Plasma Convection across the Polar Cap

We present measurements of convection velocities obtained with the Electron Drift Instrument on Cluster, using 20 passes that are close to the noon-midnight meridional plane. Taking the single spacecraft measurements the convection velocities show the expected trend as a function of IMF B_z. The unique contribution by Cluster is the ability to provide multi-point measurements, thus allowing the inference of spatial scales. Correlation studies of the convection velocities show that the characteristic length scales are larger for southward IMF than for northward IMF.

Magnetospheric convection is driven primarily by magnetic reconnection. For southward interplanetary magnetic field (IMF) reconnection occurs along an X-line on the dayside magnetopause. Once interconnected, open magnetic flux tubes are carried by the solar wind over the poles downstream, resulting in anti-sunward convection of magnetic flux over the polar caps. For northward IMF, reconnection can occur poleward of the cusps, between interplanetary field lines and open tail-lobe field lines. The result is a circulation pattern, often described as tail lobe stirring, with sunward convection over part of the polar cap.

In Fig. 1 we show 10-min averaged convection velocities as a function of IMF B_z. To remove the height dependence of the velocities which is caused by the magnetic flux tube expansion with altitude, the velocities are scaled to an ionospheric altitude of 100 km. To evaluate the sense of convection we used the velocity component along the direction given by $\mathbf{B} \times \mathbf{\hat{y}_{GSE}}$. This direction always maps to sunward convection in the ionosphere. Fig. 1 shows the expected trend, in spite of large scatter: for large negative IMF B_z essentially all velocities are directed anti-sunward ($\tilde{V}_s < 0$), and the bulk of the velocities become smaller with increasing IMF B_z. The majority of the averaged velocities are negative even for an IMF B_z as large as +5 nT. The main reason for this is that for northward IMF the convection is not expected to be uniformly sunward over the entire polar cap, but contains also regions with anti-sunward convection, the detailed distribution depending on IMF B_y.

From correlations of the convection velocities from three spacecraft it appears that the scales, when mapped down to ionospheric altitudes, are always larger than 1 km and sometimes, but not always larger than a few hundred km (cf. Fig. 2a). Splitting the data into cases of pure northward and southward IMF (Fig. 2b,c) shows that the large scales of a few hundred km exist only for southward IMF, whereas for northward IMF poor correlation occurs already at separation distances of only a few tens of km. These results are in qualitative agreement with models and observations reported in previous publications. While it seems hardly surprising that scales are larger than 1 km, poor correlation at only a few tens of km separation over the polar cap is surprising and is below the resolution achieved by the SuperDARN radars in their standard scan mode.

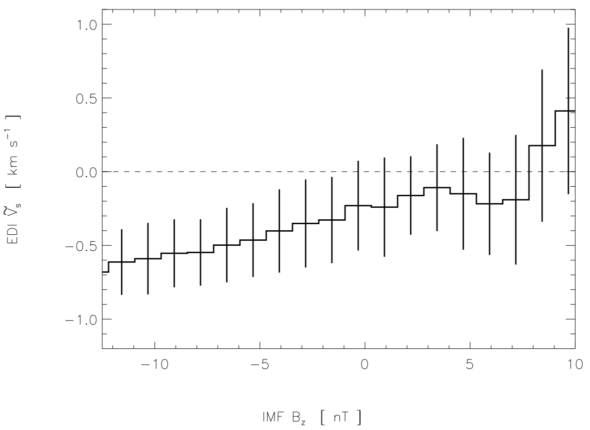

Fig 1: Histogram of scaled 10-min averaged convection velocities vs. IMF B_z. Standard deviations are shown as vertical bars.

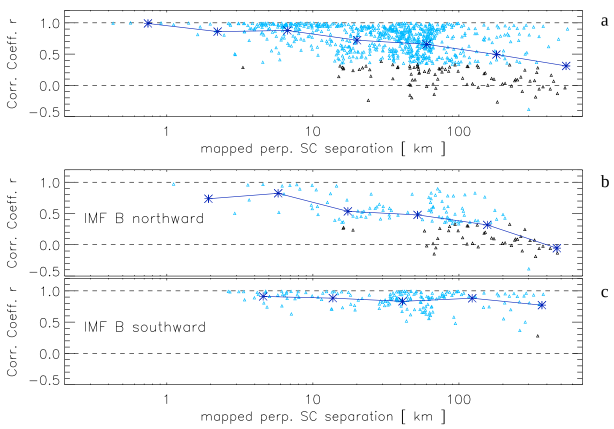

Fig 2: Correlation coefficients of 1-h intervals of convection velocities vs. mapped spacecraft separation distances; correlation coefficients below the significance threshold are colored black.

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