Influence of interplanetary medium on SuperDARN radars' scattering occurrence.

P. Ballatore (1), J.P. Villain (1), N. Vilmer (2), M. Pick (2)

(1) LPCE/CNRS, Av. de la Recherche Scientifique, Orleans, 45071 - France
(2) DASOP, UMR 8645 CNRS, Observatoire de Paris-Meudon, Meudon, 92195 - France

The effects of the characteristics of the interplanetary medium on the radar scattering occurrence, related to the whole array of SuperDARN radars installed in the northern hemisphere, have been studied over the years 1997 and 1998.

Data Analysis.

The parameters of the interplanetary medium considered here are measured by the WIND satellite and they are: (a) the solar wind proton density (N); (b) the solar wind speed (Vsw); (c) the interplanetary magnetic field (IMF).
Using the WIND measurements of the IMF and of the Vsw, we have calculated the merging electric field, E-merg.

$$E\text{-}merg = Vsw * Bt * sin2(\phi/2)$$

Where Bt is the projection of the IMF on the Y-Z GSM plane, and ϕ is the angle between B_t and the Z axis.

All the measurements (echoes) from all the six radars available in the northern hemisphere at the time of this study were considered at each UT (Universal Time) time. Ground scatter was rejected based on its spectral characteristics. For the cells of all radars considered together, the ratio, R, of the number of 'significant' echoes (echoes with a signal-to-noise, S/N, above 6 dB), Ns, versus the total number of soundings, Nt, was calculated each 6-min UT intervals (i.e., three times the time resolution of the scanning). This parameter, R, is representative of the rate of the scattering occurrence.

$$R = \Sigma_{radars}\ \Sigma_{beams}\ \Sigma_{cells}(Ns)\ /\ \Sigma_{radars}\ \Sigma_{beams\ cells}(Nt) \qquad (1)$$

We have considered the variation of R, **δR,** obtained after the subtraction of the average daily modulation calculated over one-month intervals. In the following we consider δR instead of R itself, in order to exclude the effects due to the fact that the radars do not cover uniformely all longitude locations and that they rotate during the 24 hours of the day.

$$\delta R\ (UT) = R\ (UT) - R\_average\ (UT) \qquad (2)$$

R and R_average can be calculated separately for cells located at different magnetic latitude ranges. Thus we specify the CGM (Corrected GeoMagnetic) latitude of R and δR . Moreover, by taking into account only radar cells located at specific MLT locations, R and δR can be computed for specific MLT ranges.

Figure 1 presents a plot vs. UT of the interplanetary proton density (N), the solar wind speed (Vsw), the IMF Bz component, the E-merg, and the variation of the rate of scattering occurrence for the latitude 60-67 CGM (R60-67); the vertical dotted lines indicate the interplanetary CME event on May 15, 1997. A very strong correlation is observed between δR and E-merg or B_z negative. No time shift between the solar wind data and ionospheric measurements. A shift of the order of one and half hour greatly enhances the correlation.

Statistical results

The time interval considered in the present study is related to the two years 1997 and 1998. For this period the correlation coefficients, ρ, between δR and the different parameters of the interplanetary medium were calculated. No significant correlation coefficients (of the order of 0.2 or smaller) were obtained for N or Vsw. On the contrary, the correlation coefficients for the negative IMF Bz and for the E-merg were found to be statistically significant.

We calculated the correlation coefficients ρ separately for the different seasons : winter (January, February, November and December of 1997 and 1998), equinox (March, April, September, October of 1997 and 1998), and summer (May, June, July and August of 1997 and 1998) and for different values of CGM latitudes. Figure 2 present an example of a scatter plot of δR as a function of E-merg for the different seasons of 1997. The correlation coefficient varies between 0.56 and 0.62 showing a strong correlation between these two parameters.

Figure 3 presents the coefficients ρ of the correlations between negative IMF Bz or E-merg and δR, calculated over 7-deg latitude ranges centered at the indicated CGM latitude for the different seasons. It shows a decrease with magnetic latitude for all seasons, no correlation around 73° latitude whatever the season and a small anticorrelation at latitudes higher than 76° mostly for the winter. The values of ρ for the higher latitudes must be taken with care due to the decrease in the number of points.

Figure 4 presents the correlation coefficients ρ between negative IMF Bz or E-merg with δR computed on 3-hour MLT intervals centered at the indicated MLT for the latitude range (60-67) CGM. The correlation coefficients are near a value of 0.3 and rather independent of the season and MLT. While for a latitude range (67-74 CGM, not shown here) there is no correlation except near 12 MLT for all seasons. This feature may be related to the southward motion of the cusp region with increased magnetic activity.

Finally figure 5 illustrates the histograms of the distributions of the values of all the interplanetary parameters during the winter months of 1997 and 1998 (an interplanetary/ground-based delay of 1.5 hour was considered). These histograms are shown separately for different ranges of values of δR computed in the latitude range (60, 67) CGM : (a) grey columns report results for negative value of δR, which means that the scattering occurrence is lower than its average; (b) white columns report results for δR > 0.3, which means that the scattering occurrence is significantly higher than its average. For δR > 0.3, a clear shift towards higher values of E-merg and negative Bz is shown, in agreement with the correlations previously found. There is nearly no overlapping between the two distributions. Moreover Figure 5 shows that a shift of the distributions of N and Vsw towards higher values is also observed for higher values of δR, although the effect is less important. Similar results are obtained for the summer and equinox periods.

Although, the correlation coefficients of δR with N and with Vsw are found to be not significant, the results reported in Figure 5 show that, however, these two parameters have an effect on the scattering occurrence. This could be the signature of the effects of kinetic pressure.

Conclusion

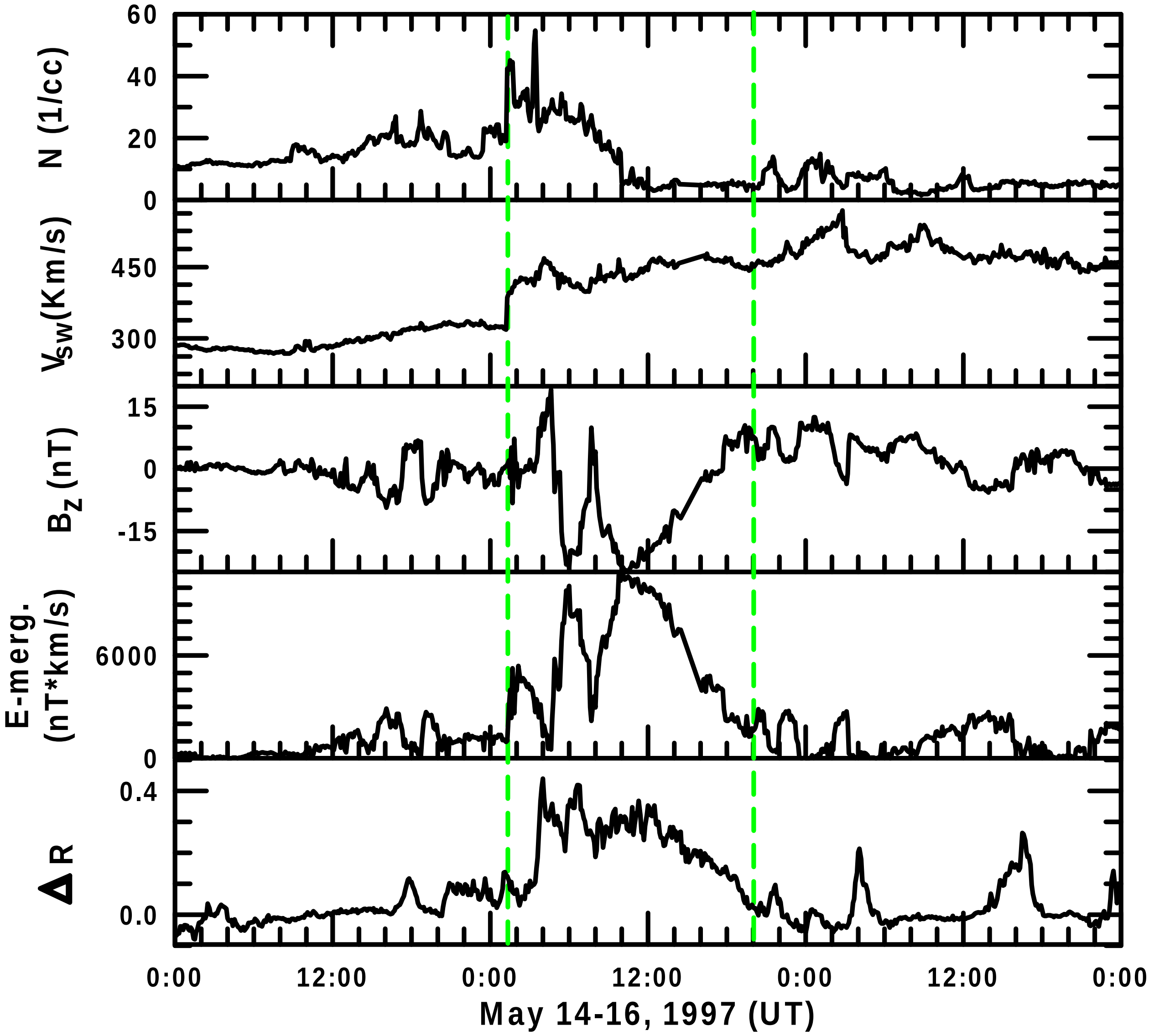
1. A higher δR is associated with higher values of N, V_{SW}, E-merg and more negative B_z.

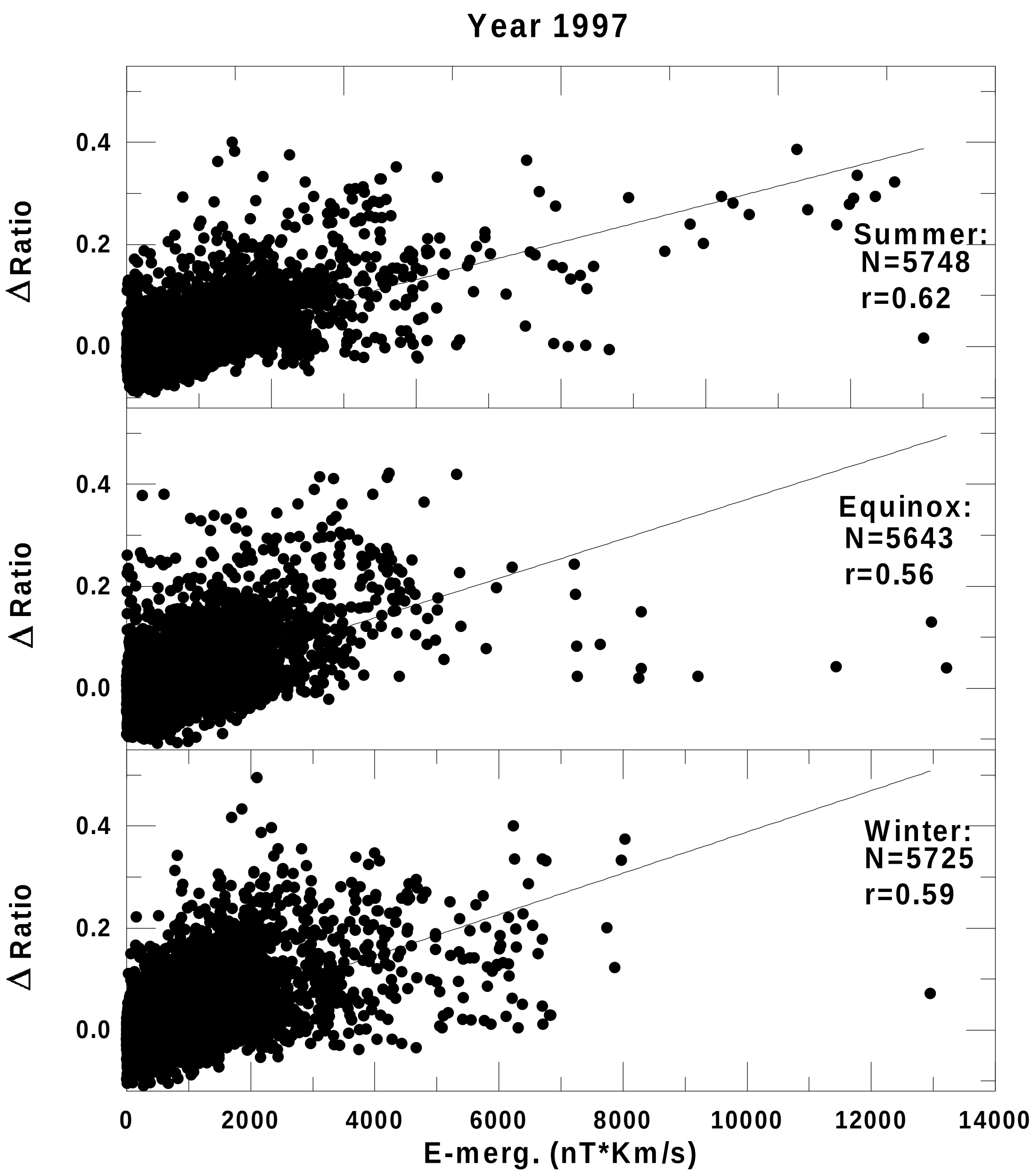
2. The linear correlations of δR with negative IMF B_z or E-merg are significant at nominal auroral oval latitudes, independent of the season.

3. The correlation of δR with N or V_{SW} are found to be not significant.

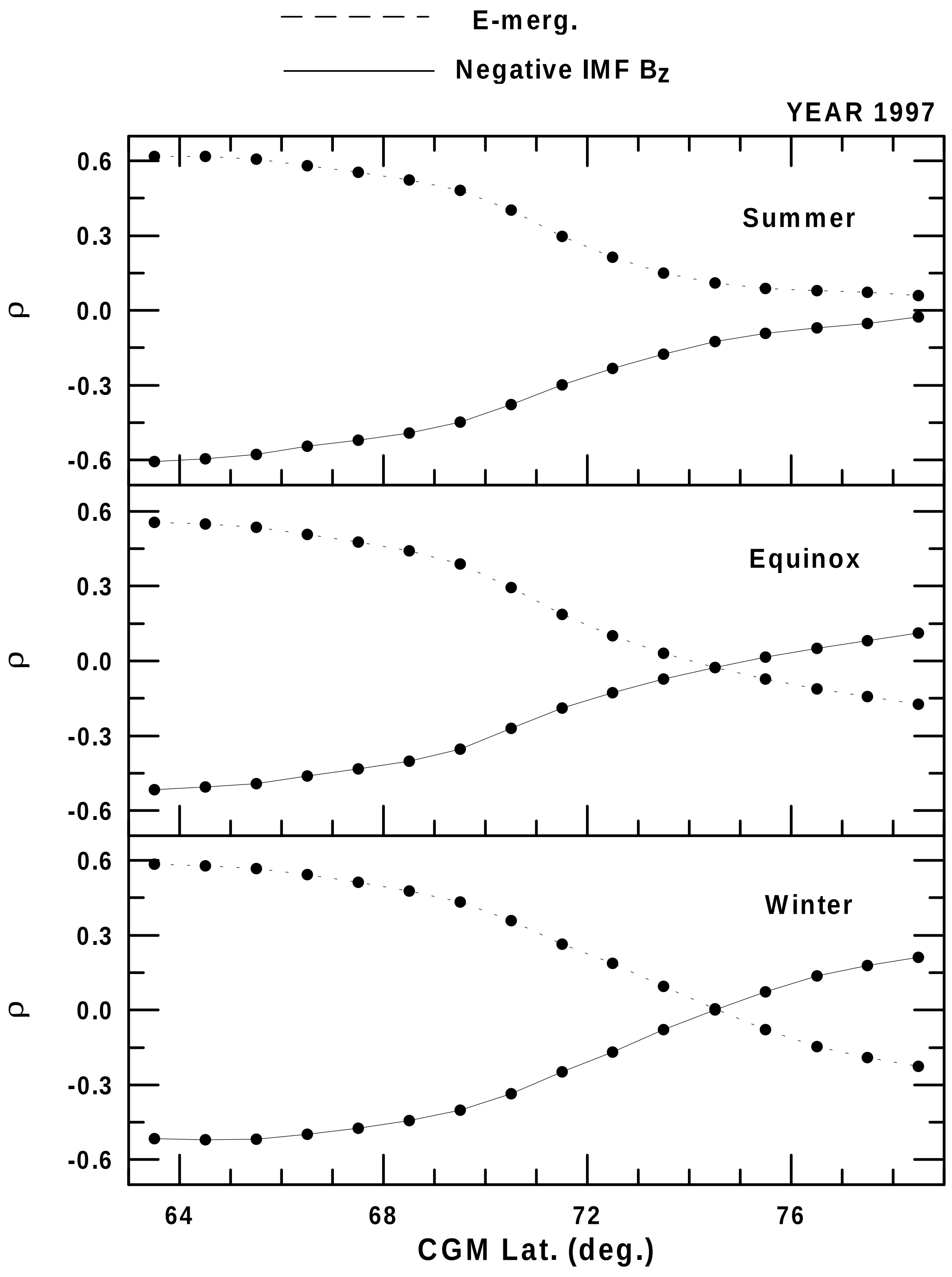
4. At latitude range 60-67 CGM, the coefficients of the considered correlations are not dependant on the MLT.

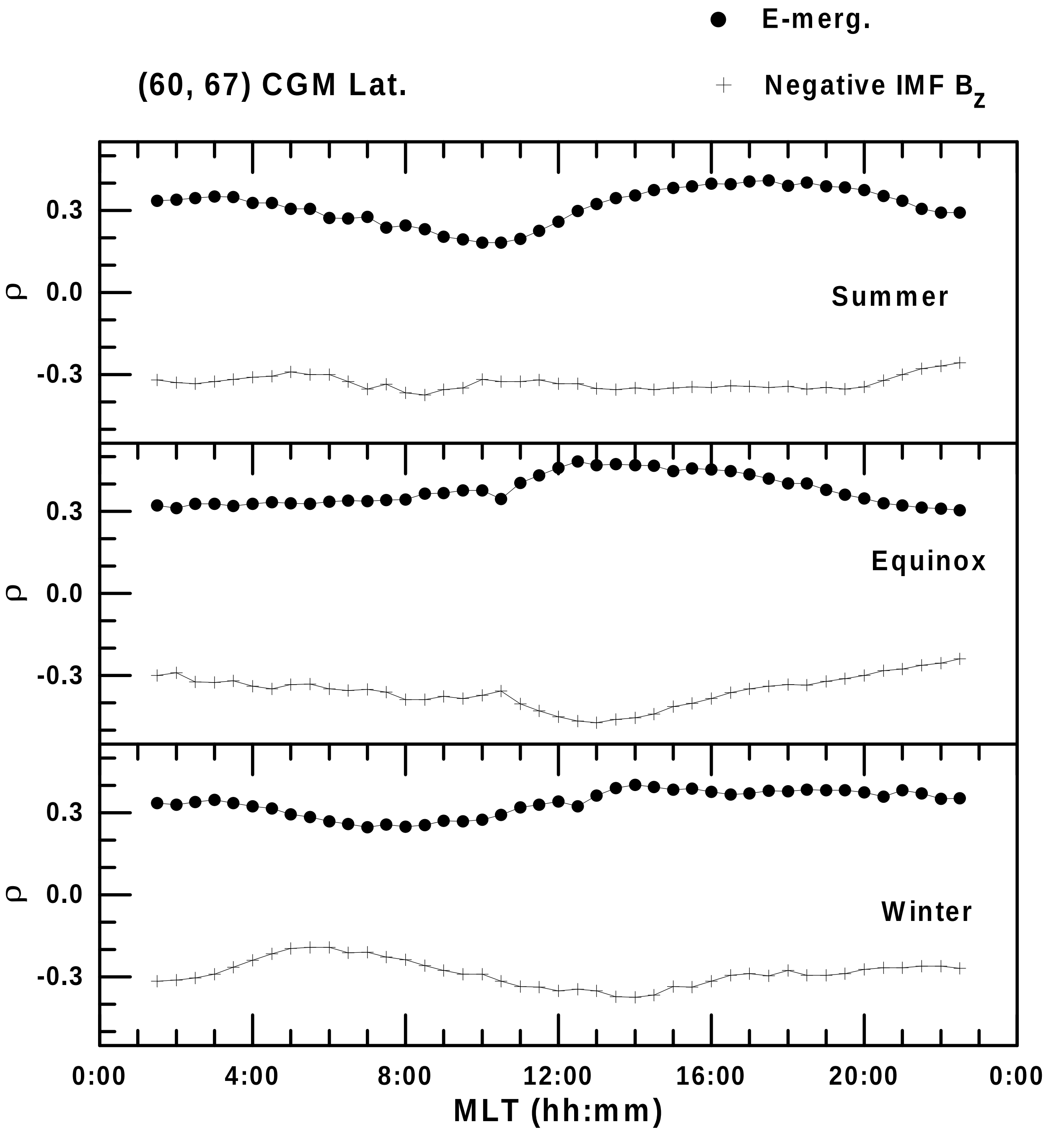
5. At latitude range 67-74 CGM, a rather significant correlation is found only around magnetic local noon, in association with the location of the ground projection of the aggregate cusp/mantle/low-latitude boundary layer region.


N (1/cc)
60
40
20
0
V_{SW}(Km/s)
450
300
B_Z (nT)
15
0
-15
E-merg.
(nT*km/s)
6000
0
ΔR
0.4
0.0
0:00
12:00
0:00
12:00
0:00
12:00
0:00
May 14-16, 1997 (UT)

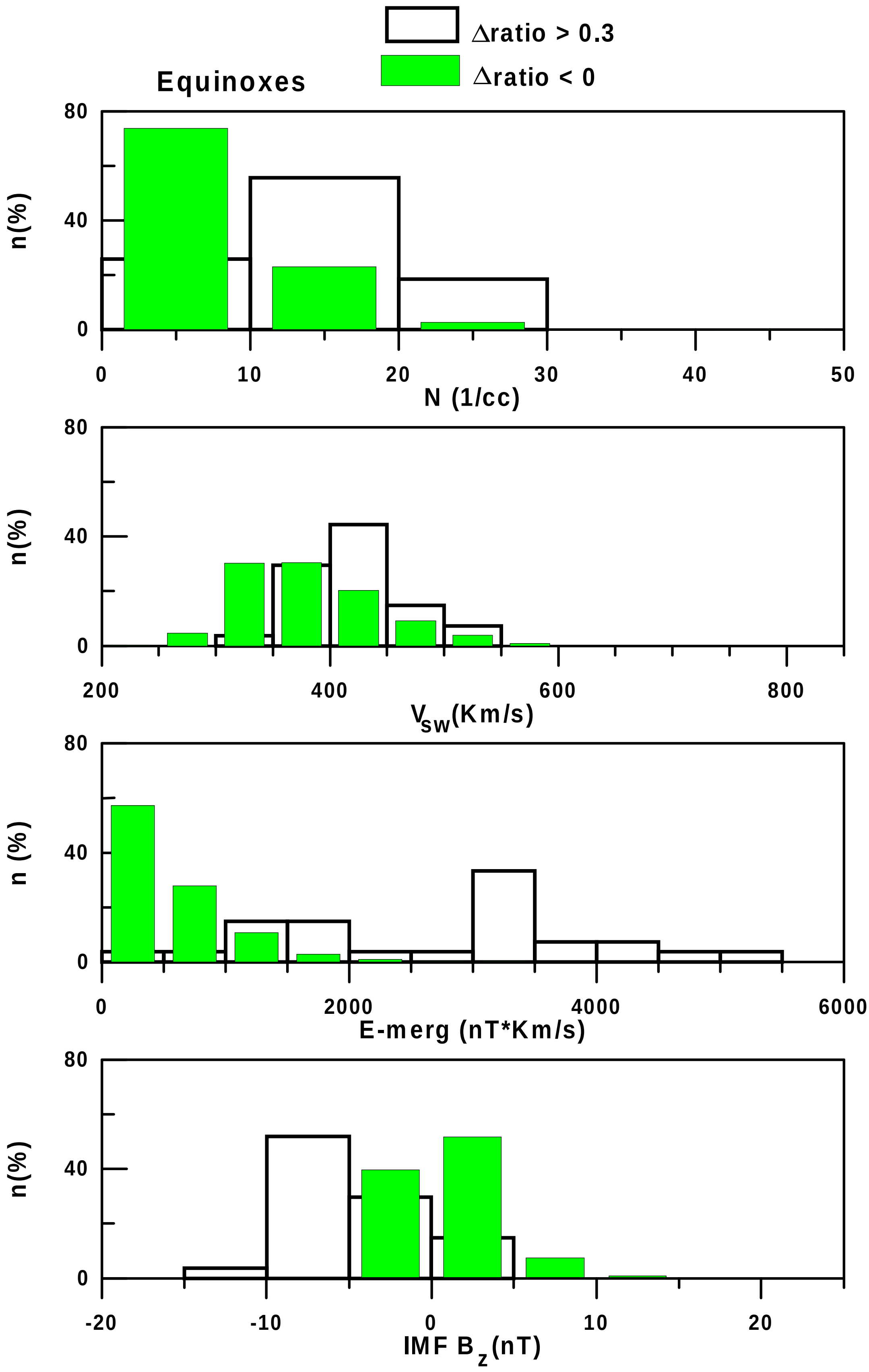


Year 1997
Δ Ratio
Summer:
N=5748
r=0.62
Equinox:
N=5643
r=0.56
Winter:
N=5725
r=0.59
0.4
0.2
0.0
0
2000
4000
6000
8000
10000
12000
14000
E-merg. (nT*Km/s)


E-merg.
Negative IMF B_Z
YEAR 1997
Summer
Equinox
Winter
ρ
0.6
0.3
0.0
-0.3
-0.6
64
68
72
76
CGM Lat. (deg.)



E-merg.
(60, 67) CGM Lat.
Negative IMF B_Z
Summer
Equinox
Winter
ρ
0.3
0.0
-0.3
0:00
4:00
8:00
12:00
16:00
20:00
0:00
MLT (hh:mm)



Δratio > 0.3
Δratio < 0
Equinoxes
80
40
0
n(%)
0
10
20
30
40
50
N (1/cc)
200
400
600
800
V_sw(Km/s)
0
2000
4000
6000
E-merg (nT*Km/s)
n (%)
-20
-10
0
10
20
IMF B_z(nT)