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Some Additional Aspects of the Unequal Activity of the Northern and Southern Solar Hemispheres: Microwave Radio Bursts and SWFs

Gladys A. Harvey [1] and Barbara Bell [2]

1. Introduction

In a study of the geomagnetic effects of major solar flares observed from 1937 through 1959, Bell (1961) found that northern sunspot groups produced 62% of all observed major flares and a significantly larger proportion (86%) of those followed by a great geomagnetic storm. Subsequent investigations (Bell, 1962; Bell and Wolbach, 1962) showed that the Northern Hemisphere of the sun has been the more frequent source of great storms for most of this century, while the Southern Hemisphere was the more frequent source in the latter half of the 19th century. Detailed study of several active-sun phenomena observed from 1957 through 1960 (Bell, 1963a,b) provided additional information on the unequal activity of the two solar hemispheres, but left unanswered certain questions of potential interest to those concerned either with forecasting solar activity and its terrestrial consequences or with theoretical understanding of active-sun phenomena.

Bell (1961, 1963a) showed that major flares were more concentrated to the solar North than were flares in general. In the present paper we investigate each category of flare importance to see whether the north-south asymmetry increases progressively with flare importance, or whether it increases abruptly for major flares.

We also investigate here the hemispheric distribution of microwave bursts. In a study of meterwave bursts of spectral types II and IV, Bell (1963a,b) showed that long-lived bursts of each type are more concentrated to the North than are short-lived bursts. However, duration alone is not the ideal measure of the "importance" of a burst. (No quantitative measures of intensity or energy content are available from present spectrum records.) Microwave-burst emission is observed much more frequently than the relatively rare emission of spectral types II and IV, and covers a wide range of magnitudes for which quantitative measures are available.

The magnitude of the microwave burst is investigated by hemisphere in relation to three terrestrial effects: polar-cap-absorption (PCA) events and geomagnetic storms, arising respectively from high- and low-energy corpuscular radiation, and sudden ionospheric disturbances, arising from shortwave electromagnetic radiation. The ionospheric events have been examined for their relationship to solar flares and microwave bursts (Hachenberg and Krüger, 1959; Harvey, 1964) without consideration of the hemispheric location of the source of the disturbance. We examine the hemispheric distribution of the sources of shortwave fadeouts (SWF) to determine whether a disproportionate number of major SWFs, like great magnetic storms, arose from northern active regions.

In a study of 2800-MHz bursts, Harvey (1965) showed that only major bursts having a peak intensity ≥ 100 flux units and a broad burst profile (half-width ≥ 8 min) were strongly associated with major geomagnetic storms. We investigate here whether the dearth of great storms from southern active regions parallels

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a dearth of southern broad major bursts, or whether even broad major bursts failed to be followed by a great storm when they arose from a southern center.

In the next section we discuss each manifestation of solar activity individually, while in the following section we consider various solar-terrestrial relationships according to the solar hemisphere from which the activity originates.

2. Hemispheric distribution of active-sun phenomena

We selected for study the 3.5 years from July 1957 through December 1960. Observations are unusually complete for this period, and it is long and active enough to provide sufficient data to establish the similarity or contrast in the hemispheric trends displayed by various types of solar activity. Table 1 lists the types and sources of the data that we analyzed.

Figure 1 shows the results for both the solar events and the most probable sources of terrestrial events, the total number of events observed in each importance category, and the percentage occurring in the Northern Solar Hemisphere.

TABLE 1.—*Types and sources of data analyzed*

Activity	Sources of data
Sunspots	Photoheliographic Results, Royal Greenwich Observatory Bulletins
Plages	McMath-Hulbert Observatory
Flares	McMath-Hulbert Observatory Working Lists of Flares for the IGY, IGC, and 1960
Major microwave bursts (2800 to 3750 MHz)	A. D. Fokker (private communication)
Microwave bursts (2800 MHz)	National Research Council CRPL–F Series Bulletins, Part B, Solar-Geophysical Data
Shortwave fadeouts	CRPL–F Series Bulletins, Part B
Geomagnetic storms	Bell list, unpublished, based on $\sum^{4} a_p$
Polar-cap absorption	Bailey (1964)

a. Sunspots.—The distribution of sunspot groups (58.9% N), shown in the first line of figure 1, is the basic asymmetry for the period, a norm to which the other percentages should be compared. That the two solar hemispheres should have so unequal a number of spot groups has itself a very small probability of chance occurrence ($P<10^{-10}$ for the observed distribution of 2690 spots, with 50% N "expected"). Of greater interest here, however, is the fact that the distribution of some spot-linked forms of solar activity deviates strikingly from the spot distribution.

Figure 1 shows also that when spot groups are subdivided by mean area (in units of 10^{-6} of the visible hemisphere), the categories up to an area of 1000 have almost identical hemispheric distributions. The percentage North is somewhat greater for spot groups of area $\geq$1000, but the difference is not statistically significant. The percentage North of the largest spot groups remains less than that of several forms of spot-linked activity.

b. Plages.—Considering only those plage regions that were identified with one or more flares in the Working Lists, we tabulated the number of flares listed as occurring in each region during its disk passage and grouped the plages into three categories according to the number of flares. As expected, the percentage of plages located in the Northern Solar Hemisphere is very close to that for sunspot groups. However, figure 1 shows that the percentage in the Northern Hemisphere increases with plage importance, when plage importance is rated by the number of flares observed in the plage.

c. Flares.—When referred to the norm of spot groups, the Northern Hemisphere is significantly ($P\approx0.0003$) more productive of flares than the Southern. With an increase in flare importance from 1 to 2 (as rated in the Working Lists), figure 1 shows a small, but not statistically significant, increase in percentage North. With a further increase in flare importance to 3 and 3+, we see a marked increase in percentage from the Northern Solar Hemisphere. When the expected asymmetry is taken as 60.6%, the average for all flares $\geq$1 in these years, the probability is 0.02 that an asymmetry as great as the observed 72.7% N for

ACTIVITY		TOTAL NUMBER	PERCENT NORTH
SUNSPOT GROUPS		2692	58.9
AREA (10^{-6})	< 100	1934	58.7
	100 – 499	606	59
	500 – 999	112	59
	≥ 1000	40	68
PLAGES		1111	58.4
NO. FLARES	1 – 19	926	57
	20 – 59	161	66
	≥ 60	24	71
FLARES		9527	60.6
IMPORTANCE	1	7316	60.6
	1+	1301	58.3
	2	691	63
	2+	131	59
	3	71	72
	3+	17	77
MICROWAVE BURSTS		289	69.2
I.I.	500 – 990	101	67
	1000 – 3000	79	68
	3100 – 9900	45	73
	10000 – 30000	38	63
	31000 – 99000	12	67
	≥ 100000	14	93
2800-MHz BURSTS		1171	60.2
(1) $I < 10$, $E < 1000$		301	55
(2) $10 \leq I \leq 100$, $E < 1000$		600	61
(3) $I \geq 100$ OR $E \geq 1000$		255	64
(3a) $I < 100$, $E \geq 1000$		72	54
(3b) $I \geq 100$, $E < 1000$		86	71
(3c) $I \geq 100$, $E \geq 1000$, NAR.		63	62
(3d) $I \geq 100$, $E \geq 1000$, BR.		34	74
SHORTWAVE FADEOUTS		1441	62.5
IMPORTANCE	1–	77	52
	1	340	61
	1+	268	68
	2–	87	71
	2	347	60
	2+	142	68
	3–	33	64
	3	111	60
	3+	36	56
GEOMAGNETIC STORMS		78	74.4
INTENSITY $\Sigma^{4} a_p$	200 – 299	26	69
	300 – 499	24	71
	500 – 999	20	85
	≥ 1000	8	88
POLAR-CAP ABSORPTION		31	71.0
EQUIV. ABS (db)	≤ 10	20	60
	10 < E.A. < 20	4	75
	≥ 20	7	100

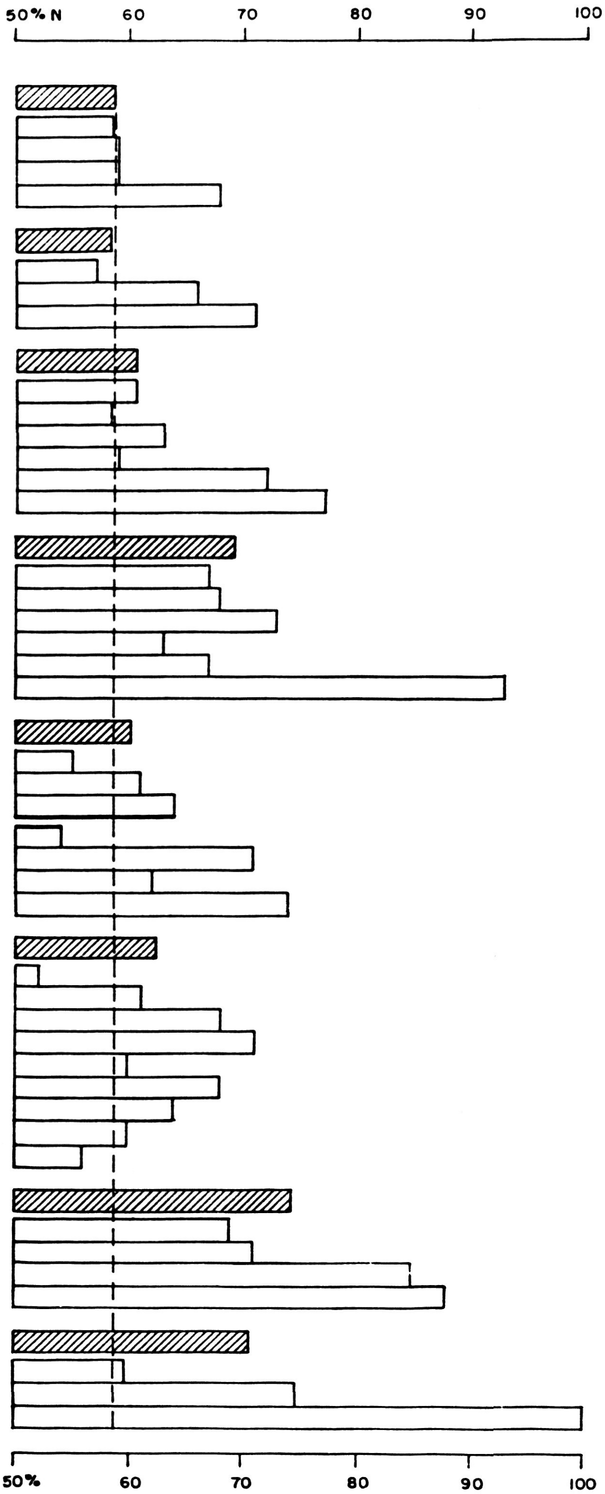

FIGURE 1.—Percentage of events occurring in the Northern Solar Hemisphere, July 1957 to December 1960: Active-sun phenomena and probable sources of terrestrial events.

the 88 major (3 and 3+) flares would occur by chance. Figure 1 also shows an unexpected, below-average concentration in the Northern Hemisphere for both groups of flares (1+ and 2+) rated as having above-average intensity for their area.

d. **Microwave bursts.**—The list of bursts available to us from 24-hour coverage includes only the larger events, with a time-integrated intensity $I.\ I. \geq 500$ (see Fokker, 1963). Figure 1 shows that 69% of these bursts arose from the solar North, a percentage significantly ($P \approx 0.002$) larger than the 60.6% for all flares. Although it is recognized that the larger the flare the greater the likelihood of a large microwave burst, this contrast between bursts and flares does not arise, as might be expected, from the high percentage of major flares in the North. The 289 microwave bursts in figure 1 show almost as high a percentage North (69%) as that displayed by the many fewer (88) major flares (72.7%). Investigation shows that a higher percentage of northern than southern flares in each importance class $\leq 2+$ is associated with a microwave burst of $I.I. \geq 500$.

Figure 1 shows no significant trend in hemispheric distribution with an increase in burst magnitude below $I.I. = 100{,}000$. Above this limit there are 14 superbursts, 13 of which arose from the Northern Solar Hemisphere. Their average *I.I.* was 200,000, while the single southern superburst attained only 110,000. (Suprisingly, five of the northern superbursts are associated with flares rated only 2 or 2+ in the Working Lists.)

e. 2800-MHz bursts.—Although not covering the complete 24 hours, the single-frequency microwave bursts observed at Ottawa provide a representative sample of microwave bursts through the entire magnitude range from the smallest observable to the larger events considered above. Moreover, the availability of the burst profiles permits us to use the characteristics of the bursts in assessing their importance and minimizes the uncertainty in magnitude determinations.

Of a total of 1953 bursts recorded at Ottawa during the 3.5 years, 1171 were associated with flares in the Working Lists. Unlike the distribution of the larger bursts in Fokker's list, the percentage of Ottawa bursts from the solar North does not differ from that of all flares recorded during the Ottawa observing hours, each being 60%. The percentage of flares accompanied by a burst (of any magnitude) is the same for both solar hemispheres.

However, active centers in the two hemispheres are not equally productive of bursts of all magnitudes and profile characteristics. The subdivision of bursts in figure 1 is based on the two measures of magnitude, peak intensity (*I*) and total energy (*E*), used previously by Harvey (1964). A coarse division by magnitude—omitting only 15 bursts so incompletely recorded that magnitude could not be determined—shows that the percentage North increases with increasing magnitude (1, 2, 3 in fig. 1).

A further subdivision of those bursts having large *I* or *E* (3 in fig. 1) illustrates the variation found in percentage North when the profile of the burst is considered. Bursts observed at 2800 MHz may be impulsive or long-enduring, or they may combine impulsive and long-enduring components (Covington, 1959); the profile of the impulsive component may be narrow or broad (Harvey, 1965). Bursts with large energy show a progressively greater percentage North with an increase in the proportion of that energy contributed by the impulsive component:

(3a) minor impulsive component, 54% N;
(3c) impulsive component relatively intense but not maintained, 62% N;
(3d) impulsive component relatively intense and maintained, 74% N.

Bursts of lesser energy show a similar increase in percentage from the solar North with increased importance of the impulsive component (1, 2, 3b). The Southern Hemisphere appears to produce a disproportionate share of bursts in which the long-enduring component predominates over the impulsive component (3a).

The larger microwave bursts and the Ottawa 2800-MHz bursts together show a progressive increase in the percentage from the solar North with an increase in burst importance, ranging from about 55% to the 93% N displayed by the microwave superbursts. (Since only 4 of the 14 superbursts were observed at

Ottawa, this category is not shown in the 2800-MHz subdivision.)

f. Shortwave fadeouts (SWF).—Of the 1892 SWFs recorded during the 3.5 years, we find that 1441 (76%) are associated in time with flares in the Working Lists. Our investigation is restricted to these SWFs. Figure 1 shows that the percentage of identified SWF sources in the solar North is greater than that of the sunspot groups, but does not differ significantly from the average value for all flares.

However, the trend in hemispheric distribution with SWF importance differs strikingly from the trends for other events appearing in figure 1. As the importance of the SWF increases from 1− to 2−, the percentage arising from the solar North increases. As the SWF importance increases further from 2+ to 3+, the percentage from the North *decreases*, quite contrary to expectation. None of the deviations from the SWF average of 62.5% N attains the 0.05 level of probability that is generally required for significance. However, the 59% N for major (3, 3+) SWFs does differ significantly ($P \approx 10^{-4}$) from the 72.7% N for major flares.

Although the Central Radio Propagation Laboratory (CRPL) lists of SWFs are as complete as current information can make them, Dodson and Hedeman (1964) have pointed out observational difficulties that affect both the number of SWFs detected and the rating of their importance. These factors doubtless have a bearing on the total number of SWFs recorded in each importance class and may influence the trends seen in the percentage North. Nevertheless, it seems unlikely that these factors could account for the decrease in the percentage of large SWFs associated with flare events in the Northern Solar Hemisphere.

g. Geomagnetic storms.—As a measure of the intensity of a geomagnetic storm we used $\sum^{4} a_p$, the sum of the four largest consecutive values of the 3-hour a_p index during the storm. Figure 1 includes only those storms that could be assigned unambiguously to one solar hemisphere, in most cases to a single most probable solar event; a few are ambiguous as to the particular flare, but not with respect to the active center or hemisphere. The systematic increase in the percentage of storms originating from the Northern Hemisphere with an increase in storm intensity, established by Bell (1961, 1963b) from a longer time period, shows clearly in the present data.

h. Polar-cap-absorption (PCA) events.—To compare the solar hemispheres in their production of high-energy protons that cause polar-cap absorption, we used Bailey's (1964) "Catalog of Principal Events" and his intensity measure, the equivalent absorption for a 30-MHz riometer. We divided the events (believed to be quantitatively uniform) into three importance categories. Figure 1 shows that the Northern Hemisphere produced a higher percentage of the more intense events ($\geq$10 db) than of the weaker PCAs, and produced all the most intense ($\geq$20 db) events.

3. Solar-terrestrial relationships

The data presented in the previous section show that, for most forms of solar activity and for terrestrial disturbances caused by solar-particle radiation, the percentage of events produced in the Northern Solar Hemisphere becomes greater as the activity increases in importance. However, the major shortwave fadeouts do not accord with this general picture. The difference between SWFs and the other major events in this respect suggests that both our knowledge of the relationships among solar phenomena and the accuracy of forecasting may be extended by including the parameter of hemispheric location. We therefore compare the northern and southern microwave bursts for their terrestrial consequences—SWFs, magnetic storms, and PCA events.

a. Shortwave fadeouts.—SWFs are closely correlated with microwave bursts (Hachenburg and Krüger, 1959; Harvey, 1964), with respect both to their production by solar events and to their importance ratings. The surprising contrast in the hemispheric distribution of the two phenomena, described in the preceding section, suggests that this correlation is not the same for the two hemispheres. Table 2 compares the microwave-burst events (*I.I.* $\geq$500) from the two hemispheres with respect to their success in producing SWFs.

TABLE 2.—*Relation between microwave bursts and SWFs**

	Northern Hemisphere				
	No. of bursts	Number with SWF			No. without SWF
		3, 3+	3−, 2+, 2	<2	
Microwave Bursts					
$I.I. \geq 100{,}000$	13	13 (100)			
31000–99000	8	5 (62)	3		
10000–30000	24	13 (54)	10	1	
3100– 9900	33	9 (27)	19	4	1 (3)
1000– 3000	54	5 (9)	33	13	3 (6)
500– 990	68	8 (12)	18	30	12 (18)
Total ($I.I. \geq 500$)	200	53 (27)	83 (41)	48 (24)	16 (8)
2800-MHz Bursts					
$I \geq 100$, $E \geq 1000$ broad	25	13 (52)	10	2	
$I \geq 100$, $E \geq 1000$ narrow	39	4 (10)	28	7	
$I \geq 100$, $E < 1000$	61	1 (2)	19	25	16 (26)
$I < 100$	571	4 (0.7)	69 (12)	160 (28)	338 (59)
Total ($I \geq 100$)	125	18 (14)	57 (46)	34 (27)	16 (13)

*Numbers in parentheses represent percentages.

In each hemisphere, the greater the microwave burst, the higher the probability of an associated SWF and the greater the average magnitude of the SWF. Every superburst ($\geq 100{,}000$) is associated with a major SWF. But at all other levels of burst magnitude the percentage of events producing a major SWF is greater for the southern than for the northern events. If the superbursts are excluded, 21.4% of northern and 36.4% of southern microwave bursts (≥ 500) were associated with a major SWF.

Table 2 also presents data on the SWF success of the Ottawa 2800-MHz bursts, to show the effects both of restricting the investigation to approximately those hours of the day when SWF detection was most complete (Dodson and Hedeman, 1964) and of including events with weaker microwave-burst emission. Here, too, we see the general correlation between burst and SWF magnitudes; the highest production rate of major SWFs occurs in association with the large broad-profile bursts, whose average intensity and energy both exceed those of the narrow-profile bursts (broad: average $I \sim 1230$, average $E \sim 25{,}000$; narrow: average $I \sim 475$, average $E \sim 8000$; see also Harvey (1965, p. 2963)). However, events in the Southern Hemisphere remain the more successful producers of major SWFs in each burst category.

The relatively high percentage of major SWFs associated with events in the Southern Hemisphere is not the only evidence for a hemispheric difference in the production of ionizing radiation. While the success ratio for major SWFs is higher for southern than for northern microwave bursts, this does not hold true for lesser SWFs. Table 2 shows that events in the Southern Hemisphere have a lower percentage of association with minor (<2) SWFs than do events in the Northern Hemisphere. This tendency is most conspicuous for the small (2800 MHz: $I < 100$) burst events, but it appears also with the larger burst events (microwave burst: $I.I. \geq 500$; 2800 MHz: $I \geq 100$). Table 3 shows yet another reversal. Although the difference is not large,

TABLE 2.—*Relation between microwave bursts and SWFs**—Continued

	Southern Hemisphere				
	No. of bursts	Number with SWF			No. without SWF
		3, 3+	3−, 2+, 2	<2	
Microwave Bursts					
$I.I. \geq 100{,}000$	1	1 (100)			
31000–99000	4	3 (75)	1		
10000–30000	14	9 (64)	4	1	
3100– 9900	12	9 (75)	2		1 (8)
1000– 3000	25	3 (12)	14	4	4 (16)
500– 990	33	8 (24)	12	8	5 (15)
Total ($I.I. \geq 500$)	89	33 (37)	33 (37)	13 (15)	10 (11)
2800-MHz Bursts					
$I \geq 100$, $E \geq 1000$ broad	9	7 (78)	1	1	
$I \geq 100$, $E \geq 1000$ narrow	24	11 (46)	9	4	
$I \geq 100$, $E < 1000$	25	3 (12)	9	6	7 (28)
$I < 100$	402	5 (1.2)	37 (9)	78 (19)	282 (70)
Total ($I \geq 100$)	58	21 (36)	19 (33)	11 (19)	7 (12)

*Numbers in parentheses represent percentages.

a consistently higher percentage of southern than of northern SWFs occurs in association with flares that lack any detected 2800-MHz burst.

A check of all the flare events, without regard to bursts, showed that in every flare category—with the exception of 3+, where every flare was associated with a major SWF—events in the Southern Hemisphere were more productive of major (3, 3+) SWFs and less productive of minor (<2) SWFs than were seemingly similar northern events.

Huang (1964) has pointed out another manifestation of the unequal influence of northern and of southern solar activity on the ionosphere. For the years 1956 to 1960, he found that the noon critical frequency (f_0F2) associated with the disk passage of large northern sunspots was smaller than that associated with large southern spot groups. This result could be interpreted as evidence that southern spot groups produced more ionizing radiation than did seemingly similar northern groups.

b. **Geomagnetic storms and PCA events.**—Figure 1 showed that the hemispheric distribution of the sources of the microwave superbursts strikingly resembles that of the sources of the high- and low-energy corpuscular radiation producing the larger PCAs and magnetic storms. Unfortunately, the situation is less straightforward than this parallelism might suggest. Examination of the individual major events reveals that microwave superbursts preceded eight (73%) of the PCAs greater than 10 db, but only three (37%) of the storms with $\sum^4 a_p \geq 1000$ and eight (29%) of the storms with $\sum^4 a_p \geq 500$. Thus, the hemispheric distribution of the sources of the microwave superbursts appears to account adequately for that of major PCAs, but not for that of great storms.

Table 4 gives data by hemisphere on the geomagnetic conditions (described by $\sum^4 a$) subsequent to major microwave bursts in four importance categories, and to major Ottawa bursts subdivided into those with a broad and those with a narrow profile. The greater the

TABLE 3.—*Distribution of SWFs without microwave burst*

	Northern Hemisphere			Southern Hemisphere		
	3, 3+	3−, 2+, 2	<2	3, 3+	3−, 2+, 2	<2
SWF with no microwave burst ≥500	34	242	441	27	164	270
Percent of total SWF	(39)	(72)	(90)	(45)	(83)	(95)
SWF with no 2800-MHz burst	1	14	87	1	15	65
Percent of total SWF	(4)	(10)	(31)	(4)	(21)	(42)

importance of the microwave burst, measured by the integrated intensity (*I.I.*), the higher the probability that it will be followed by a great storm, or indeed by any storm ≥200. The same holds true for 2800-MHz major bursts with importance determined by profile width, in agreement with previous results by Harvey (1965).

However, the data indicate that a higher percentage of northern than of southern bursts, in each range of burst importance, is followed by a great storm. Indeed, great storms are significantly associated only with major burst events originating in the Northern Solar Hemisphere. For northern bursts with *I.I.*≥10,000 or a broad profile, the probability of a chance association as high as that observed is $\leq 10^{-9}$, while for bursts with 1000 ≤ *I.I.* ≤ 9900, the probability is $\sim 10^{-4}$, and for 2800-MHz bursts with a narrow profile, it is ~0.05 (see Bell (1963a) for the procedure used to estimate the probability of chance association). Major bursts from the Southern Solar Hemisphere, even those with a broad profile or with *I.I.*≥10,000, are not followed by a great magnetic storm more often than would be expected by chance.

The probabilities that a magnetic storm will follow a broad major burst at 2800 MHz are similar to those found by Bell (1963a, Table 5, line i) for meterwave bursts of spectral type IV subdivided by solar hemisphere. This agreement is not surprising in view of the association between broad 2800-MHz bursts and type IV bursts (Harvey, 1965).

Northern microwave bursts with *I.I.*≤100,000

TABLE 4.—*Relation between microwave bursts and geomagnetic activity**

	Northern Hemisphere				
	Number of bursts	Number followed by $\sum^4 a_p$			
		≥500	300–499	200–299	<200
Microwave Bursts					
I.I.≥100,000	13	10 (77)	2		1 (8)
31000–99000	8	2 } (34)	2	2	3 } (34)
10000–30000	24	9 }	6	1	8 }
1000– 9900	87	16 (18)	11	14	46 (53)
2800-MHz Bursts					
I≥100, *E*≥1000					
broad	25	11 (44)	5	3	6 (24)
narrow	39	6 (15)	5	8	20 (51)

*Numbers in parentheses represent percentages.

are more likely (77%) to be followed by a great geomagnetic storm than is any other solar event studied to date. Each of the great storms of November 12 and 15, 1960, was preceded by two microwave superbursts. However, as noted above, such bursts account for less than half the greatest storms.

Table 5 shows the relationship between microwave bursts and PCA events for the two solar hemispheres, with each PCA attributed to a single solar event. The greater the importance of the microwave burst, the greater the probability of association with PCA. High-energy protons were detected above the earth after 12 of the 14 microwave superbursts. Bursts in the range $31{,}000 \leq I.I. \leq 99{,}000$ also show a substantial though lesser association with PCA events. Five of the seven largest (≥ 20 db) PCAs and three of the four in the 10- to 19-db range followed microwave bursts of $I.I. \geq 100{,}000$. A broad profile characterized all 2800-MHz bursts associated with major PCAs.

Unlike the situation with great magnetic storms, the contrast between the solar hemispheres in PCA production seems adequately explained by the hemispheric differences in productivity of major microwave bursts. The solar hemispheres do not differ significantly in the percentage of microwave bursts associated with PCA. Moreover, only four PCA events in Bailey's (1964) catalog do not appear to be associated with any microwave burst ≥ 1000; the largest of these attained 10-db absorption (March 25, 1958), and Bailey notes in two cases that "the association with solar flare and radio noise events is very uncertain or unknown."

The six ground-level cosmic-ray (GCR) events recorded during the 3.5-year interval all occurred in association with northern bursts, four with $I.I. \geq 100{,}000$, one with $I.I. = 87{,}000$, and one with $I.I. = 7500$. Three were associated with 2800-MHz bursts, all with broad profiles.

Fokker (1964) has pointed out that the largest microwave bursts were not concentrated close to sunspot maximum, but showed the same tendency as the larger PCA events and the GCR events to avoid sunspot maximum.

4. Conclusions

In the 3.5 years from July 1957 through December 1960, the relative activity of the solar hemispheres in producing solar events and event-linked terrestrial disturbances differed markedly from the basic north-south distribution (59% N) of the sunspot groups. For most types of activity the inequality between the hemispheres increased with increasing importance of the solar event. Distributions from 85% to 100% N occur for microwave bursts of integrated intensity $\geq 100{,}000$, for PCA events

TABLE 4.—*Relation between microwave bursts and geomagnetic activity**—Continued

	Southern Hemisphere				
	Number of bursts	Number followed by $\sum^{4} a_p$			
		≥ 500	300–499	200–299	<200
Microwave Bursts					
$I.I. \geq 100{,}000$	1		1		
31000–99000	4				4 } (56)
10000–30000	14	1 (7)	3	4	6 } (56)
1000– 9900	37	3 (8)	5	6	23 (62)
2800-MHz Bursts					
$I \geq 100$, $E \geq 1000$					
broad	9	1 (11)			8 (89)
narrow	24	1 (4)	2	3	18 (75)

*Numbers in parentheses represent percentages.

TABLE 5.—*Relation between microwave bursts and PCA**

	Northern Hemisphere				
	Number of bursts	Number linked with PCA (db)			Number without PCA
		≥20	19–10	<10	
Microwave Bursts					
I.I. ≥100,000	13	5	2	4	2
31000–99000	8	1		2	5
10000–30000	24	1		2	21 (88)
1000– 9900	87		1	4	82 (94)
2800-MHz Bursts					
I ≥100, *E* ≥1000					
broad	25	3	1	3	18 (72)
narrow	39			2	37 (95)

*Numbers in parentheses represent percentages.

of absorption ≥10 db, for GCR events, and for great $\left(\sum^{4} a_p \geq 500\right)$ geomagnetic storms. These asymmetries substantially exceed even those of the largest sunspot groups. (Moreover, many of the major events did not originate in either the largest sunspot groups or in the most flare-rich plage regions.)

The hemispheric distribution of the greater microwave bursts accounts adequately for the distribution of the PCA sources, but not for that of the great-storm sources. Even when possessing the burst attributes that appear most favorable to a subsequent geomagnetic storm, events in the Southern Solar Hemisphere did not show any significant association with great magnetic storms.

The hemispheric distribution of the sources of major SWFs differs markedly from that of the sources of other major events—flares, microwave bursts, magnetic storms, PCAs—as only 59% were produced by northern solar activity. The tendency for southern flares to produce more than their share of major SWFs appeared consistently, whether the data were subdivided by flare importance or by burst magnitude. The evidence suggests that solar activity in the Southern Hemisphere produced a greater effect on the ionosphere than did seemingly similar northern activity but, on the other hand, produced a smaller geomagnetic effect.

It would thus appear that, in recent years, a greater proportion of the energy released by the larger southern flare events tends to go into shortwave electromagnetic radiation producing SWFs, while more of the energy released by the larger northern events tends to go into the ejection of corpuscular streams producing magnetic storms.

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TABLE 5.—*Relation between microwave bursts and PCA**—Continued

	Southern Hemisphere				
	Number of bursts	Number linked with PCA (db)			Number without PCA
		≥20	19–10	<10	
Microwave Bursts					
I.I. ≥100,000	1		1		
31000–99000	4			2	2
10000–30000	14			2	12 (86)
1000– 9900	37			4	33 (89)
2800-MHz Bursts					
I ≥100, *E* ≥1000					
broad	9			3	6 (67)
narrow	24			1	23 (96)

*Numbers in parentheses represent percentages.

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Abstract

The relative activity of the Northern and Southern Hemispheres in the production of solar and solar-linked terrestrial events is investigated for the period July 1957 through December 1960, with particular attention to shortwave fadeouts (SWFs) and to microwave radio bursts, including those observed at 2800 MHz at Ottawa. The magnitude of the microwave bursts is investigated, by hemisphere, in relation to three terrestrial effects: polar-cap-absorption (PCA) events, geomagnetic storms, and SWFs.

As with solar flares, geomagnetic storms, and PCA events, the percentage of microwave bursts associated with the Northern Solar Hemisphere increases with increasing importance of the event, to around 90% for bursts of integrated intensity $\geq 10^5$, great magnetic storms, and PCA events with absorption ≥ 10 db. This substantially exceeds the percentage of all sunspot groups (2692—59% N) and of the largest spot groups with mean area ≥ 1000 millionths of the solar disk (40—68% N). In unexpected contrast, a relatively low percentage of major (3, 3+) SWFs are found to come from the Northern Solar Hemisphere (59% N).

The hemispheric distribution of the greatest bursts appears to account for that of the PCA sources, but not for that of the sources of great storms or of major SWFs.

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