equatorward). Such an assumption requires rather significant drift velocities which are really observed sometimes. *Smiddy et al.* [1977] measured the velocities up to 9.8 km/s in the subauroral jets. *Wescott et al.* [1993] observed motions of inhomogeneities in Barium plasma clouds with speeds reaching 20 km/s. Perhaps, the clouds got into a jet at those moments.

A similar model of the earthward jet in the plasma sheet was suggested by *Sergeev and Lennartsson* [1988] in order to avoid the convection crisis. Unlike our model, they supposed only one jet and did not connected it with auroral arcs.

3. Conclusions

Both the multi-jet and bubble models of the magnetospheric convection allow to avoid the "convection crisis". In the case of jets the latter ones could be naturally connected with discrete auroral arcs, since the field-aligned currents flowing at edges of the jets could be responsible for the formation of elongated structures in the regions of the current flowing out of the ionosphere. The following discrete aurora manifestations can be readily interpreted under this assumption: 1) the arc location at the poleward edge of the jet in the dusk sector and at the equatorward edge in the dawn one; 2) the ionospheric plasma depletion in the jets; 3) more regular and long-living arcs in the dusk sector as compared with those in the dawn one; 4) a high level of arc conjugancy under quiet conditions and disappearance of the arcs in the polar cap at the substorm growth stage, when the polar cap magnetic field lines turn open.

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