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ION ENERGY DISPERSION EVENTS IN THE CUSP/CLEFT AND MANTLE: GENERAL DISPERSION SIGNATURE

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Abstract. From the DMSP F7 satellite measurements for September, October and November 1984 (112 polar cap crossings), the ion dispersion structures forming the general energy decline are studied in the 08 - 14 MLT sector under quiet IMF B_z/B_y conditions. The meridian component of the dispersion-forming velocity and the injection source latitude inferred from the lower cutoff fit are compared with IMF B_z/B_y, solar wind velocity, solar wind electric field, 3-hr K_p index and magnetic local time (MLT). The poleward dispersion-forming velocity values are found to drop while IMF B_z southward increasing. Under IMF B_z northward double dispersion signatures with both equatorward and poleward general energy declines were observed under quiet conditions in one hemisphere only. The results obtained from their study would reflect the Axford-Hines convection footprint and are in favor of 4-vortex convection system under IMF B_z>0. General dispersion signatures are found being not always consistent with those expected for given IMF B_y polarity thus implying that B_y effects don't settle the amount of 'wrong' dispersion events. The probable source position is found to be adjacent to the equatorward and poleward statistic cusp boundaries, shifting equatorward with increasing 3 hr K_p index. The steady convection flow input is shown to prevail in general energy decline forming. However, a number of dispersion events still don't match the theoretical predictions for convection behavior and perhaps require more complex explanation.

Introduction

The energy decline in ion precipitations is usually interpreted to be a result of the velocity filter effect for downflowing magnetosheath particles injected into the convecting flux tube [Rosenbauer et al., 1975]. However the formula describing this effect [Lockwood, 1993] stays the same for both the model of a fixed precipitation source & moving field lines and for model with no convection flow projection onto the direction in which the precipitation source is moving across the magnetic field lines.

The agility of the open magnetic flux boundary (identified by precipitation characteristics) in relationship to IMF B_z variations & geomagnetic activity was shown by Makita et al. [1985]. The continuous manner of the cusp signature independently on the convection flow is reported in [Nilsson et al., 1996]. The polar cap boundary displacement in the dawn-dusk direction driven by IMF B_y variations was predicted by Heppner [1972]. Optical observations also give an evidence for the precipitation source motion independent of the convection flow [Fasel et al., 1995; Smith et al., 1982].

The relation of the convection patterns to IMF B_z/B_y, MLT and geomagnetic conditions can be found in [Heppner, 1972; Burke et al., 1979; Heelis, 1984; Lyatsky et al., 1985; Heelis et al., 1986].

Surveys of dispersion signatures reveal the dayside ion dispersion precipitations might have their energy decline being convinced with the expected ionosphere Dungey[1961] convection flow [Woch and Lundin, 1992, Reiff et al., 1980]. However, the cases of 'wrong' dispersion (in relation to IMF B_z sign) have been reported in [Potemra et al., 1992, Newell and Meng, 1995] besides Potemra et al. [1992] suggested a poleward energy decline for IMF B_z>0 to be a result of the injection source motion. The cases of V-shaped ion dispersion shown in [Woch and Lundin 1992; Reiff et al., 1980], have been suggested by Menietti and Burch [1988] also to be a result of the poleward motion of the precipitation source.

The characteristic value of the convection velocity at ionosphere level is of 0.5..1 km/s up to 2 km/c [Yamauchi et al., 1996]. The velocity of motion of the equatorward edge of auroral forms is of about 0.1...0.2 km/s (estimated after keograms given in Fasel et al. [1995]). The cusp displacement in latitude in response to IMF B_z turning from +15 to -15 nT was at least 5° during 15 minutes that is ~0.6 km/s [Brown et al., 1981] at the ionosphere level, thus, being comparable with the convection velocity value.

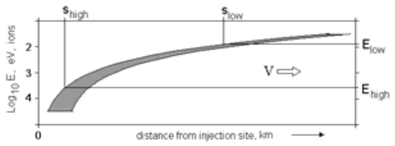
The goal of our study was to examine the degree in which the statistical properties of fitted average energy declines match those of the steady convection flows and whether they are effected by the injection source motion across the field lines.

Data description and analysis technique

We select ion precipitation spectra from low-altitude (~800 km) polar-orbiting DMSP/F7 spacecraft. The spacecraft carries a plasma detector, which measures the differential energy flux of precipitating electrons and ions in 19 logarithmically spaced channels ranging from 0.032 to 30 keV at 1s time resolution [Newell and Meng, 1995, and references therein]. The solar wind observations are provided with AMPTE IRM spacecraft (solar wind velocity and 3-component IMF data) with temporal resolution of 5 seconds. Observations refer to the period from September to November 1984, when the IRM spacecraft made observations directly upstream from the dayside bow shock at a distance less than ~17 R_E.

Total of ~220 crossings in 08-14 MLT sector with available for measurements ion energy declines were considered, 50 for $B_z>0$ and 62 for $B_z<0$ of them have quiet and deep quiet IMF B_z/B_y background during the preceding half hour. IMF B_z intervals with 2-3 minute excursions into the opposite polarity or containing other dramatic variations have been removed from the data set. The ion signatures were separated onto *general dispersion signature* forming the average energy decline within several degrees of latitude and *fine structure elements* responsible for its fluctuations. The actual study focuses on general energy declines only.

To determine the meridional component of the dispersion-forming velocities and the latitude of the injection source, we fit the lower energy cutoff of the dispersion signature by formula (1) according to [Lockwood, 1993], with the source field-aligned altitude being fixed at 10 R_E.

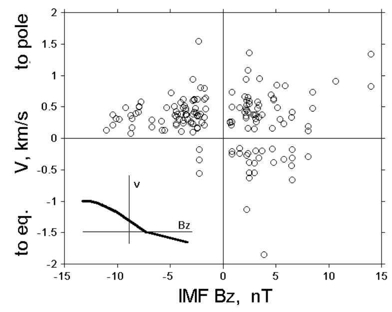


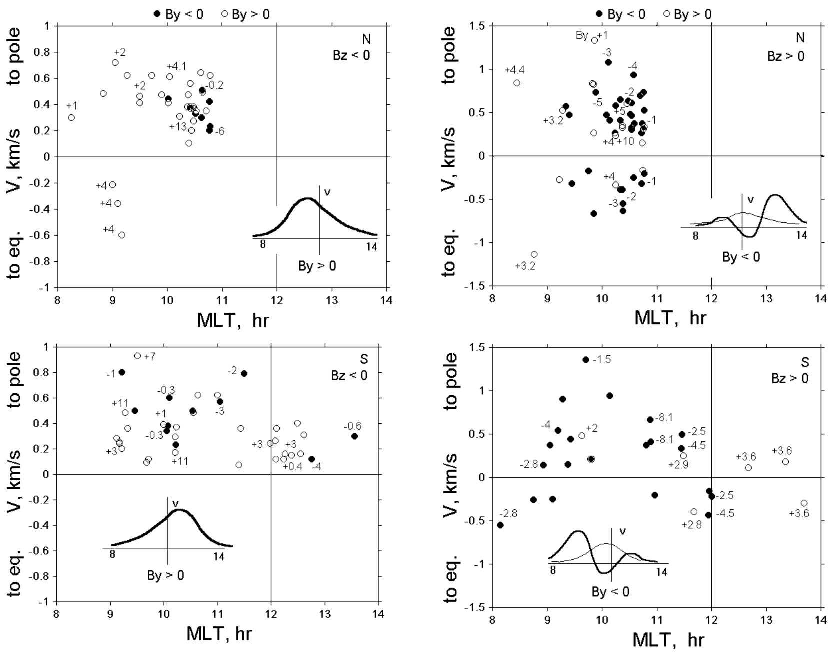
dispersion forming velocity

$$V = \frac{(s_l - s_h)}{h\sqrt{m/2}} \cdot \frac{\sqrt{E_h E_l}}{(\sqrt{E_h} - \sqrt{E_l})} \quad (1)$$

Fig.1. Proton dispersion signature from steady source shaped due to convective shift of the downflowing particles; s_{low} and s_{high} are the site distances from the injection source, where protons with respective field-aligned energies E_{low} and E_{high} precipitate, h being their injection altitude, assumed to be about 10 R_E , and m is the proton mass.

Results





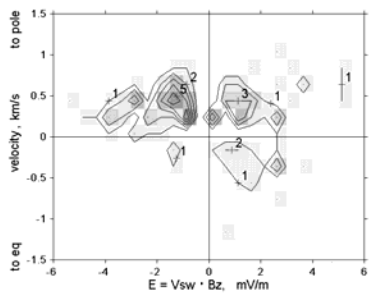


Fig.2. V vs. IMF B_z with expected convection velocity behavior.

Fig.3. Occurrence rate of V vs. $E=B_z \cdot V_{SW}$

4a) Northern hem., $B_z<0$; **4b)** Northern hem., $B_z>0$;
4c) Southern hem., $B_z<0$ **4d)** Southern hem., $B_z>0$;
Fig.4.V vs. MLT, with expected convection velocity behavior for $B_y>/<0$, denoted by light/heavy circles; characters indicate B_y values. Note the different velocity scales used in each panel.

The meridian component of the dispersion-forming velocity as a function of IMF B_z and of (IMF $B_z \cdot V_{sw}$) product in Fig.2 and 3 is shown. The occurrence rate of poleward velocities (Fig.3) tends to increase with increasing B_z negative and then drops that is close to predictions for convection velocity affected by electric field saturation [Longenecker and Roederer, 1981]. For B_z positive large scattering in poleward velocities is observed with the same tendency and no such tendency would be observed for equatorward velocities. In Fig.4, b,d, the two brunches for $B_z>0$ occur due to ‘wrong’ directed energy declines and V-shaped dispersion signatures. The latter were registered mostly in the northern (autumn) hemisphere in actual data set.

B_y effects are known to rotate the convection pattern up to ~one hour dawnward(duskward) in the northern(southern) hemisphere for $B_y>0$ due to the poleward convection enhancement in the respective sector [Heppner, 1972; Rezhenov, 1990]. As seen from Fig. 4, only a part of velocity distributions are consistent with shifts predicted by B_y effects. Double counter-directed energy declines can be identified in Fig.4,b,d via equal B_y values and one can see they don’t match well the B_y predictions.

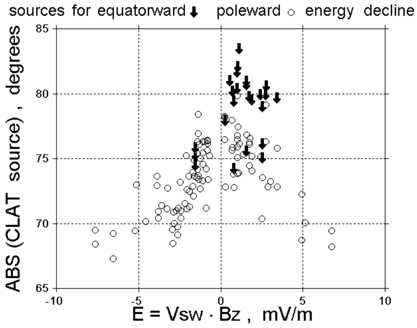


Fig.5. Injection source latitude vs. $E=B_z \cdot V_{SW}$. Arrows mark equatorward energy declines

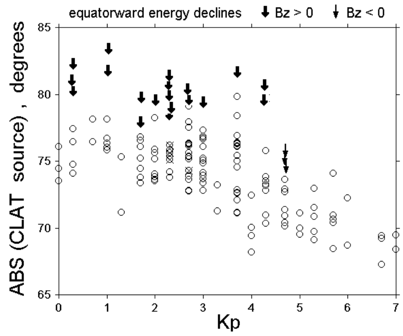


Fig.6. Injection source latitude vs. K_p. Arrows with white point mark wrong dispersion for $B_z<0$.

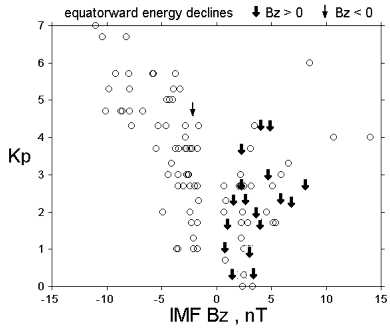


Fig.7. K_p vs. B_z after 30 minute quiescence in IMF B_z.

Module of an injection source latitude corresponding to the high energy end of the fitting curve versus solar wind induced electric field and K_p in Fig. 5 and 6 are shown. In Fig.7 K_p as a function of IMF B_z being quiet during 30 preceding minutes is given. The symmetry in probable positions of sources for two directions of electric field is consistent with symmetric K_p behavior versus IMF B_z that is the measured energy declines have been affected by source motion due to geomagnetic activity. Sources inferred from equatorward energy declines for $B_z>0$ are located at higher latitudes, including those being part of V-shaped dispersions, and have poor reaction to K_p index, whereas the sources inferred from poleward energy declines show linear correlation with K_p.

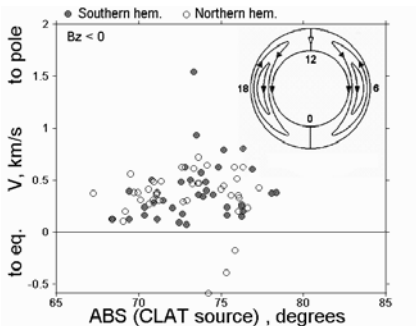


Fig.8. V vs. injection source latitude, $B_z<0$, with Axford-Hines convection pattern

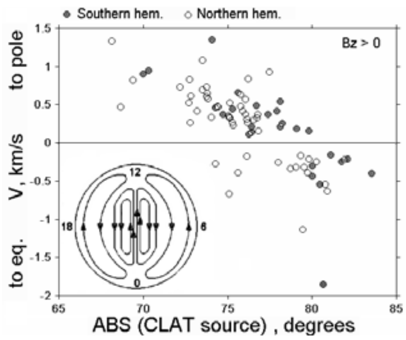


Fig.9. V vs. injection source latitude, $B_z>0$, with 4-cell convection pattern expected

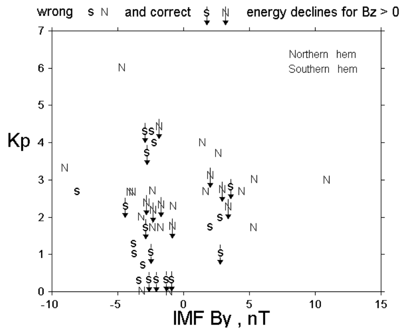


Fig.10. Correct (↓) and wrong (°) energy declines for $B_z>0$ vs. B_y and K_p

The velocity value versus probable injection source position is presented in Fig. 8 and 9 separately by hemispheres. The meridian velocity has its maximum near ~75° in both hemispheres, which is consistent with predictions of Axford-Hines convection [Axford, 1964] rather than with that of Dungey [1961], since in the latter case the velocity value would stabilize with increasing latitude. The smooth change in velocity sign with increasing latitude under $B_z>0$ is consistent with four-cell convection pattern [Burke et al., 1979; Rezhenov, 1981]. Thus, the V-shaped dispersions under quiet IMF B_z put onto the four-cell convection system, but in the northern (autumn) hemisphere only. In Fig.10 a large part of 'wrong' energy declines is observed under strong B_y component. But both 'wrong' and 'correct' energy declines are shown to occur under the same K_p & B_y conditions. Results in Fig.4 confirm too that some part of 'wrong' energy declines is not explained in terms of relationship to IMF B_z/B_y conditions.

Conclusions

Consideration of ~112 ion dispersion events at the scale of general energy decline under steady IMF conditions have revealed the convection-related velocity filter effect makes important contribution into the ion dispersion. Particularly, the dispersion-forming velocity was found not to increase with increasing B_z southward and to change sign with latitude under B_z northward as well as to separate into two-directional patterns. Thus, at least a part of counter-directed energy declines under Bz northward could be due to features of ionosphere convection pattern. However, a portion of ion dispersion events have their energy declines being inconsistent with both B_z and B_y values thus requiring perhaps more complex explanation. Evidence for presence of the injection source motion based on the source latitude and dispersion-forming velocity correlation with K_p suggests the source motion is also a possible factor contributing the 'wrong' energy decline forming.

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