EVIDENCE FOR SOLAR-CYCLE EVOLUTION OF NORTH–SOUTH FLARE ASYMMETRY DURING CYCLES 20 AND 21

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Abstract. The record of flare incidence from January 1969 to October 1988 indicates that the north–south (N–S) distribution of large flares is periodic and approximately in phase with the 11-year sunspot cycle. These data are based on observations of the whole-disk Sun in continuum soft X-rays which commenced in early 1969 and have proceeded without interruption to the present time. The pattern of occurrence, observed for slightly less than two sunspot cycles, is that large flares concentrate in north heliographic latitudes soon after solar minimum and then migrate gradually southward as the cycle progresses. By the end of the cycle, most large flares occur in the south. The degree of N–S asymmetry apparently is a function of the intensity of the flare; the most intense flares show the largest amount of N–S asymmetry. The data suggest that sunspots and flares may be driven by distinctly different excitation mechanisms arising at different levels in the convection zone. This conjecture is supported by recent work of Bai (1987, 1988), who has discovered that the superactive regions producing the majority of flares rotate at a speed substantially different from the Carrington rate, which is based primarily on the observed motion of sunspots.

1. Introduction

It is well known that many types of solar phenomena exhibit some form of N–S asymmetry (Reid, 1968; Hansen and Hansen, 1975; Roy, 1977; Verma, 1987). Furthermore, it appears that some of these asymmetries have time-scales not necessarily related to either the 11-year sunspot cycle or the 22-year heliomagnetic cycle. Roy (1977) reported that flares are asymmetrically distributed in heliographic latitude, and that these distributions are dependent on the importance of the event. He also asserts that the periods of the asymmetries are not connected to either the 11-year or 22-year cycles. Results presented here using more recent flare data tend to confirm the influence of flare intensity on the degree of asymmetry, but they also indicate that the period of this asymmetry is indeed related to the 11-year sunspot cycle.

Roy's (1977) investigation of N–S asymmetries in flare distributions covered a much longer period of time than the present study and was limited to large flares (Dodson and Hedeman (1975) criteria for major flares). Moreover, Roy also considered a variety of phenomena: white-light flares since 1859, major flares occurring between 1955 and 1974, sunspot magnetic configurations between 1962 and 1974, and large sunspot occurrences between 1955 and 1974. Roy's main conclusion was that the northern hemisphere dominates over the south in all these categories and that (at least in the case of flares) the degree of asymmetry increased with the importance of the event. Table 1 from Roy (1977) contains the cumulative N–S distributions of major flares, sunspot magnetic classes (non-complex and complex), and sunspot areas. These data firmly

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establish the fact of N–S asymmetry in these phenomena, due primarily to northern predominance. They do not, however, preclude the possibility of periodic cycles because the data, as presented, contain only cumulative totals in each hemisphere for the respective periods and data sets.

It is also well known that many types of solar phenomena besides flares exhibit a tendency to N–S spatial asymmetry. In most cases these asymmetries appear to be related to the 11-year sunspot cycle, although the periods of different phenomena often show peculiar phase shifts with respect to the 11-year cycle. Certain other phenomena do not appear to be related directly to the 11-year cycle, but seem to respond to a much longer periodicity.

The next section reviews the work of other investigators of N–S asymmetries of solar phenomena. This is followed by the main experimental evidence in the present study for an 11-year periodicity in the N–S asymmetry of large flares, spanning approximately two activity cycles and based on X-ray observations from the GOES satellites. Section 4 contains a discussion of how the present work corroborates other recent discoveries that suggest that flares and sunspots are driven by disturbances originating at various levels in the convection zone. This discussion also includes the possible connections among long-lived active regions, giant convective cells, global magnetic fields, the coronal green line, and flares. Section 5 concludes with a brief summary of this work and the anticipated direction of research related to mechanisms for hemispheric asymmetries as an asymmetric part of the global magnetic field.

2. N–S Asymmetries in Solar Phenomena

The spatial distribution of solar flares described in the following section appears to indicate that asymmetry in large flares is related to the 11-year cycle. This is not necessarily true for all types of transient solar phenomena, although many types seem to follow a similar trend. In this section we describe the results of other authors' investigations of N–S asymmetries and show that asymmetries affect many types of phenomena, due principally to a long period of northern dominance that has resurfaced during several previous solar maxima. However, some additional evidence (Hansen and Hansen, 1975; Verma, 1987) seems to indicate that the predominance shifted to the southern hemisphere during recent cycles (20 and 21) for certain types of solar phenomena.

Perhaps the longest continuous record of solar phenomena is that of sunspot activity. White and Trotter (1977) investigated the possibility that sunspot areas could be asymmetrically distributed. They concluded, however, that 'on the average the solar magnetic cycle occurs uniformly in the north and south solar hemispheres'. Since it is clear in the White and Trotter data set that the sunspot areas are unequally distributed N–S in any given sunspot cycle, the above statement evidently implies that no distinguishing systematic pattern could be discerned from a long record (nine 11-year cycles) of sunspot areas, and that the inequalities evened out over an extended period of time.

Swinson, Koyama, and Saito (1986) also examined relative sunspot numbers as well as sunspot areas. They concluded that both solar phenomena displayed a N–S asymmetry on an 11-year basis and that the maximum degree of asymmetry occurred about 2 years after solar minimum. A 22-year dependence also was notable, in that even 11-year cycles produced larger asymmetries than odd cycles. These data were drawn from a 110-year sunspot record.

Several statistical studies of flares have discussed N–S asymmetry as part of a more comprehensive analysis. Bell and Glazer (1959) considered the period 1937–1953 and could discern no N–S asymmetry. Reid (1968), on the other hand, reported on the statistics of flares for the period 1958–1965 and discovered N–S asymmetries due to northern predominance. Other evidence points to the predominance of the northern hemisphere during cycle 20 (between 1964 and 1976). Howard (1974) studied solar magnetic flux data for the period 1967 to 1973. He found that the total flux in the north exceeded that in the south by 7% over this interval. Magnetic flux asymmetries increase sharply above 70° latitude, where the magnetic flux amplitudes tend sharply to small magnitudes. Middle-latitude N–S flux differences, on the other hand, are only about 3%. Furthermore, there is clear evidence of solar cycle dependence at large flux levels below 40° latitude, with maximum occurring about 1969–1970. The solar cycle dependence appears to diminish at high latitudes. This data set did not extend to the adjoining sunspot cycles, so a periodicity is not clearly discernible.

Asymmetries in the coronal green line (Fe XIV 530.3 nm) covering almost three sunspot cycles, 1947 to 1976 (Özgüç and Üçer, 1987), also indicate that the northern hemisphere dominated slightly over the south with respect to this phenomena during cycle 20. In cycle 19 the asymmetry initially favored the south and then moved gradually north. The effect is weak at low latitudes and increases with increasing latitude, just as in the case of total magnetic flux described above.

All the phenomena discussed up to this point appear to contain N–S asymmetries that are more-or-less in phase with the 11-year cycle; however, the green coronal line seems to have a longer time-scale, perhaps synchronous with the 22-year cycle. At present the record is too short to make this last distinction. Other types of phenomena tend to reinforce the notion that, during the past two 11-year cycles, activity within each cycle began in the northern hemisphere and then migrated south.

Hansen and Hansen (1975) traced the positions of filaments from 1964 to 1974. They contend that the overall filament configuration and its evolution with time compactly represent the general topology of photospheric magnetic fields and their evolution during the course of a solar cycle. Again this study addressed events during cycle 20. During the first half of 1964 the great preponderance of filament activity was north of the solar equator. Gradually the filaments formed in the southern hemisphere so that, by midcycle in 1969 and 1970, the distribution was about equal between hemispheres. A strong polar crown, of opposite polarity to the main body of diagonal filaments, formed at about this time, at about −60° latitude. However, this polar crown had disappeared by 1971, as a new polar crown was being established in both hemispheres by the polar extremities of the middle-latitude filaments. Aside from the new northern crown, it appears that by

1974 a weak dominance of filament activity had settled in the southern hemisphere; there is no indication of how the filaments developed beyond that point.

Verma (1987) discussed five types of solar activity for cycles 19, 20, and 21. These include major flares, type II radio bursts, white-light flares, gamma-ray bursts, hard X-ray (HXR) bursts, and coronal mass ejections (CMEs). In the main, Verma found that asymmetries in all phenomena prevailed in the north during cycles 19 and 20 and in the south in cycle 21. Major-flare data were not included in his list of phenomena for cycle 21, nor were gamma-ray bursts, HXR bursts, or CMEs included in the phenomena listed for cycles 19 or 20.

Particularly notable is that the N–S asymmetries decreased monotonically in all categories with each succeeding cycle. However, since only cumulative counts of events in each category in each hemisphere are listed by Verma for each cycle, it is not possible to discern from these data a variation within each cycle. For example, in cycle 19 there were 407 major flares in the north and 195 in the south. In cycle 20 there were 589 major flares in the north and 330 in the south. These results clearly show a northerly bias, but fail to indicate if a systematic change occurred during the progress of either cycle.

All five solar phenomena listed by Verma for cycle 21 show a southerly bias in the event incidence. There were 8 northerly and 17 southerly white-light flares; however, the first white-light flares to appear in cycle 21 were northerly, shifting gradually to the south during the cycle (Neidig, 1988).

The evidence thus far seems to indicate that most phenomena associated with variable solar activity are keyed to the 11-year sunspot or the 22-year heliomagnetic cycle. It appears that, superimposed on these well-observed periodicities, there is a much longer cycle of unknown duration (possibly over 100 years, judging from the northerly bias in white-light flares). Verma's results suggest that the preponderance of solar activity may have shifted from north to south and that this shift may have occurred during solar cycle 21.

3. An 11-Year N–S Asymmetry in Large Flares

The spatial distribution of flares in heliographic latitude was studied to determine whether these spatial asymmetries were periodic in any sense, and whether the asymmetries were dependent on the intensities of the flares or any other associated characteristic. The results of the first phase of this study, shown in Figure 1, dealt with the large flares (NOAA class $\geq$ M9) of the most active part of solar cycle 21 (1977 to 1984).

The heliographic latitude of each event is plotted in the upper panel with respect to the date of occurrence. Several features and peculiarities are immediately apparent. At the beginning of the cycle, virtually all large flares occurred in north latitudes, mostly above 18° N. Then, as the cycle progressed, there was an obvious shift in the statistical centroid of position to the south.

In the lower panel of Figure 1 we have depicted the cumulative flare counts by a continuous line. The upper trace represents the cumulative count of northerly flares, and the lower trace represents the cumulative count of southerly flares. The vertical breadth

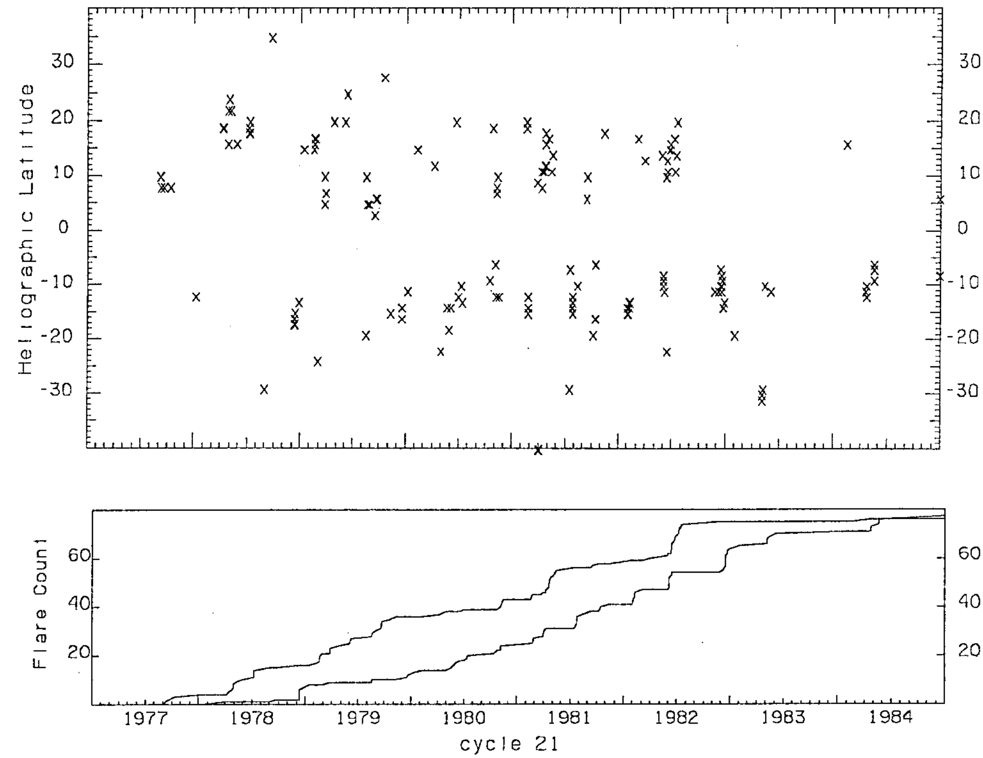

Fig. 1. Distribution of large flares ($\geq$ M9) with respect to heliographic latitude, from 1977 through 1984. The width of the stepped, diagonal band (lower panel), bounded by the cumulative counts of northern hemisphere (upper bound) and southern hemisphere (lower bound), represents the excess of the northern hemisphere flares. This excess effectively disappears by 1984 (the end of major activity).

of the band, therefore, is a measure of northern excess up to that point. By the end of major activity in mid-1984, this excess had effectively vanished as the late southern predominance overtook and balanced the cumulative number of events in northern latitudes.

It is customary among authors investigating N–S asymmetry to compute an asymmetry index $A = (N-S)/(N+S)$, thus providing a convenient quantitative measure of asymmetry that may be useful when making comparisons. This procedure was not used in the present study because it was believed that a purely graphical representation, such as shown in Figure 1, reveals many important features that would be lost in any averaging scheme. Additionally, in the case of large flares, the relatively small number of events introduces a large uncertainty into an asymmetry index for small time bins. The vertical breadth of the diagonal band in Figure 1, indicating northerly excess, is intended to demonstrate asymmetry quantitatively while preserving all the other special characteristics of the large flare distribution.

Some of these special characteristics seen in Figure 1 are worth noting. Flares clearly avoid the equatorial region, as do most active regions, there being no $\geq$ M9 flares within

$\pm 5°$ latitude. The episodic nature of temporal occurrence of large flares is also obvious. This is due largely to the fact that a relatively small number of 'super active regions' produce the majority of flares (Bai, 1987, 1988). Although there are no sustained event periods revealed in these data, there are several concentrations of events separated by about 6 months. In a few uncommon instances we have observed a simultaneity of flares (perhaps accidental, but curious) occurring in the north and south hemispheres at about the same latitude, sometimes involving a single flare in each hemisphere (as in the high-latitude flares of September 1978) and sometimes involving a cluster of flares (November 1980 and again in June 1982). This suggests a sympathetic process linking the two hemispheres in a concerted global response to some underlying driving force.

The fact that the distribution of major flares appears to have evolved spatially, and that cumulative flare counts were approximately equal during the active part of cycle 21, is strong evidence that the N–S asymmetry of large flares is periodic and approximately synchronous with the 11-year sunspot cycle. However, data collected within the present solar cycle (starting September 1986 – see *Solar Geophysical Data*, March 1988) suggest that even if the flare-asymmetry cycle has about the same duration as the sunspot cycle, they are not necessarily in phase. The possibility of a phase shift is discussed further in Section 4.

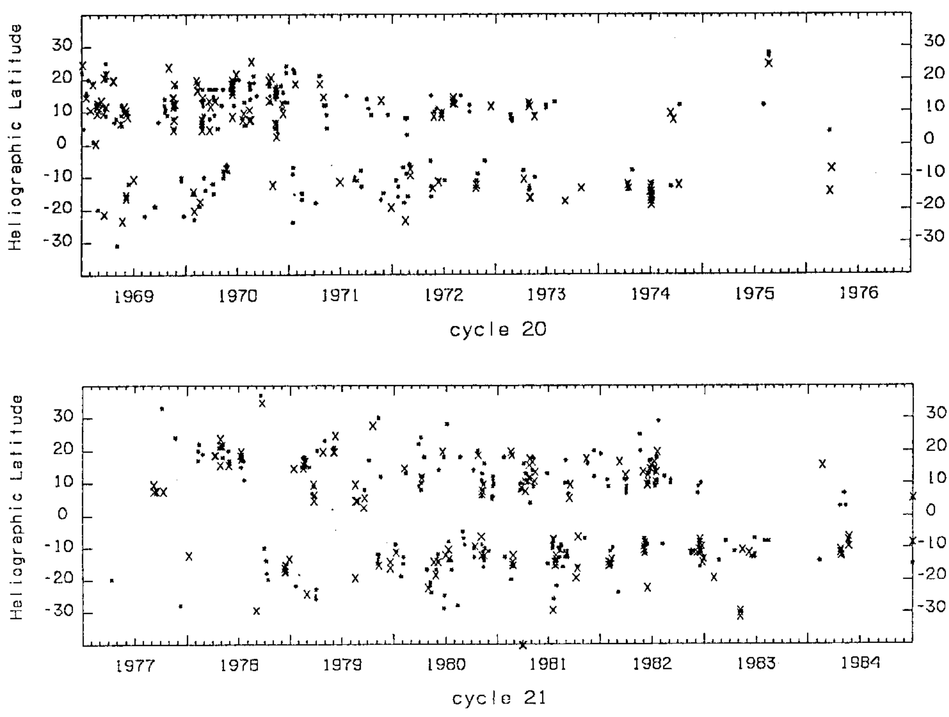

Fig. 2. Distribution of > M3 and X-class flares from 1969 to 1984, with respect to heliographic latitude. The X-class flares are denoted by Xs, and the M-class flares are denoted by asterisks. This plot contains the majority of solar cycles 20 and 21, during which flares have been observed in X-rays by geosynchronous monitoring satellites.

The second phase of the study investigated the possible dependence of asymmetry distributions on flare intensities, encompassing both cycles 20 and 21. Figure 2 contains a stack plot for the two solar cycles of heliographic latitude distributions of all flares of >M3 and X class from 1969 through 1984. These data represent the complete historical record of flares in this intensity range and date, observed in X-rays from NOAA spacecraft beginning with SMS in 1969.

Cycle 20 was well under way at the beginning of this record, but the maximum was to occur about a year later. It is clear, nonetheless, that a northern bias had already been established for large flares (Xs indicate X-class flares, asterisks indicate M-class flares). Northern predominance persisted through the first half of 1971, when the main concentration shifted southward and remained there until the end of the cycle in May 1976. This shift was due more to the near extinction of northerly flares than to an increase in southerly flares (which never occurred). The level of flare incidence in the south remained more-or-less constant throughout most of the cycle. An overall northern bias prevailed in cycle 20, just as indicated by Roy (1977).

The >M3 flares in Figure 2 are apparently distributed more evenly than are the X flares, although a northerly bias is still evident. The tendency seems to indicate that the asymmetries are in fact a function of flare intensities. In order to reduce the influence of large M flares in this distribution, the stack plot was repeated for this time period in Figure 3, but only for the low-intensity M flares: M1, M2, and M3. At these levels

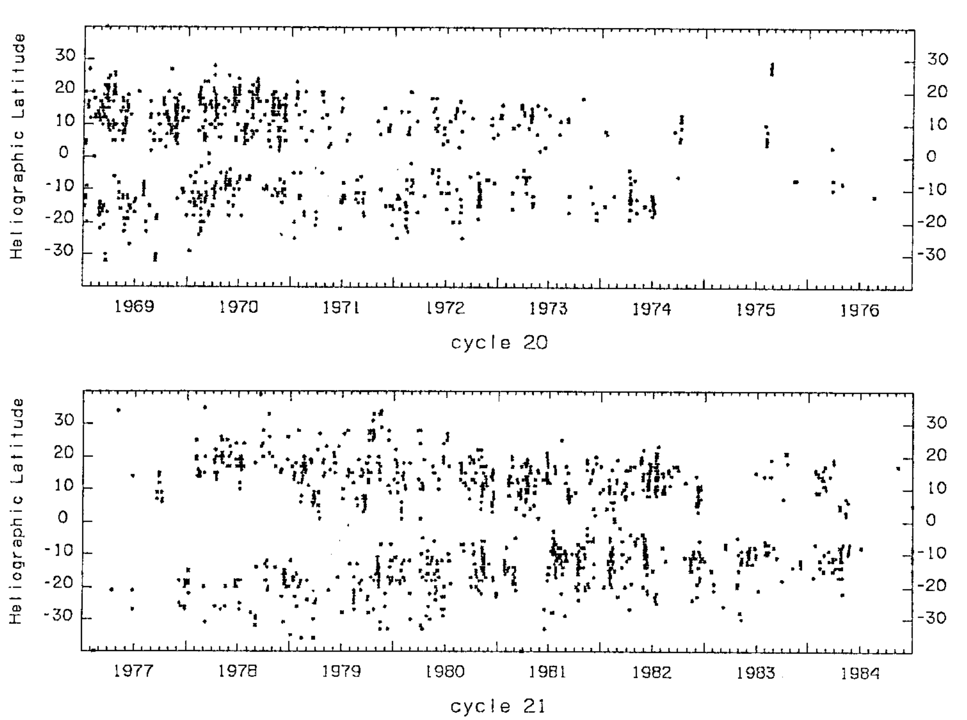

Fig. 3. This plot is the same as the one in Figure 2, but it contains only low-level, M-class flares, M1 to M3, to demonstrate the declining effect of N–S asymmetry with declining flare intensity.

of flare intensity, the asymmetry is significantly smaller. One can still detect a trend for north to south during cycle 20 and cycle 21. No historical record exists for flares less than M1 before 1986, but it seems reasonable that the trend continues toward symmetry with smaller events down to nonflaring active regions and quiescent sunspots.

To test this hypothesis, the initial latitude and latitudinal drift rate were computed for each flare class in each of the two solar cycles. This computation is based on the simple formulation that the statistical center of flare activity drifts linearly with time throughout the cycle according to

$$\phi(t) = \phi_0 + \dot{\phi} t ,$$

where ϕ_0 is the starting latitude at the beginning of the cycle and $\dot{\phi}$ is the drift rate.

The results of this (least-squares) computation are listed in Table I and shown in

TABLE I

Initial latitudes and drift rates as a function of flare class

Flare class	Points	Initial lat (err) (deg)	Drift rate (err) (deg yr^{-1})	Dispersion (deg)
		Solar cycle 20		
M1	737	8.48(0.79)	−2.31(0.33)	13.63
M2	228	8.10(1.45)	−1.92(0.50)	12.78
M3	115	8.82(2.07)	−2.17(0.78)	13.62
M4	78	5.88(2.56)	−1.66(0.91)	13.31
M5	45	11.71(3.40)	−3.60(1.33)	12.79
M6	41	13.61(3.32)	−4.00(1.36)	12.42
M7	35	8.92(3.83)	−1.60(1.23)	12.78
M8	21	2.96(3.95)	1.58(1.61)	10.36
M9	34	13.99(2.74)	−1.08(1.21)	10.29
X1	67	11.15(2.37)	−2.69(0.85)	12.97
X2	22	8.42(4.13)	−2.46(1.21)	11.19
X3	15	21.25(2.65)	−7.03(0.85)	6.01
X4	14	13.91(4.36)	−1.85(1.94)	11.41
X>4	23	21.75(3.37)	−6.04(1.41)	9.30
		Solar cycle 21		
M1	975	1.79(1.38)	−0.54(0.31)	16.14
M2	302	7.02(2.33)	−1.43(0.52)	15.11
M3	172	1.84(2.93)	−0.41(0.70)	14.94
M4	93	13.18(4.04)	−2.66(0.89)	14.68
M5	57	11.13(6.05)	−2.77(1.33)	14.76
M6	31	11.42(5.41)	−2.96(1.34)	13.07
M7	26	−6.85(7.46)	1.13(1.67)	14.09
M8	31	15.11(6.92)	−2.90(1.64)	13.84
M9	28	5.26(7.31)	−1.49(1.99)	15.03
X1	81	6.94(4.51)	−2.42(1.09)	16.12
X2	34	14.24(6.52)	−2.27(1.44)	15.44
X3	14	16.22(12.11)	−4.48(2.62)	14.27
X4	8	9.20(10.92)	−2.80(1.97)	9.91
X>4	18	23.46(5.37)	−4.80(1.11)	8.97

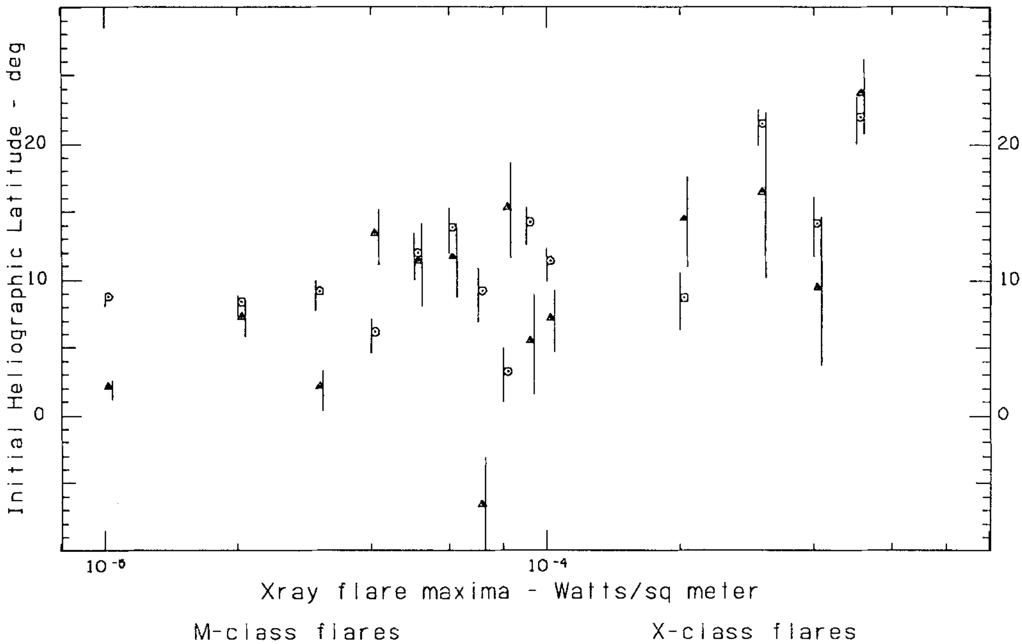

Fig. 4. Heliographic latitude at the beginning of each solar cycle vs flare class, cycle 20 (open circles), cycle 21 (triangles). The apparent trend is toward higher initial latitudes with higher-intensity flares. The horizontal scale is logarithmic in X-ray intensity and also indicates flare class according to the NOAA definition of flare class, where M-class flares begin with 10^{-5} W m^{-2} and X-class flares begin with 10^{-4} W m^{-2}.

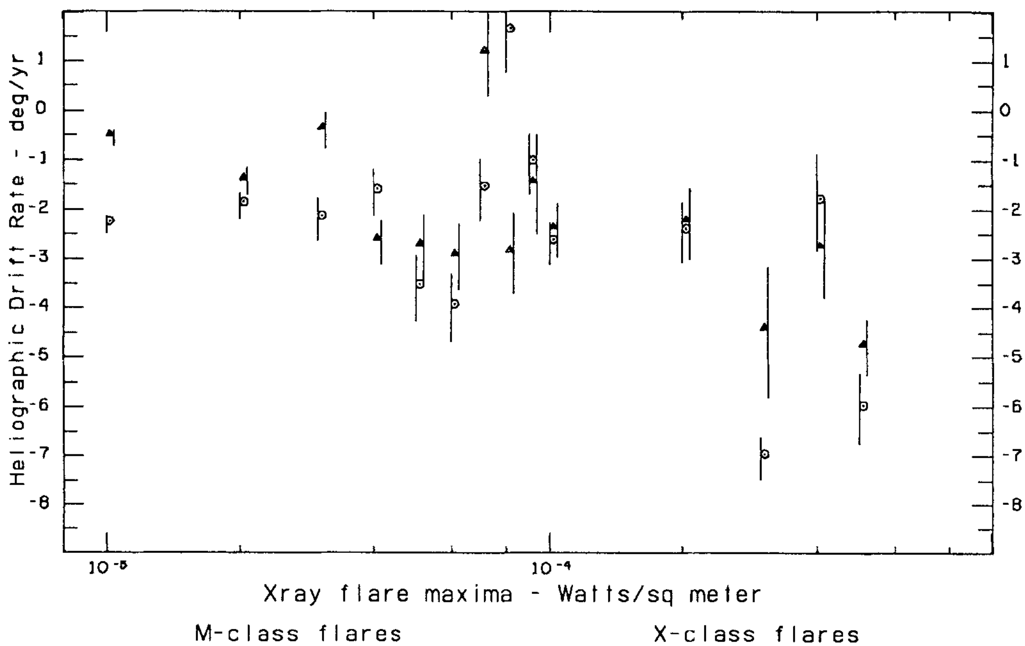

Fig. 5. Latitudinal drift rate vs flare class. With a single exception in each solar cycle, drift rates are negative (southward) for all flare classes. The drift rates trend to larger magnitudes in increasing flare intensity.

Figures 4 and 5, where the initial latitude and drift rate are plotted against X-ray flux maxima (flare class). Except for two anomalous cases (M8, cycle 20; and M7, cycle 21), all drift rates are negative, i.e., southward. Furthermore, there is a general trend to higher initial (beginning of cycle) latitudes with increasing flare intensity and a trend to more negative drift rates, also with increasing flare intensity. These trends are more pronounced in cycle 20 (open circles) than in cycle 21 (open triangles) for large flares. Despite the scatter in the computed latitude and drift parameters, it seems clear that large flares commence each cycle at higher northern latitudes and then drift southward at higher rates than do less intense flares.

4. Discussion

The present study examined the day-by-day latitudinal occurrence of flares and discovered that the spatial distribution evolved slowly during each of the two most recent solar cycles; the center of activity was to the north early in the cycle and then moved progressively southward. Indeed, if only cumulative counts of northern vs southern hemisphere incidence for the entire period from 1969 to 1984 had been considered, the result would have displayed a marked northern bias as indicated by Roy (1977). This kind of accounting, however, would have obscured the important fact that, during the latter part of each cycle, the southern hemisphere was predominant in flare incidence.

The weight of evidence presented by Roy is that over a relatively long period, approximately 120 years in the case of white-light flares, the northern hemisphere of the Sun has been dominant. A long period of northern dominance apparently extends to other types of phenomena, as discussed in Section 3. It may develop that this historical period, during which many kinds of phenomena are observed, is only a segment of a very-long-term cycle of N–S variability. There is little doubt, however, that shorter periods of N–S variability exist and that these generally correlate with the solar cycle.

The clear association of solar flares with the 11-year sunspot cycle, as indicated by the present study, does not necessarily mean that flares are merely an extension of sunspot activity carried to a very high level. The data reveal three prominent facts suggesting that flares and sunspots, while probably related to a more fundamental global phenomenon, are driven by distinctly different source mechanisms: (1) the spatial distribution of flares becomes more asymmetric with increased flare intensity, (2) the superactive regions, where the majority of flares occur, rotate at a speed substantially different (26.72-day synodic period) from the Carrington rate (27.27-day synodic period (Bai, 1987, 1988)), and (3) the asymmetry cycle of flares is out of phase with the asymmetry cycle of sunspots. Property (3) arises from the observations that sunspot N–S asymmetry (greatest northerly excess) seems to occur about 2 years following solar minimum (Swinson, Koyama, and Saito, 1986). In contrast, the northerly cumulative excess in flares appears to occur about 3 to 4 years following solar minimum. However, the phase difference between sunspots and flares is difficult to quantify, making property (3) a rather weak association.

One essential result of this study is the apparent continuum of spatial asymmetry as a function of flare intensity. Other authors investigating solar phenomena (see Section 2) indicate that some asymmetry extends to quiescent sunspots, but to a much smaller degree. It appears, therefore, that the continuum of spatial asymmetry spans the activity level of active regions from quiet sunspots to large flares, although the variation may be far from linear. There is reason to believe, from this and related studies noted below, that active regions producing flares and active regions producing quiet sunspots originate in different locations within the convection zone. Although it is true that both phenomena occur in active regions, there is evidence that a dichotomy exists between flare-producing active regions and non-producing active regions. Bai (1987) detected the presence of 'super-active regions' from hard X-ray burst spectrometer data for the period 1980–1985. These active regions produced the majority of flares during that period. He also discovered a pair of 'active zones' in each hemisphere, in which the elements of each pair were separated by about 180 deg and the pairs were shifted about 80 deg from one hemisphere to the other. Using a statistical analysis, Bai calculated the rotation period of the active zones and found it to be substantially shorter than the Carrington rotation period (based on sunspot motion). The Carrington longitudes of active zones increase by 7.07 deg per rotation.

The rotation period of active zones is similar to that of large-scale magnetic polarity patterns (McIntosh, 1981). McIntosh and Wilson (1985) have proposed that the large-scale magnetic patterns are a result of eight giant convection cells, four boundaries of which are updrafting regions and the other four are downdrafting regions. The implication is that active regions form near the boundaries of convection cells and that Bai's long-lived active zones may form near the boundaries of giant convection cells. The existence of these giant convection cells, however, is still conjecturable at this time. McIntosh and Wilson suggested further that the boundaries of giant convection cells were the source of magnetic fields from deep in the convection zone of the Sun.

These associations tend to foster the idea that flares concentrate in active regions that originate at a deeper than normal level. Large flares in particular may be more intimately associated with large-scale convective patterns and global magnetic fields.

Very recent, unpublished information on the coronal green line suggests that this phenomenon is also asymmetric and that the asymmetry is connected with global, non-dipolar magnetic fields. Osherovich discovered a green-line enhancement in the southern hemisphere, commencing in late 1982, about the same time that the flare concentration shifted to the southern hemisphere (Osherovich, 1988). Green-line enhancements were observed at selected periods when the Sun was very quiet. This was done to illuminate the effect of the weak global field, which is disrupted by the presence of activity. Osherovich, Tzur, and Gliner (1984) have proposed that the N–S asymmetry is caused by the presence of a quadrupole component in the global poloidal field. The green-line effect, however, is perhaps a better tracer of magnetic asymmetry owing to its greater sensitivity to plasma density and temperature, and the fact that the quadrupole component is more intense near the surface than is the dipole component.

5. Conclusions

The present study, covering most of the two most recent solar cycles, has found that the spatial distribution of flares varies within a solar cycle such that the preponderance of flares occurs in the north during the early part of the cycle and then moves south as the cycle progresses. This effect is more pronounced for large flares. In cycle 20, for all classes of flares, the northern hemisphere maintained overall dominance over the south, an effect that had been noted for earlier solar cycles by several authors. But in cycle 21 the total incidence of large flares was about equal in each hemisphere by the end of the cycle.

The tendency for the spatial asymmetry in the flare distribution to increase with increasing flare intensity has been noticed by previous authors, and this effect is particularly obvious in the present work. Flare data from 1988, 2 years after the start of solar cycle 22, seem to indicate that the flare asymmetry cycle is out of phase with the sunspot cycle as well as the sunspot asymmetry cycle.

All of the above effects, coupled with the recent research by Bai (1987, 1988) in the differential rotation of long-lived 'active zones' where large numbers of flares are produced, give the impression that the surface phenomena, sunspots and flares, have generating sources that originate at different levels in the convective zone. Furthermore, the suspected associations of 'active zones' with large-scale magnetic structure, and the association of flare N–S asymmetry with the coronal green line, suggest that flare occurrence is related to a weak global magnetic field of long-period variability. The evidence presented thus far reveals a need to investigate further the incidence of flares with respect to large-scale coronal structure and photospheric structure.

Though few in number since the beginning of 1985, large flares have been predominantly southern through 1988, with a large concentration situated between $-16°$ S and $-22°$ S occurring in June 1988. Although seven out of eight flares since the beginning of cycle 22 (all in 1988) were in the southern hemisphere, it may be significant that the flares were located at relatively high latitude. This is characteristic of a new cycle, suggesting either that the 11-year asymmetry cycle is not in phase with the sunspot cycle or that it may not always commence with northern predominance.

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