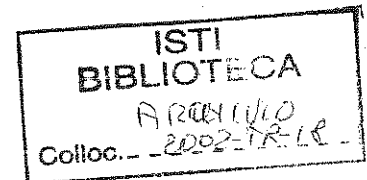


# **Pc5 Micropulsation power at conjugate high-latitude locations**

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## **Abstract.**

The micropulsation power, integrated over the Pc5 frequency range, has been calculated for the horizontal component of the geomagnetic field at the high-latitude conjugate locations: Dumont D'Urville (corrected geomagnetic coordinates: 80.61 S, 235.76 E) and Mould Bay (corrected geomagnetic coordinates: 80.85 N, 272.65 E). Because of the different distance between the geographic and the geomagnetic poles in each hemisphere, the comparison between the Pc5 power observed at Dumont D'Urville and at Mould Bay shows the relative importance of geomagnetic effects and solar illumination effects in driving low-frequency micropulsation activity. In particular similarities observed at the two sites can be explained in terms of their common geomagnetic characteristics, while differences can be attributed to the different sunlight or solar zenith angle configurations. Results show that the local summer Pc5 power is statistically higher in the northern hemisphere than in the southern one. This hemispherical difference is smaller for the local equinoxes and it is only very slight or absent for the local winters. These findings are interpreted in terms of the proportionality between the Pc5 power and the ionospheric conductance, which is higher at Mould Bay due to more permanent and direct sunlit conditions during the local summers and the equinoxes. Thus, the different geographic coordinates affect the Pc5 power at the two considered sites so much that their effect is visible regardless the geomagnetic similarities. However the influence of the geomagnetic activity on Pc5 power is found to be more significant than these geographical effects or than the seasonal effects. In fact for  $K_p < 2$  the difference of simultaneous observations at Mould Bay and at Dumont D'Urville is  $< |10| \text{ nT}^2$  with

an occurrence > 70%. The magnetic local time modulation of Pc5 power is similar in both hemispheres, being determined by the equivalent geomagnetic characteristics and regardless possible geographical differences. In particular the occurrence of sunlit higher Pc5 power at Mould Bay than at Dumont D'Urville is not localized in one specific magnetic local time sector. The present observations are compared with previous results about the solar illumination effects on the geomagnetic activity and on the auroral brightness. Finally, no solar cycle effect is observed on the Pc5 power level, or on its hemispherical dependence, or on its daily modulation.

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## **1. Introduction**

Although both closed or open magnetospheric field lines can occur at northern and southern high latitude locations, a rather good conjugacy has been observed [e.g., Belon et al., 1969; Mizera et al., 1987]. However hemispherical asymmetries have also been reported and mostly attributed to the different ionospheric conductivity at opposite local seasons [Mizera et al., 1987; Newell and Meng, 1988; Ballatore et al., 2000]. In particular hemispherical differences can be expected for the Pc5 (periods in the range 150-600 s) micropulsations, because of their higher intensity during the local summer than during the local winter [e.g., Ballatore et al., 1998a].

Several peculiar characteristics have been observed for the Pc5 power in both hemispheres and the most recurrent are: 1) its good correlation with the solar wind speed, in agreement with an origin related to hydromagnetic waves from the Kelvin-Helmholtz instability at the magnetopause [e.g., Odera, 1986; Arnoldy et al., 1988]; 2) its possible enhancement near the magnetic local noon (MLN), related to the location of the magnetospheric cusp, where several mechanisms can generate hydromagnetic waves [e.g., Olson, 1986; Engebretson et al., 1995; Ballatore et al.,

1998a]; 3) its possible power enhancement in the near magnetic local midnight (MLM), related to substorm impulsive features [e.g., Olson, 1986; Ballatore et al., 1998a].

Although these Pc5 power characteristics are common in the north and south, there are sources of hemispherical differences which are expected to be active. Apart from the local season influence, the present paper deals with the effects related to the different distance between the geographic and the geomagnetic poles in the two hemispheres [Fraser-Smith, 1987]. In fact, the different distances from the geographic pole cause the solar radiation in the local summer in the northern high latitudes to be different than that during local summer in the geomagnetically conjugate location in the southern high latitudes. This may influence the level of the hemispherical low-frequency geomagnetic power. In fact, ULF power enhancements have been also observed near the geographical local noon and related to higher ionospheric ionization because of the more direct solar radiation at this time (e.g., Gupta, 1975; Morris and Cole, 1987).

In Ballatore et al. (1998a) the effect of the magnetic local time (MLT) at 80°S CGM (Corrected GeoMagnetic) was more significant than any other effects. In particular, simultaneous observations at an array of stations distributed in longitude showed that specific geomagnetic-interplanetary configurations are associated with increase of Pc5 pulsations at all stations (i.e., longitudes or magnetospheric regions), but the intensity of the pulsation is significantly controlled by the specific MLT of the specific station at the moment (in UT, Universal Time) of the occurrence. These results were derived by observations in the same Antarctic regions, while the geographic-geomagnetic difference between the northern and southern hemisphere was not investigated.

Generally a rather good agreement between Pc5 in the two hemispheres can be expected during specific events. E.g., simultaneous ULF observations in the two conjugate high-latitude regions have shown evidence of a high degree of similarity during the SSC event on May 23 1996 [Matthews et al., 1996]. In addition, statistical comparisons of northern-southern high-latitude ULF waves showed that their temporal variation and/or the power level can be different in the two hemispheres

with an occurrence of 63%, with simultaneity and the same level of power in 1/3 of the total cases [Posch et al., 1998].

In this context, the present paper is intended to detail the similarity and/or differences between the Pc5 power in the two hemispherical high-latitude regions. In particular the influence of the different distance between the geographic and the geomagnetic poles and the seasonal effect are differentiated and compared. By considering years close to the solar maximum and close to the solar minimum, the possible relationship between Pc5 power conjugacy and solar cycle is investigated.

## **2. Data Analysis and Experimental Observations**

The total horizontal geomagnetic components, measured by magnetometers located at the geomagnetically conjugate stations Mould Bay (MBC) and Dumont D'Urville (DRV), whose coordinates are reported in Table I, have been analyzed. Their spectra have been calculated over each 3-h (UT) interval by using the maximum entropy method and the fast Fourier transform (Press et al., 1990), and results are found to be in good agreement with each other. Then the 3-h resolution Pc5 powers have been derived by integrating over the frequency range (1.7-6.7) mHz. The time periods under study are the years 1991 and 1992 (at nearly maximum solar activity) and years 1995 and 1996 (at nearly minimum solar activity).

In order to study possible seasonal dependence, data have been analyzed separately in the three periods: (a) January, February, November, December, (b) March, April, September, October, (c) May, June, July, August.

### **2a. Distributions of Pc5 powers.**

In Figure 1 the distributions of the 3-h powers obtained at the two stations for the years 1991 and 1992 are represented during local summers (left panels), equinoxes (middle panels) and local winters (right panels). The local summer at MBC is the seasonal period c listed above, while the local summer at DRV is the seasonal period a; similarly, the local winters are the periods a and c respectively at

MBC and DRV. Then the equinoxes (b period listed above) are the only periods simultaneous at both stations.

Considering the equinoctial panels in Figure 1, we note that the distributions of powers at MBC are shifted towards higher values, with a number of occurrence of 3-h intervals in the interval 0-50 nT about 7% (about 68 3-h events) higher at DRV than at MBC.

For considerations related to local summers and local winters in Figure 1, we recall that higher power is expected during the local summer than during the local winter (e.g., Ballatore et al., 1998a). This effect is visible in Figure 1, where occurrences of low power (0-50 nT) are tens of percentage higher in the right panels than in the left ones.

For comparison between the local summers (or the local winters) at MBC and DRV, it is necessary to consider that these periods are not simultaneous at the two stations. Thus, in particular, differences are expected due to the different geomagnetic activity. In fact, previous results demonstrated significant correlations of Pc5 power with the solar wind speed or with the Kp index (e.g., Arnoldy et al., 1988; Ballatore et al., 1998a). Being the solar wind speed and the Kp linearly correlated (e.g., Ballatore, 2002), we report here only considerations related to the Kp index in order to compare the different periods: Figure 2 shows the distributions of Kp index for each seasonal period and each year under study. In particular, for year 1991 Figure 2 indicates higher Kp values during the northern summer (southern winter) and the opposite for year 1992.

By comparing Figure 1 and 2, we note a tendency during the local summer to have higher Pc5 power at MBC than at DRV. This is so also for the local summers of year 1992, when the Kp activity is lower during May-June-July-August than during January-February-November-December, so that pulsation power at MBC might be expected to be lower than at MBC.

Differently, during the winter periods, Figure 1 shows that the Pc5 power is higher at DRV during 1991 and at MBC during 1992, in agreement with higher Kp activity during northern summer in 1991 and during the northern winter in 1992.

Similarly to Figure 1, in Figure 3 the distributions of Pc5 power occurrences are reported for the years 1995 and 1996, separately for each seasonal period. The powers observed during these years are shown to be generally lower than the ones in Figure 1, in agreement with the occurrence of smaller Kp, as shown in Figure 2.

In Figure 3, during the equinoxes, the distributions of the power observed at MBC are shifted toward values higher than at DRV. The same shift is more evident during the local summer periods of both years. Only during 1995 this can be related (at least in part) to the Kp activity slightly higher in May-June-July-August than in January-February-November-December.

During the local winter periods, Figure 3 shows that Pc5 powers observed at MBC and DRV are about the same amplitudes, with only a very slight shift of the distribution for MBC toward higher pulsation powers. This result is in agreement with the expectations from the Kp activity: e.g., in 1996 the Kp activity is higher during winter at MBC than during winter at DRV.

#### 2b. Distributions of differences between the Pc5 power at DRV and MBC.

In order to study the hemispherical asymmetries with inclusion of the seasonal effects, we have calculated the difference between the Pc5 power at DRV minus the one at MBC for each 3-h UT interval over all the years considered. The distributions of these differences are illustrated in Figure 4 and 5, respectively for  $Kp < 2$  and  $Kp > 3$ . Kp values are from the OMNI database at NSSDC (USA National Space Science Data Center) and these are integer numbers equal to  $Kp \cdot 10$ . Thus,  $Kp < 2$  corresponds to  $(Kp \cdot 10) < 20$  and  $Kp > 3$  corresponds to  $(Kp \cdot 10) > 30$ . This specific division has been chosen in order to obtain the maximum distance between the geomagnetic activity levels, having about the same number of data points in the two ranges (as it can be observed in Figure 2).

Results are shown separately for the periods: (a) January, February, November, and December; (b) March, April, September, October; (c) May, June, July, August. Thus these periods are simultaneous (with the same Kp) in both hemispheres, and they refer to opposite local seasons (except the equinoxes).

Since the spectral powers are only positive, in Figures 4 and 5 the negative X-axis range indicates occurrences of Pc5 activity higher at MBC and the positive one indicates Pc5 activity higher at DRV. Thus, the Figure 4 shows that the occurrence of higher Pc5 activity is more frequent at MBC during the northern summer and at DRV during the northern winter, in agreement with seasonal expectations (e.g., Ballatore et al., 1998a). Moreover Figure 4 illustrates that the Pc5 North-South differences are not significantly affected by the solar cycle. In particular during the northern summers it is shown that the percentage of occurrences of DRV-MBC power in the range  $(-5, 0)$  nT<sup>2</sup> is higher in 1991 than during the other years. This is explained considering the distribution of the  $K_p < 2$  (see Figure 2): for the summer of 1991 there are about 9% 3-h intervals in the range of  $(0, 1)$   $K_p$  and about 18% in the range  $(1, 2)$   $K_p$ , thus occurrences of  $K_p < 1$  are about 50% of the ones with  $K_p$  between 1 and 2. This latter percentage is always definitely less than 50% for the other years, indicating relatively higher disturbances (i.e. higher occurrence of  $K_p > 1$ ) during periods with  $K_p < 2$ . For example for 1992 (the most similar to 1991), Figure 2 shows about 19.5% of occurrences of  $K_p < 1$  and 31.5% of occurrences of  $1 < K_p < 2$ .

The Figure 5 is similar to the Figure 4 but for periods with  $K_p > 3$ . It shows the effect of the increased geomagnetic activity as an increase of the differences between northern and southern Pc5 power. Again, it is not possible to note a systematic association with the solar cycle, while differences among the distributions are attributed to the different distributions of  $K_p$  in the considered range of  $K_p > 3$  (as it can be noted in Figure 2).

In order to quantify the difference between North-South Pc5 power during quieter and more disturbed geomagnetic conditions we mention that during the northern summer the occurrence of differences in the range  $(-10, 0)$  nT<sup>2</sup> is almost double for  $K_p < 2$  than for  $K_p > 3$ , and so it is also during the northern winter for the occurrences in the range  $(0, 10)$  nT<sup>2</sup>. For examples (see Figure 4 and 5): during the northern summer of 1992, in the range  $(-10, 0)$  nT<sup>2</sup>, we have 62% of occurrences for  $K_p < 2$  and 33% for  $K_p > 3$ ; during the northern winter of 1991 we have 52% of occurrences in the range  $(0, 10)$  nT<sup>2</sup> for  $K_p < 2$  and 26% for  $K_p > 3$ .

### 2c. Daily modulations.

In order to study similarities for the daily modulation of Pc5 pulsations at MBC and DRV stations, the 3-h Pc5 powers have been averaged separately for each 3-h interval and results are reported in Figure 6a (year 1991 in top panels and year 1992 in bottom panels), for years near the solar maximum. Results are shown separately for each seasonal period and separately for  $K_p < 2$  (dots) and for  $K_p > 3$  (asterisks). The comparison between years 1991 and 1992 (in Figure 6a) shows that, although differences exist from year to year, the Pc5 power vs. time is a flatter curve for  $K_p > 3$ , while it has a deeper minimum around the MLM, for  $K_p < 2$ . For these latter quiet periods, there is always a major maximum around the MLN, in association with the cusp location and in agreement with previous findings (e.g., Ballatore et al., 1998a; and references therein). During the local summer, the increase of power during higher  $K_p$  is more significant in the geomagnetic nightside than it is in the geomagnetic dayside. Further we note that, during the local winter and for  $K_p > 3$ , the power around the MLM can be equal or higher than it is around the MLN. Finally we note the possibility of a small secondary peak around the MLM also during  $K_p < 2$ , as it is during the local summer of year 1992 at MBC.

The daily modulations during years closer to the solar minimum, are reported in Figures 6b, similar to Figures 6a but for the years 1995 and 1996. Comparison between Figure 6a and 6b shows that the differences between periods of maximum or minimum solar activity are not more significant than the differences observed between 1991 and 1992 or between 1995 and 1996. One exception could be the much more evident peak around the MLM during  $K_p > 3$  which can become the major peak, e.g., during the local winter of 1995 at DRV or during the local winter of 1996 at MBC. This effect is explained considering that (see Figure 2): the percentage of  $K_p$  in interval 3-4, with respect to  $K_p$  in the whole interval 3-8, is higher during 1991-1992 than during 1995-1996. Thus, for data points with  $K_p > 3$ , years 1995 and 1996 are, on average, more geomagnetically active periods. In particular we verified that in the specific MLM time interval for 1995-1996 there is higher disturbance than at the same time during the other years.

### 3. Discussion

Previous studies showed that the Pc5 power level is higher during the local summer than during the local winter and this finding was interpreted in terms of the higher ionospheric ionization during sunlit conditions (e.g., Ballatore et al., 1998; and references therein). This result is visible also in our data as illustrated in Figure 1 and 3. In addition, in these latter Figures there is evidence of a tendency to have higher Pc5 power in the northern hemisphere than in the southern one. This result is clear during the equinoctial seasonal intervals (simultaneous in both hemispheres) for all the four years considered, independent of the solar cycle.

The comparisons between local summers and local winters at the conjugate locations MBC and DRV (taking into account the effects of the different geomagnetic activity in the considered periods) demonstrate that the average Pc5 power is higher in the northern summer than in the southern summer, even when northern periods of lower geomagnetic activity are compared with southern periods of higher geomagnetic activity (e.g., during year 1996). Similarly, higher northern power is observed during the equinoxes, but the effect is smaller than during the local summers.

Moreover, the average Pc5 power during the northern winter is about the same as the one in the southern winter, with possibility of being higher in the South than in the North, depending on respective geomagnetic activity level (e.g., during the local winters in 1991).

The sunlit higher power in the North, which is not related to the Kp effects, is also not related to the different interplanetary conditions in the compared periods. This can be observed considering that the solar wind speed is known to be linearly correlated with the Kp (e.g., Ballatore, 2002). In addition, we have verified that the IMF By and Bz are not differently distributed in the different seasonal periods considered. In particular when higher occurrence of Kp is observed this can be associated with higher occurrence of southern IMF (in agreement with geomagnetic expectations), but this is the only possible association. This is in agreement with the

fact that previous findings demonstrated low or null correlation between the low frequency pulsation power and the IMF  $B_y$  and  $B_z$  components (e.g., Posch et al., 1998; Ballatore et al., 1998a; and references therein). Similarly to the IMF, the distributions of other interplanetary parameters (in particular the clock angle and the dynamic pressure) have been studied and the fact that the local summer Pc5 power is higher at MBC than at DRV cannot be explained in terms of interplanetary origin.

Because of the fact that the higher Pc5 power in the northern local summer (and during equinoxes) cannot be directly related to planetary geomagnetic activity or interplanetary configuration, its dependence on local hemispherical origin can be inferred. In particular, the smaller distance between the northern than the southern geographic and geomagnetic poles implies for MBC and DRV (both located at equal geomagnetic coordinates) a different daily excursion with respect to the Sun zenith angle during the 24 UT hours. We suggest that, during the summer sunlit, a more intense and permanent solar UV effect is found closer to the geographic pole, i.e. for higher geographic latitudes. Thus, MBC is expected to be radiated by EUV sunlight more permanently than DRV, as it can be observed from Table I: the geographic latitude at DRV, compared to the one at MBC, is about  $10^\circ$  further from the pole.

A model expressing the solar EUV Pedersen conductance as a function of the solar zenith angle, solar F10.7 radio flux and the local magnetic field is reported by Shue et al. (2001), who studied the correlation between this conductance and the auroral brightness. They found a positive correlation in the early morning and an anticorrelation in the premidnight sector. This is in agreement with previous observations by Newell et al. (1996): the auroras observed in the afternoon and premidnight sectors are 3 times more frequent in darkness than in sunlight. The difference between early morning and premidnight auroras can be associated to the different morphology of these auroras, being weak and diffuse in the dayside or intense and discrete in the nightside (e.g., Meng and Akasofu, 1983; Shue et al., 2001). In a direct comparison between aurora brightness and Pc5 power is important to take into account the fundamental different nature between these phenomena. In any case our results can suggest a proportionality between Pc5 power and ionospheric conductance, similar to the case of early morning weak auroras.

An indirect comparison between micropulsations and auroras can be done by comparing the northern auroral indices, AE, AL and AU with the low frequency micropulsation power. In particular the comparisons of AE, AL and AU with Pc3, Pc4 and Pc5 power have demonstrated the existence of significant correlations (Ballatore et al., 1996; and references therein). These correlations are significant at all MLT sectors if the ULF power is calculated at a northern hemisphere station. Differently these correlations are affected by north-south asymmetries if the ULF power is calculated for a station in the southern hemisphere. In particular micropulsation power at latitude  $-80$  CGM is not correlated with northern auroral indices around the cusp geomagnetic noon-time region. Since we do not have availability of a southern hemisphere AE, it is not convenient to consider in the present work the AE index as an indicator of the auroral activity. For this reason we have referred only to Kp (Figure 2) as a valid indicator of geomagnetic activity at MBC and DRV, independent of the hemisphere.

The comparison between results shown in Figure 1 and 3 with previous published results is not possible, in fact previous northern-southern comparisons of low-frequency pulsation power were done by considering observations of simultaneous events or simultaneous time intervals in the northern and southern hemisphere (e.g., Posch et al., 1998; and references therein). Thus, these works investigated the effects of seasonal and hemispherical differences mixed together.

Similarly to these previous approaches, in Figure 4 and 5 we reported the distributions of the northern-southern differences. The Kp ranges were restricted to only data for  $Kp < 2$  and  $Kp > 3$  (separately) in order to observe the possible geomagnetic effect on seasonal-hemispherical Pc5 power differences. Results show that there is about 50% more occurrence of differences smaller than  $110 \text{ nT}^2$  for  $Kp < 2$  than for  $Kp > 3$ . Compared with Figure 1 and 3, this indicates that the geomagnetic activity affects the Pc5 power more significantly than the specific season or hemispherical characteristics. This result is in agreement with previous observation of significant decrease of the correlation between the southern geomagnetic index AES-80 and the northern Joule-Heating (whose coefficient is

generally of the order of 0.9) during the most disturbed conditions (Ballatore et al., 2000).

The solar illumination relationship with the geomagnetic activity is different of the one with the Pc5 power. In fact geomagnetic activity is known to peak at equinoxes (e.g., Russell and McPherron, 1973; Clua de Gonzalez et al., 1993), while Pc5 power is observed to peak during the local summer. In particular Lyatsky et al. (2001), after studying the occurrence of higher geomagnetic activity during the equinoxes, suggested that geomagnetic activity peaks when the nightside auroral zones of both hemispheres are in darkness, as during equinoctial periods. This is related to the suppression of the intense discrete auroras during the sunlight (Newell et al., 1996), assumed the positive correlation between auroral occurrence and geomagnetic activity indices. Considering Lyatsky et al.'s results we can deduce that the influence of the discrete aurora occurrence is not as significant on the Pc5 power as it is on the geomagnetic activity. However it is worth to note that, in our specific case, the expected higher geomagnetic activity during the equinoxes is not clear in the Kp distributions for each year separately, e.g. for the 1992 (see Figure 2).

Observing Figure 4 and Figure 5, it is possible to note that more than 70% of occurrences have a difference of power between DRV and MBC smaller than  $110 \text{ nT}^2$  for  $K_p < 2$ , and more than 58% of occurrences have a difference of power between DRV and MBC smaller than  $120 \text{ nT}^2$  for  $K_p > 3$ , independent of the specific months considered. This statistical northern-southern agreement is higher than the one reported by Posch et al. (1998), who found that the ULF activity was simultaneous and of similar power in both hemispheres only on about 1/3 of considered days.

However our present results can be considered consistent with the results by Posch et al. (1998) considering that they differentiated ULF activity also with respect to their frequency distributions (e.g., the occurrence of narrow-band and broad-band Pc5 pulsations were classified as different events).

The comparison among results in Figure 1, 3, 4 and 5 shows that differences between the years of maximum (1991-1992) and minimum (1995-1996) solar activity are directly related to the different occurrence of geomagnetic activity in the considered periods. In particular, the solar cycle is not directly affecting the seasonal,

nor the hemispherical characteristic level of pulsation power. Similarly, no effects related to the solar cycle can be deduced by taking into account the daily modulation of Pc5 power at MBC and DRV, as it can be seen by comparing Figure 6a and 6b, and taking into account the Kp distributions reported in Figure 2.

In particular it is found that, during the quietest periods, there is a major peak of Pc5 power around the MLN, while this is not necessarily a major peak during the intervals with  $K_p > 3$ . This is in agreement with the expected shift of the dayside cusp toward higher latitudes (closer to MBC and DRV) and with previous results (e.g., Ballatore et al., 1998a; and references therein). The possible secondary peak around MLM during the periods of  $K_p < 2$  can be explained with the occurrence of nightside substorms in the polar cap, which are known to take place at these high latitude in association with the auroral oval poleward shift during the quietest geomagnetic periods (e.g., Weatherwax et al., 1997; Ballatore et al., 1998a).

Previous studies of geomagnetic data at the Antarctic station McMurdo (at southern latitude  $\sim 80^\circ$  CGM, similarly to MBC and DRV) during local winter May-June 1994 showed the occurrence of one major peak of Pc5 power around the MLM, which emerged more clearly by considering only periods with  $K_p > 3$  (Ballatore et al., 1998b). This kind of daily modulation occurs at times also in the present data and both at MBC or at DRV, but only during the local winter seasons, e.g. in 1995. Therefore the present study confirms that the Pc5 daily modulation with one major peak around MLM characterizes the only local winter season as previously supposed by Ballatore et al. (1998b). Moreover, the association of this peak with the substorm occurrence and with the shift of the nightside auroral oval toward higher latitudes at winter (Olson, 1986; Ballatore et al., 1998b; and references therein) is now confirmed. The fact that previous McMurdo observations were related to year 1994 and the present MLM-peak of power occurs at MBC and DRV during the local winters 1995 and 1996 (see Figure 6b) suggests an independence of the solar cycle and an independence of the specific hemispherical characteristics.

In summary, the comparison between Figure 6a and 6b indicates that the major characteristics of the Pc5 power daily modulations are similar in the two hemispheres and independent of the solar cycle.

#### 4. Summary and Conclusions

The Pc5 power level at the conjugate locations MBC and DRV has been investigated. Results show that the northern hemisphere power is higher than the southern hemisphere one. This effect is seasonal dependent: the local summer power at MBC is clearly higher than at DRV, this DRV-MBC difference is less significant during the equinoxes and only very slight or absent during the local winter. Because of the equivalent geomagnetic locations for the two considered stations, these findings may be attributed to the different geographical coordinates (associated with different solar zenith angles and solar EUV ionospheric conductance) or to possible geomagnetic or interplanetary differences. However geomagnetic activity and interplanetary conditions are equal for both hemispheres during the equinoxes, which are simultaneous northern-southern periods. Thus the higher Pc5 power at MBC than at DRV is certainly originated by geographical differences during the equinoxes. In addition, the histograms of Kp planetary geomagnetic index and of the interplanetary parameters (in particular IMF, clock angle and dynamic pressure) have been compared during the northern and southern local summers (or winters). This comparison has demonstrated that the MBC/DRV different Pc5 power cannot be interpreted solely in terms of geomagnetic activity or of interplanetary origin. Thus, the summer higher Pc5 power at MBC is explained by considering that its geographic latitude is about 10 deg higher than the one at DRV (see Table I). In fact, during the local summer, the EUV sunlit radiation is more direct and permanent (with consequent higher ionospheric ionization/conductance) closer to the Earth's rotational pole.

The observations above are in agreement with previous results about the Pc5 power seasonal dependence, suggesting that increases of solar EUV ionospheric conductance are associated with increases of Pc5 power (e.g., Ballatore et al., 1998a; and references therein). A similar relationship with the solar EUV ionospheric conductance was obtained for the weak diffuse auroras observed in the early morning sector (Shue et al., 2001). However these are just one specific class of auroras, different of the nightside discrete auroras, which are known to be suppressed by

sunlight (Newell et al., 1996). The discrete auroras, generally are associated with substorm occurrence and are known to enhance the geomagnetic activity. In fact, Lyatsky et al. (2001) explain the maximum geomagnetic activity during equinoxes by considering that both northern and southern nightsides are in darkness at these periods. The fact that the Pc5 power maximizes during the local summer and not during the equinoxes is a further confirmation of the opposite effect of the solar illumination on discrete aurora and on micropulsation power.

Considering the comparison of simultaneous Pc5 activity in the two hemispheres, a rather good agreement is found: more than 70% of occurrences have a MBC-DRV power difference smaller than  $|10| \text{ nT}^2$  for  $K_p < 2$ , and more than 58% of occurrences have a DRV-MBC power difference smaller than  $|20| \text{ nT}^2$  for  $K_p > 3$ . These results are compared with previous northern-southern ULF power comparisons by Posch et al. (1998).

The solar EUV ionospheric conductance influences the Pc5 power at MBC and DRV so much that the effect is visible regardless the equivalence of the geomagnetic coordinates. At the same time the MBC/DRV geomagnetic conjugacy causes similar Pc5 power dependence on the geomagnetic activity and on the MLT. In particular the geomagnetic activity effects are dominant on any seasonal or geographical influence. In addition, both at MBC and DRV, the Pc5 power modulation vs. MLT is determined by the influence from the geomagnetic cusp (causing MLT dayside power peak) and from the geomagnetic substorms (causing MLT nightside power peak). The effects of these phenomena are so dominant on the Pc5 power daily modulation that the latter is not affected by the geographical differences. This result is in agreement with previous findings showing the important relationship between Pc5 power level and MLT sectors, regardless any local time differences (Ballatore et al., 1998a).

Comparisons between observations close to the solar maximum and to the solar minimum activity do not show evidence of any possible direct association between the Pc5 power and the solar cycle.

## 5. Acknowledgements

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## 6. References

- Arnoldy, R.L., L.J. Cahill Jr., M.J. Engebretson, L.J. Lanzerotti, and A. Wolfe, Review of hydromagnetic studies in the Antarctic, *Rev. Geophys.*, 26, 181, 1988.
- Ballatore, P., M. Candidi, S. Ballatore, and A. Meloni, Northern polar disturbance relationship with (1.7-6.7 mHz) geomagnetic field fluctuations at high southern latitudes, CNR Internal Report, IFSI-96-6, 1996.
- Ballatore, P., L.J. Lanzerotti, and C.G. MacLennan, Multistation measurements of Pc5 geomagnetic power amplitudes at high latitudes, *Journ. Geophys. Res.*, 103, 29,455, 1998a.
- Ballatore, P., M.J. Engebretson, C.G. MacLennan, and M. Candidi, Ground based observations of Pc3-Pc5 geomagnetic pulsation power at Antarctic McMurdo station, *Annali di Geofisica*, 41, 141, 1998b.
- Ballatore, P., L.J. Lanzerotti, G. Lu, and D.J. Knipp, Relationship between the Northern Hemisphere Joule heating and geomagnetic activity in the southern polar cap, *Journ. Geophys. Res.*, 105, 27,167, 2000.
- Ballatore, P., Effects of fast and slow solar wind on the correlations between geomagnetic indices and interplanetary medium, *Journ. Geophys. Res.*, 107, 1227, 2002.
- Clua de Gonzalez, A.L., W.D. Gonzalez, S.L.G. Dutra, and B.T. Tsurutani, Periodic variation of geomagnetic activity: A study based on the Ap index, *Journ. Geophys. Res.*, 98, 9215, 1993.
- Engebretson, M.J., W.J. Hughes, J.L. Alford, E. Zesta, L.J. Cahill Jr., R.L. Arnoldy, and G.D. Reeves, Magnetometer array for cusp and cleft studies observations of the spatial extent of broadband ULF magnetic pulsations at cusp/cleft latitudes, *Journ. Geophys. Res.*, 100, 19,371, 1995.

- Fraser-Smith, A.C., Centered and eccentric geomagnetic dipoles and their poles, 1600-1985, *Journ. Geophys. Res.*, 25, 1, 1987.
- Gupta, J.C., Long period Pc5 pulsations, *Planet. Space Sci.*, 23, 733, 1975.
- Lyatsky, W., P.T. Newell, and A. Hamza, Solar illumination as cause of the equinoctial preference for geomagnetic activity, *Journ. Geophys. Res.*, 28, 2353, 2001.
- Matthews, D.L., J.M. Ruohoniemi, J.R. Dudeney, C.F. Farrugia, L.J. Lanzerotti, and E. Friis-Christensen, Conjugate cusp-region ULF pulsation responses to the solar wind event of May 23, 1989, *Journ. Geophys. Res.*, 101, 7829, 1996.
- Mizera, P.F., D.J. Gorney, and D.S. Evans, On the conjugacy of the aurora: High and low latitudes, *Geophys. Res. Lett.*, 14, 190, 1987.
- Morris, R.J., and K.D. Cole, Pc3 magnetic pulsations at Davis (Antarctica), *Planet. Space Sci.*, 35, 1437, 1987.
- Newell, P.T., and C.-I. Meng, Hemispherical asymmetry in cusp precipitation near solstices, *Journ. Geophys. Res.*, 93, 2643, 1988.
- Newell, P.T., C.-I. Meng, and K.M. Lyons, Suppression of discrete aurora by sunlight, *Nature*, 381, 766, 1996.
- Odera, T.J., Solar wind controlled pulsations: a review, *Rev. Geophys.*, 24, 55, 1986.
- Olson, J.V., ULF signatures of the polar cusp, *Journ. Geophys. Res.*, 91, 10,055, 1986.
- Press, W.H., B.P. Flannery, S.A. Teukolsky, and W.T. Vetterling, *Numerical recipes, the art of scientific computing*, pp.430-435, Cambridge University Press, 1990.
- Posch, J.L., M.J. Engebretson, A.T. Weatherwax, D.L. Detrick, W.J. Hughes, and C.G. MacLennan, Characteristics of broadband ULF magnetic pulsations at conjugate cusp latitude stations, *Journ. Geophys. Res.*, 104, 311, 1998.
- Russell, C.T., and R.L. McPherron, Semi-annual variation of geomagnetic activity, *Journ. Geophys. Res.*, 78, 92, 1973.
- Shue, J.-H., P.T. Newell, K. Liou, and C.-I. Meng, The quantitative relationship between auroral brightness and solar EUV Pedersen conductance, *Journ. Geophys. Res.*, 106, 5883, 2001.

Weatherwax, A.T., T.J. Rosenberg, C.G. Maclellan, and J.H. Doolittle, Substorm precipitation in the polar cap and associated Pc5 modulation, *Geophys. Res. Lett.*, 24, 579, 1997.

## 7. Figure Captions

*Figure 1.* Histograms of the Pc5 power at the stations DRV and MBC during the years 1991 (bottom panels) and 1992 (top panels); results are shown separately for the local summer (left panels), equinoctial (middle panels) and local winter (right panels) periods.

*Figure 2.* Histograms of the Kp occurrence, separately for each seasonal period and each year 1991, 1992, 1995 and 1996.

*Figure 3.* Similar to Figure 1, but for the years 1995 (bottom panels) and 1996 (top panels).

*Figure 4.* Histograms of the differences of the power at DRV minus that at MBC for the seasonal period indicated and for the years 1991, 1992, 1995 and 1996; results are shown for the only data points corresponding to  $K_p < 2$ .

*Figure 5.* Similar to Figure 4, but for the only data points corresponding to  $K_p > 3$ .

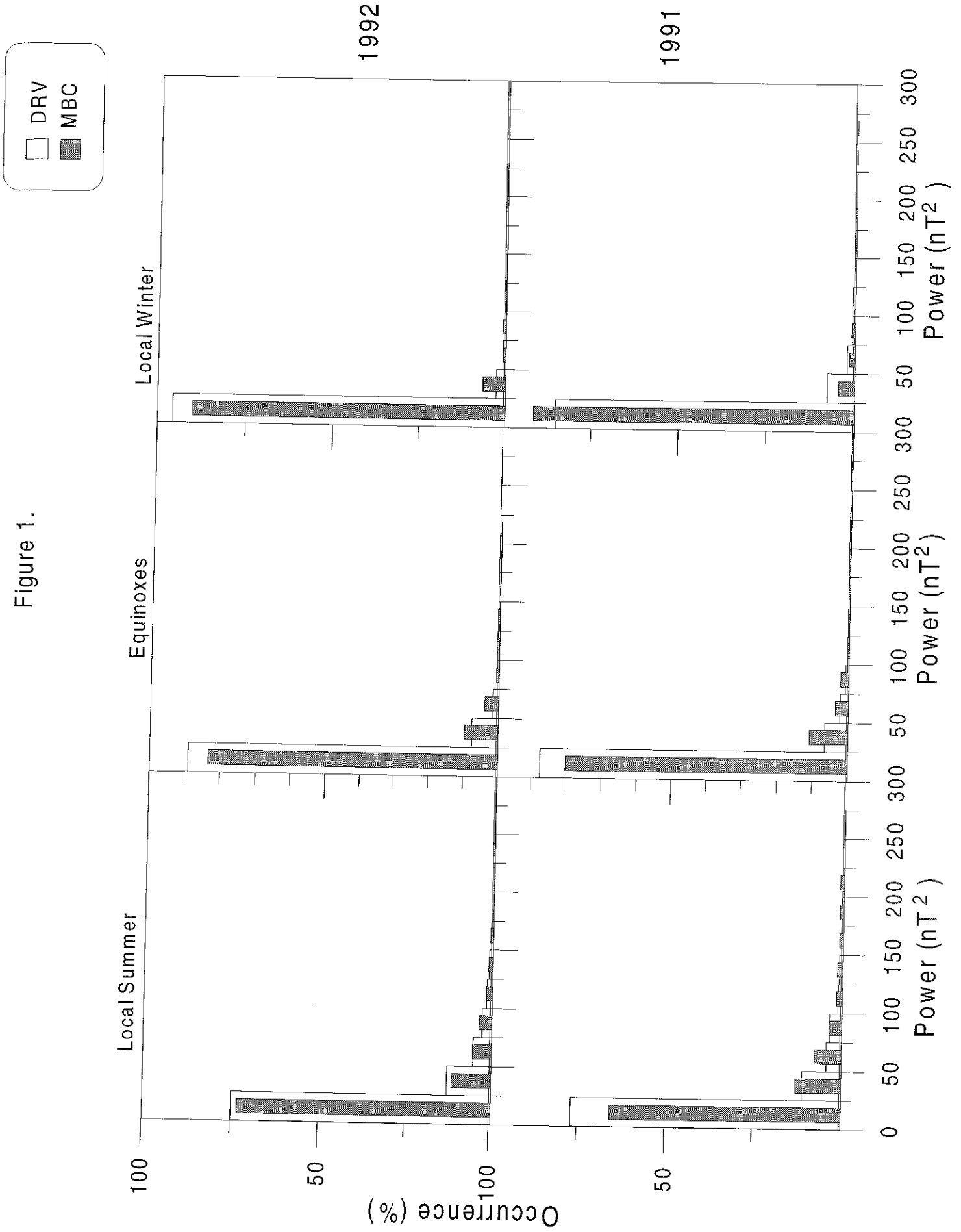
*Figure 6a.* Average Pc5 power for each 3-h UT interval of the day at the two locations MBC and DRV; each column refers to the months of the year 1991 (top panels) or year 1992 (bottom panels) specified at the top; results are shown separately for data with  $K_p < 2$  (dots) and  $K_p > 3$  (asterisks); the arrows indicate the magnetic local noon at the considered station.

*Figure 6b.* Similar to the Figure 6a, but for the year 1995 (top panels) and 1996 (bottom panels).

**Table I.**

Station	Code	Geographic Latitude	Geographic Longitude	CGM Latitude	CGM Longitude	Magnetic Local Midnight
Mould Bay	MBC	76.2°N	119.4°W	80.85°N	272.65°E	10:29 UT
Dumont D'Urville	DRV	66.7°S	140.0°E	80.61°S	235.76°E	12:54 UT

Figure 1.



- Jan., Febr., Nov., Dec.
- ▨ March, Apr., Sept., Oct.
- May, June, July, Aug.

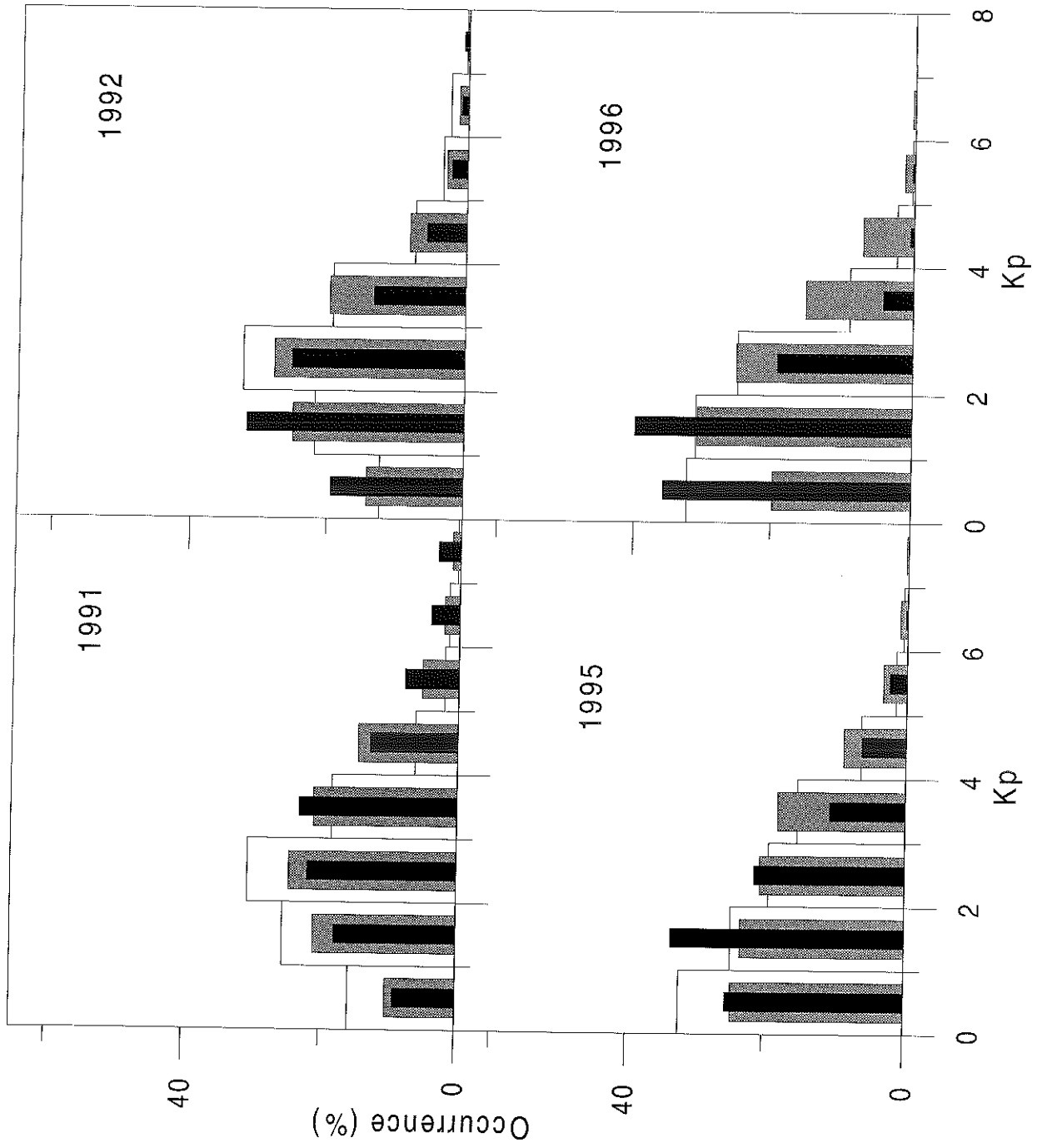


Figure 2.

Figure 3.

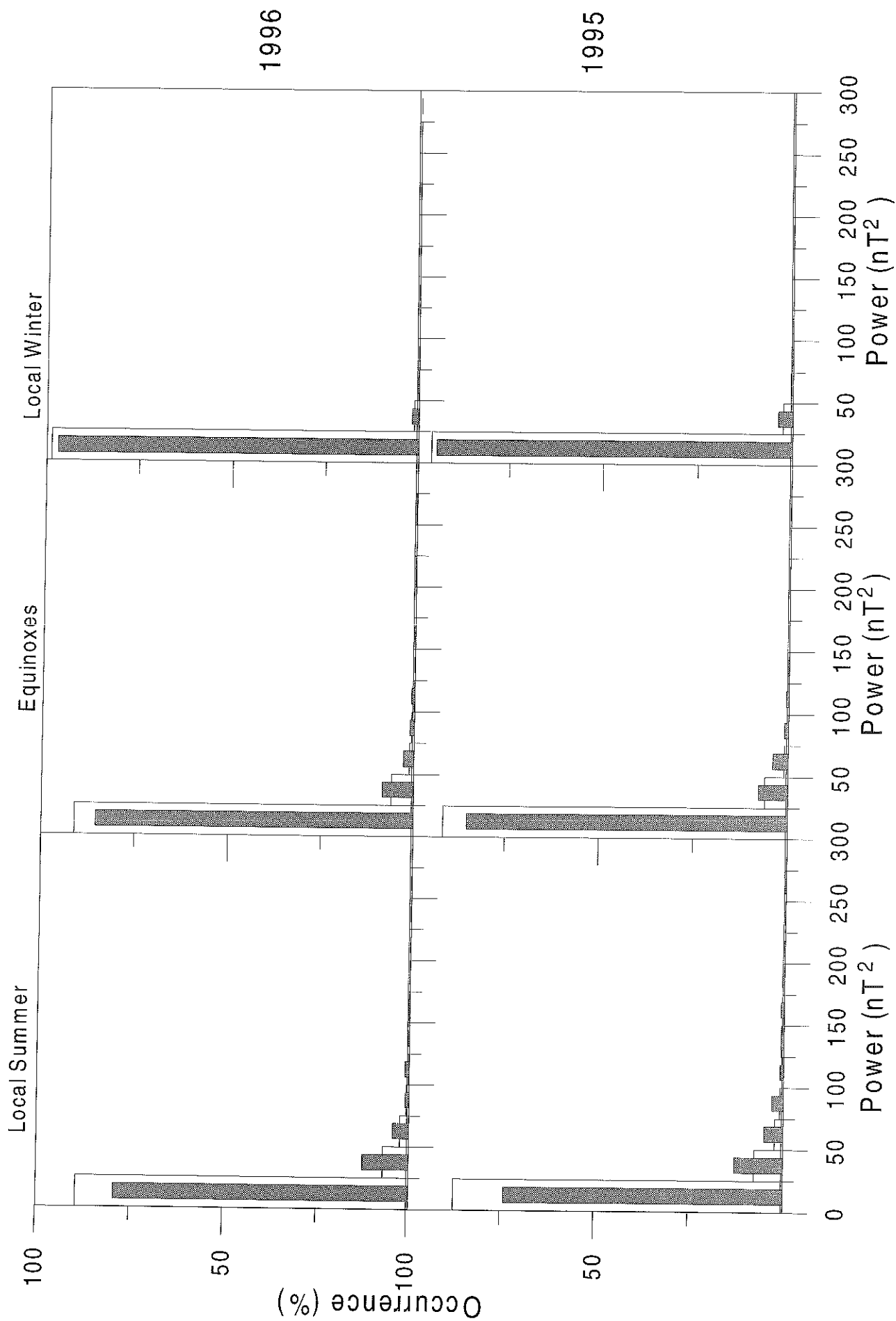
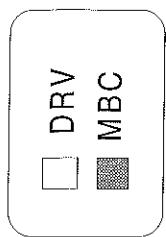


FIGURE 4.

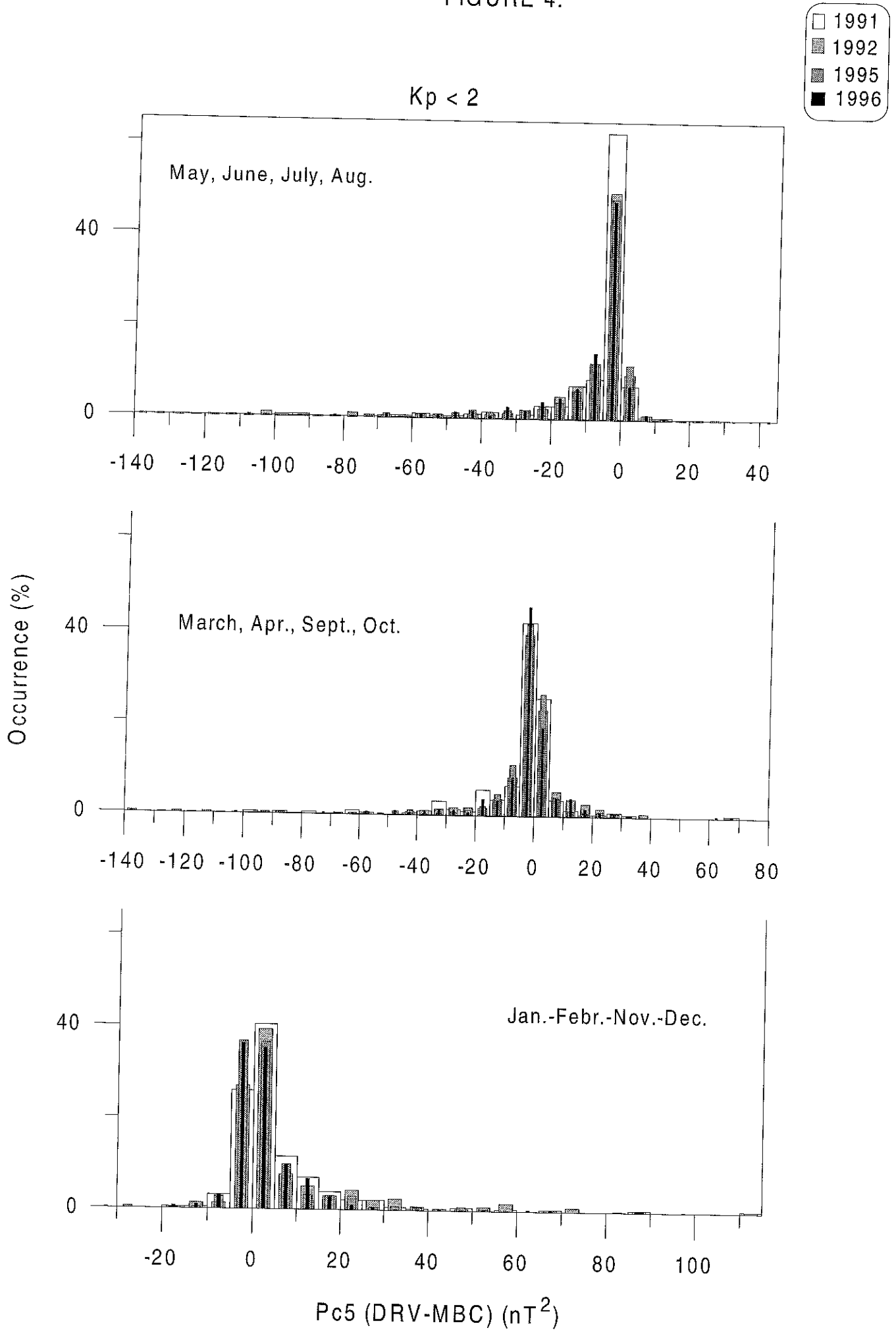


FIGURE 5.

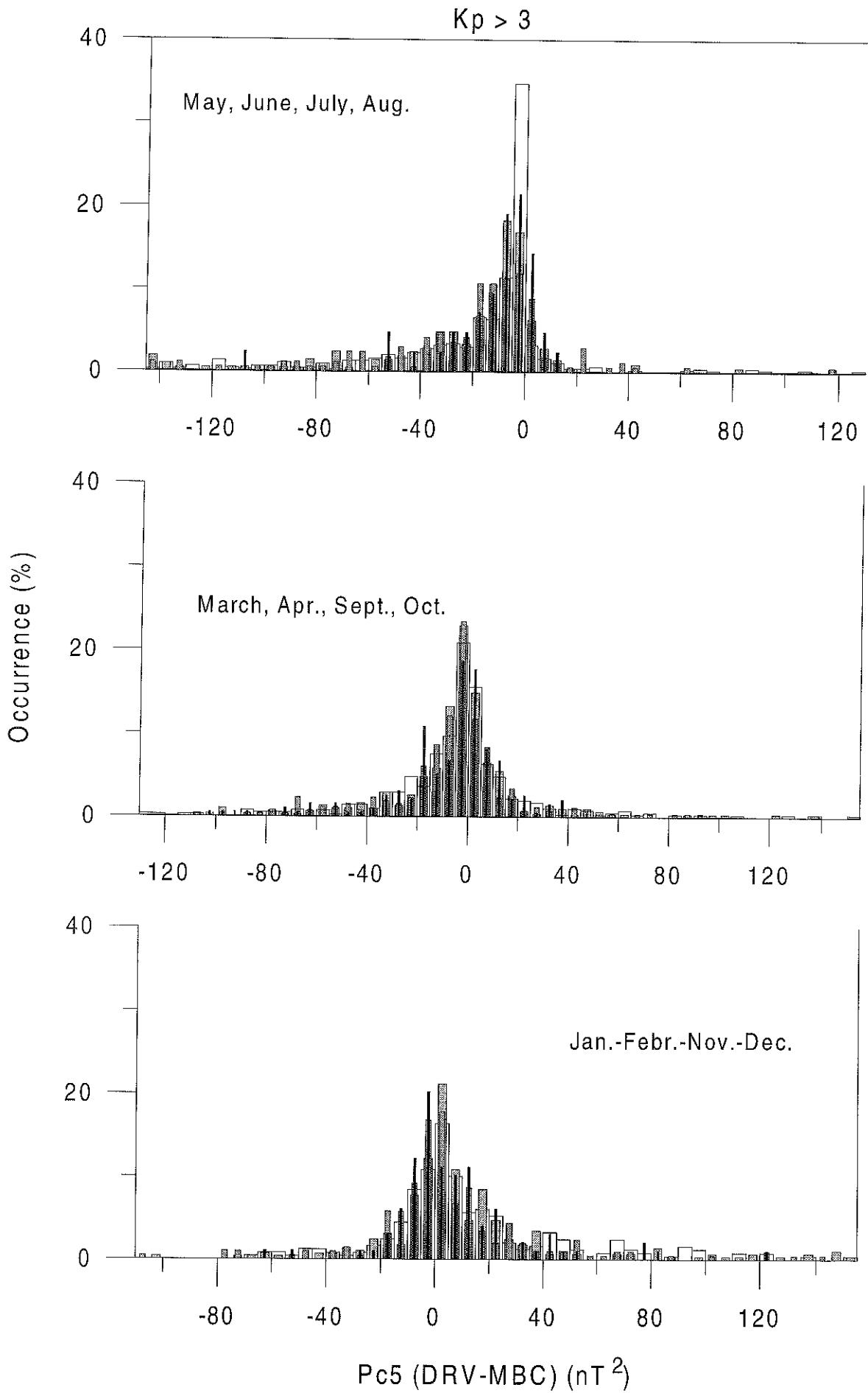
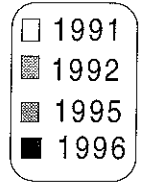


Figure 6a

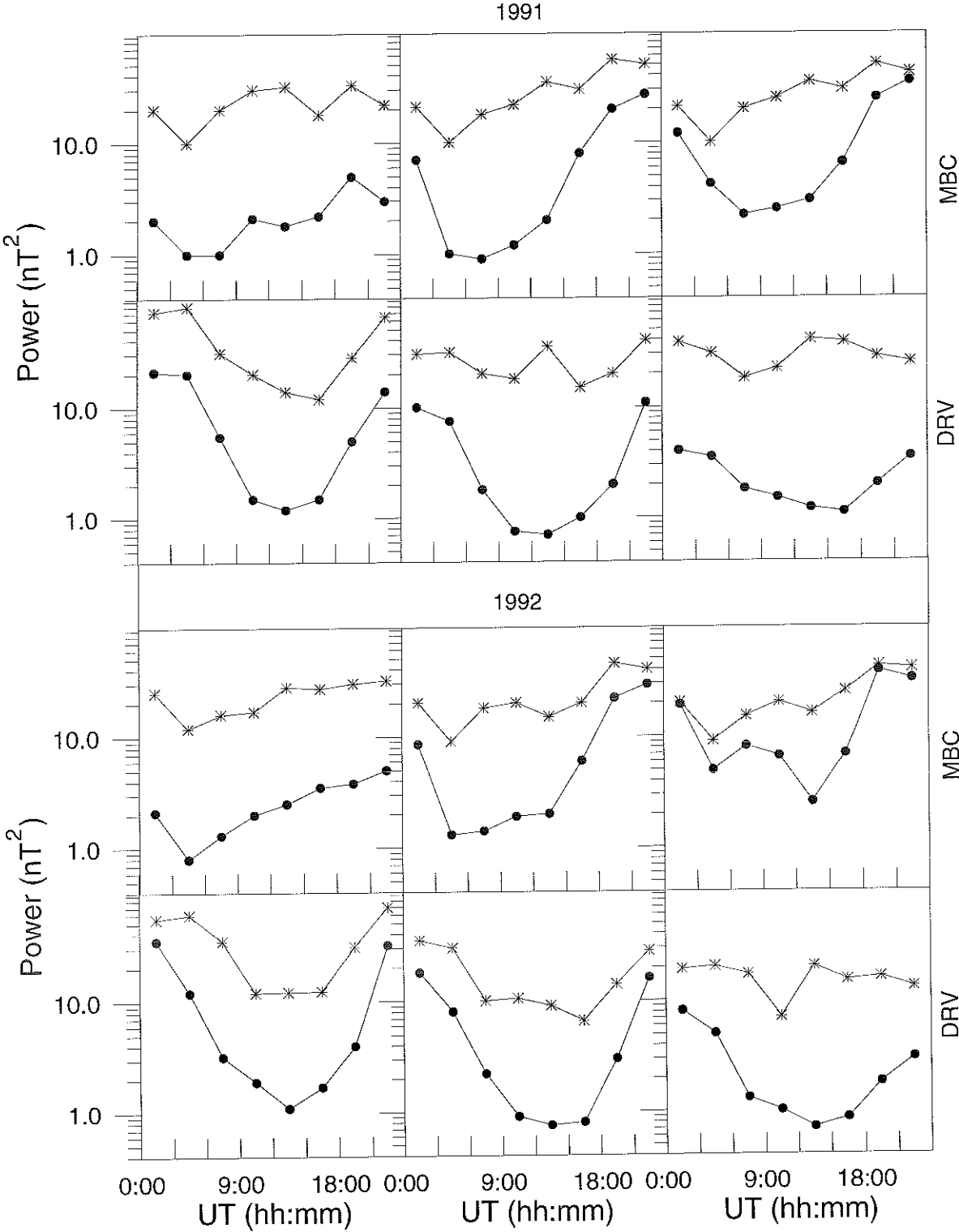


Figure 6b

