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About the seasonal distribution of geomagnetic activity

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ABSTRACT

The annual distribution of geomagnetic activity is studied through the geomagnetic indices *aa*, Dst and AE, according to different levels of intensity for each of the indices. For thresholds that correspond to moderate to fairly intense storms, the distribution follows the well-known pattern of a seasonal variation, with maxima around the equinoxes and minima near the solstices. However, the observed pattern deviates from this behavior as the distribution refers to levels associated to the occurrence of more intense storms. For the latter type of storms, the geomagnetic index *aa* shows the occurrence of a peak in July (but not in January, as a seasonal symmetry would suggest). The contribution of very intense storms to the July peak seems to be evenly distributed along the 11 solar cycles covered by this index. Furthermore, although the records for the indices Dst and AE are restricted to shorter time intervals as compared to *aa*, they also show the possible existence of this peak for July.

The present analysis gives also some indications for the existence of a peak in November in the distribution of very intense storms. This peak shows up particularly for the indices Dst and AE, whose records go back only to 1957. Therefore, its real existence is more questionable than that of the peak for July.

INTRODUCTION

The geomagnetic activity distribution is known to be characterized by a typical seasonal variation of semiannual waveform, with maxima around the equinoxes and minima near the solstices. The cause of this seasonal variation is still a matter of controversy but it is basically attributed to one or more of the three models known respectively as axial, equinoctial and Russell-McPherron mechanisms (see e. g. Russell and McPherron, 1973; Crooker and Siscoe, 1986; Clúa de Gonzalez et al., 1993, Orlando et al., 1993, and references therein). However, a more detailed study of the annual variation of the geomagnetic activity seems to indicate that the monthly distribution is not as predicted by the seasonal pattern, when the statistics is restricted to high levels of intensity. In particular, the existence of a peak around July in the distribution of intense events has been mentioned in previous studies (Clúa de Gonzalez et al., 1993; Bell et al., 1997). In the temporal analysis of the *Ap* index conducted by Clúa de Gonzalez et al. (1993) for the interval spanning solar cycles 17 through 21, it was observed the presence of a peak in July for the monthly number of days with maximum value of *Ap* > 150 nT. This peak seems to be present in all the considered solar cycles but without a corresponding peak in January, as a symmetric seasonal variation would suggest. The fact that this July-peak appears precisely for the most intense storms has induced Clúa de Gonzalez et al. to disregard the unequal North-South distribution of observatories as the cause of this asymmetry, because any error originated in this inequality would influence the distribution of weak and moderate storms as well.

Since, in our knowledge, the possible existence of a peak of occurrence of intense storms in July has not been examined yet in detail, and considering the important consequences that a better understanding of the annual variations of the geomagnetic activity may have, the present analysis was undertaked with the aim of extending the statistics to different geomagnetic indices and to longer time intervals, as compared to the above mentioned studies.

MONTHLY DISTRIBUTION OF THE *aa* INDEX

The three-hourly geomagnetic index *aa*, closely related to the planetary indices *ap* and *am*, has been recorded since 1868 (see e.g. Allen and Feynman, 1979; Mayaud, 1980). In the present analysis, the monthly numbers of days with *aa* above different levels (aa $\geq$ 90, 120, 150, 180 and 210) have been plotted in Figure 1. As can be seen in upper panel of this figure, for *aa* $\geq$ 90, the distribution shows the classical seasonal behavior with two maxima around the equinoxes. However, in the following panels, as the level of *aa* increases, the distribution tends to show a more significant peak in July. For *aa* $\geq$ 180, this peak becomes equivalent to that for September and larger than the March peak, both associated to the semiannual pattern. Furthermore, the July peak (with six events) exceeds the monthly average in the 1 sigma level of confidence and exceeds the corresponding to the equinoctial months, although the statistics becomes poorer.

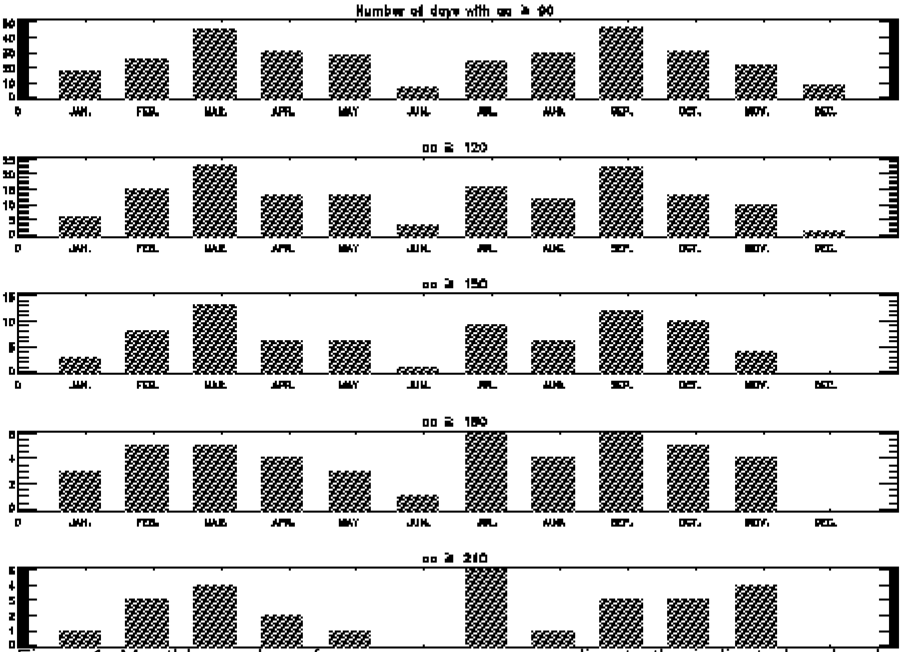

Figure 1. Monthly number of occurrences corresponding to the indicated aa levels, for the time interval 1868-1988.

The histogram given in Figure 2 shows how the storm occurrence for July varies with the solar cycle. In this figure the number of days of July with *aa* above the indicated levels (which are the same as in Figure 2) are plotted for each year. All solar cycles, except #12, #14 and #15, present disturbed days in July. As expected, these occurrences show up mainly around solar maxima, due to the high level of intensity of the involved events. Since the statistics is based on the geomagnetic activity of each day, it may happen that two disturbed days correspond to the same magnetic storm, as is the case for some of the years in the histogram corresponding to *aa* $\geq$ 90 (1972, 1892, 1946, 1959, 1961, and 1982). Therefore, the number of storms is actually less than the number of disturbed days at this level of activity. However, in the histogram for *aa* $\geq$ 210 each disturbed day in July corresponds to one isolated storm, so that both numbers agree and are equal to 5, which represents 20% of the total number of storms for that level. It may be interesting to notice that for three cycles the maximum *aa* exceeds the limit of 300 (1941, 1958 and 1959) and can be considered as very intense storms.

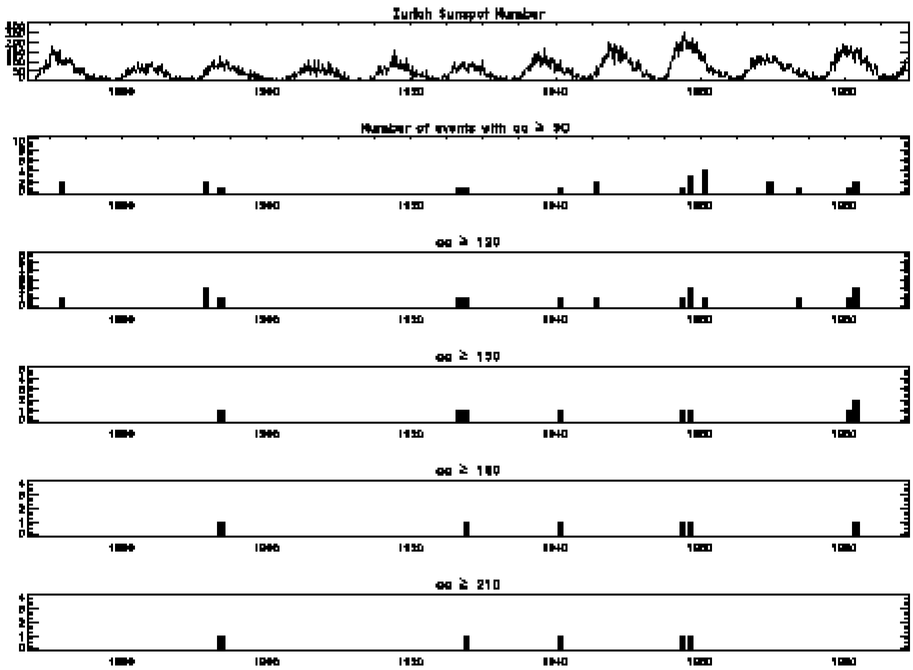

Figure 2. Year by year number of days of July with aa exceeding the indicated threshold.

It should be mentioned that for the distribution of the most intense storms, a peak in November can also be observed. However the year by year analysis has shown that it is mainly due to two severe storms that occurred during the cycle #19 (1958 and 1960) and to one that occurred during cycle 21 (1882), therefore being less uniformly distributed than that of July.

MONTHLY DISTRIBUTION OF THE Dst AND AE INDICES.

A similar statistical analysis has been performed based on the geomagnetic index *Dst*, for the years 1957 through 1996. In this case, the occurrence of storms was computed according to their peak *Dst* values. Figure 3 shows the monthly distribution of storms for peak *Dst* levels exceeding negative values of 150, 170 and 190 nT, respectively.

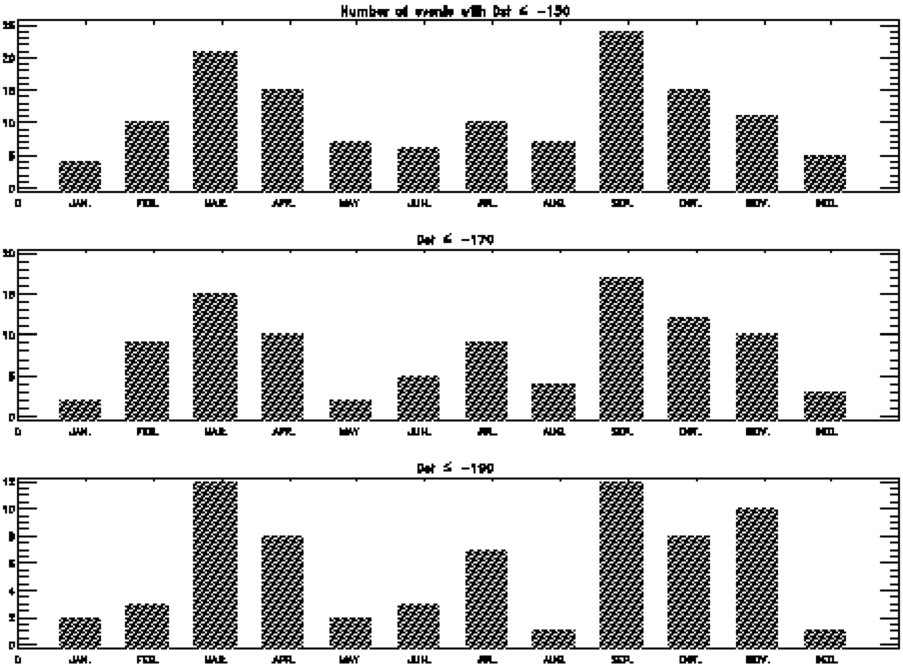

Figure 3. Number of events with peak |*Dst*| larger than the indicated values, for years 1957-1996.

As can it be seen in these figures, there is some indication on the possible existence of the July peak in the *Dst* distribution as well. For storms that reach *Dst* peaks below -150 nT (upper panel), the occurrence for July (10 events) is still below the monthly average (11.25). However, for the other two plotted levels (-170 and -190 nT), it is above that average. One significant aspect of the presence of this July peak in the *Dst* distribution is the fact that it should not be affected by the North-South asymmetries of stations during the solstices, since this index is obtained from low latitude observatories.

It is observed in the *Dst* histograms that there is also a noticeable contribution for November. Differently from what was said about the *aa* distribution, the contribution to this peak is more or less uniformly spread along cycles 19 through 21.

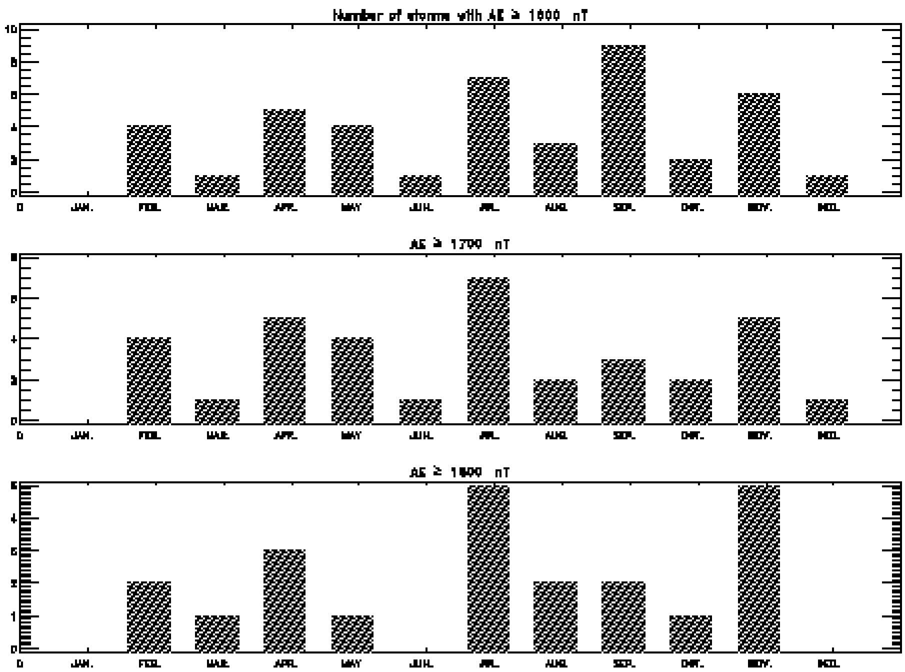

Figure 4. Number of events with peak *AE* larger than the indicated values, for years 1957-1987.

A further statistical analysis has been done on basis to the *AE* (*Auroral Electrojet*) index. This index, introduced by Davis and Sugiura [1966], measures the global auroral electrojet activity, and has also been recorded since 1957 [see e.g. Allen and Feynman, 1979; Mayaud, 1980]. Figure 4 shows the monthly distribution of storms according to their *AE* level, from 1957 through 1987. The selected storms are those for which the *AE* level exceeds the respective levels of 1600, 1700 and 1800 nT. The *AE* distribution in this figure also gives indication of the existence of the July peak which, for the three shown thresholds, is above the mean monthly occurrence within 1 sigma level of confidence. The November peak also shows up, particularly in the histogram at the bottom panel (*AE* $\geq$ 1800 nT).

DISCUSION AND CONCLUSIONS

From the statistical study presented in this paper, it becomes more evident that the classical seasonal variation of geomagnetic activity (Russell and McPherron, 1973) mainly reflects the behavior of the weak to moderate levels of storm intensity. The distribution of intense and very intense storms (e. g. peak *aa* $\geq$ 200, peak Dst $\leq$ -280 nT) seems to be more complex. The indications of a peak in July for the distribution of intense storms are in agreement with the results of previous studies [Clúa de Gonzalez et al, 1993; Bell et al., 1997]. However, it is shown that this peak also exits in the *Dst* and *AE* indices and that is much more pronounced for the distribution of very intense storms. To a less conclusive extent, there is also an indication of the existence of another peak in November, especially for the distribution of very intense storms.

Although it is beyond the scope of this paper to explain the existence of the additional peaks (July and November) in the seasonal distribution of intense geomagnetic storms, possible mechanisms related to these "non-classical" distribution should be considered. Differences between the amplitude of Arctic and Antarctic auroral electrojet indices have been observed, with the northern index values being generally bigger than those of the southward ones [Silbergleit et al., 1996]. These differences may be related to hemispheric/seasonal asymmetries in ionospheric conductivities. Sato et al. [1996] have suggested that the asymmetry in the processes observed at both auroral regions can be associated with the observation that the triggering source for auroral breakup is not located near the equatorial plane of the magnetosphere, but in a localized region between the magnetosphere and ionosphere in one hemisphere. As a consequence, this asymmetric behavior could cause a major energy deposition in one of the auroral zones, especially at the solstices. Perhaps the peaks in July and in November are related to this type of ionospheric asymmetric behavior. Recently Daglis (1997) has emphasized the importance of the role of ionospheric O^+ ions in the ring current population, particularly during intense storms. Such a role could be perhaps governed by the ionospheric conductivity changes. Finally, another mechanism that deserves investigation concerning this hemispherical asymmetry is the offset in the non-centered dipole of the earth's magnetic field, which may define different geometrical structures for the North South auroral regions.

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