ANALYSIS OF POLAR CAP ABSORPTION EVENTS
I. EFFECT OF SOLAR AND SOLAR INDUCED CONDITIONS PRIOR TO THE PCA EVENTS

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ERRATA

Table 1.	PCA No. 28, Range of Start Times should be 16/0600 - 16/1200
Table 2.	BO, Basler & Owren, date should be 1964
Table 3.	PCA No. 31, Remove (5000) from the 2800 Mc/s column
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1.0 SUMMARY AND RECOMMENDATIONS

1.1 Summary

This study has been based on an analysis of solar and solar and solar induced terrestrial phenomena during the period from a few days before to a few days after the occurrence of solar flares that are known to have produced proton streams that were detected in the vicinity of the earth as polar cap absorption events.

Most of the analysis is limited to 59 PCA events that can, with reasonable certainty, be associated with solar flares, although some attention will be given to an additional 47 small events in an effort to, where possible, increase the statistical significance of the associated phenomena.

In many respects the analysis carried out in this study is similar to statistical evaluations that have been made by a number of investigators who were looking for correlations between specific solar phenomena. However, the basic objective of this study has been quite different. We are searching for those solar phenomena, or conditions, or combinations that can be used to predict with an acceptable degree of confidence whether or not a dangerous radiation conditions will exist outside the earth's atmosphere or magnetic field from an observed condition on the sun. In addition, we must be able to evaluate the magnitude of the danger, and the amount of time available for protective action.

The characteristics of solar flares and the associated solar region, which are the source of the high energy particles that cause polar cap absorption events, have been evaluated in terms of those phenomena that are generally associated with, or are, indications of active solar regions.

These phenomena are treated individually and in combinations to assess the probability that a given condition or region might be the source of a proton stream.

Plage regions, sunspot groups, flares, loop prominences, short wave radio fadeouts, solar radio emissions at discrete frequencies, and spectral emissions of Type II and Type IV that are reliably associated with PCA events, have been studied.

Solar induced disturbances in the earth's magnetic field as indicated by the planetary three hours index, K_p, and derived daily index, A_p, for the four or five days preceding the PCA flare have been used in a search for a correlation between the geomagnetic conditions and the proton stream travel time and the intensity of the event.

In addition to the analysis of solar regions, flares, and flare induced phenomena associated with the PCA events, we have, for the purpose of comparison, analyzed a limited number of large and magnetically complex sunspot groups; large, bright and flare productive plage regions, all flares of importance 3+, and selected flares of importance 3.

It is possible at this time to eliminate some of the parameters or phenomena from primary consideration and recommend others for additional analysis:

<u>Sunspot</u> - If a proton event is observed, there is a high probability that the flare occurred in a large magnetically complex sunspot group; however, the probability that a large magnetically complex sunspot group will be the source of a proton producing flare is very small.

Proton producing flares are more likely to occur in sunspot groups that have remained constant in area $\pm$ 10%, or were increasing in area during a period of several days.

Plage Regions - Large, bright, and flare productive regions do not appear to be necessary conditions for the production of a PCA-flare.

Nearly 40% of the proton flares occurred in plage regions with average maximum areas less than 6000 millionths. Approximately 50% of the proton events occurred from plage regions during their second rotation. All but one of the PCA events occurred in plage regions in the second or later rotation. There is a very low probability that a new plage region will be the source of a proton flare.

Flares - There is a high probability that an importance 3+ flare will be followed by an important PCA event, if the flare is accompanied by a major short wave radio fadeout and a radio burst at a frequency between 2800 and 3750 Mc/s.

Loop Prominence - If a flare on the solar disk has an associated loop prominence, there are good indications that a proton event will follow.

Magnetic Conditions - The flare proton event delay time or event size does not appear to be influenced by the variation of the three hour K_p index or the derived daily A_p during the four or five days preceding the flare.

1.2 Recommendations

Many of correlations and associations examined during this study were limited to the association of the chosen phenomena to PCA events, the extension of the analysis to non-PCA flares and solar regions that did not produce PCA events should be carried out.

Plage Regions - Plage characteristics during the four or five days prior to PCA-flares and non-PCA flares of importance 2+ and 3 should be classified. Plage turbulence prior to or during major flares, and in particular PCA flares, should be investigated by a careful study of flare patrol films.

Flares - Major flares not associated with PCA events should be analyzed in terms of the chosen parameters for possible distinguishing characteristics of PCA and non-PCA flares.

Radio Emissions - Sunspot groups associated with PCA flares should be investigated for radio emissions from flares preceding the PCA-flare. If the PCA-flare regions are radio noisy, the evaluation should be extended to spot groups with non-PCA flares of importance 3. A few cases of importance 3 flares not followed by PCA events have been investigated. This analysis should be extended to give a better statistical sample. In particular those cases where the flare was reported by at least one observatory with importance 3+, and was reduced to importance 3 in the McMath-Hulbert working list (Table 11).

Loop Prominence Systems - The association of loop prominences on the solar disk with PCA flares shows a good correlation, especially for the years 1960 through 1963 where prominences were found for 12 of the 16 disk flares and for four of the five limb flares. Conversely, there were only two disk loop prominences reported (Bruzek) that were not associated with PCA flares from the basic list, and one of these occurred at the time of a very small PCA (Number G22, Table 8).

On the basis of the outstanding success of PCA flare loop prominence association, a thorough search should be made for additional loop prominences at the time of the other PCA-flare during 1960 through 1963.

2.0 GENERAL STATISTICAL SUMMARY

2.1 Selected PCA Events

The 106 Polar Cap absorptions (PCA) or possible PCA's were chosen from a large number of original sources (Table 3) and catalogues of PCA events compiled by Bailey (1964), Basler and Owren (1964), Malitson (1963), Warwick and Haurwitz (1962) and the 5 volumes of the Solar Activity Catalogue, Jonah, Dodson-Prince, and Hedeman (1965). These PCA events have been classified into three groups:

(a) PCA events detected by two or more techniques that can be associated with a solar flare with reasonable certainty. There are 59 events in this group (Table 1, 3, 4, 5 and 6).

(b) Small PCA events and events for which a flare association is questionable or not possible. There are 24 events in this group (Table 7).

(c) Small PCA events during 1960 reported by Gregory only (24 events, Table 8).

While some of the events listed in Tables 7 and 8 will be analyzed in some detail the major effort of this study has been devoted to the 59 events listed in Table 1.

2.2 PCA-Flare Central Meridian Distance

The distribution of the 59 flares are shown in Table 1A in terms of flare importance and flare central meridian distance.

Flare Importance	E90 to E60	<E60 to E30	<E30 to CM	CM to <W30	W30 to <W60	≥W60	Total
1	0	0	0	0	0	1	1
2	2	2	3	2	1	3	13
2+	0	0	3	2	1	1	7
3	0	4	4	7	5	5	25
3+	1	2	3	2	5	0	13
Total	3	8	13	13	12	10	59

TABLE 1A

PCA Flares-Central Meridian Distance Distribution

This shows a distinct performance for the western two thirds of the visible hemisphere (81%). Slightly less than 50% of all flares occurred between East 30 and West 30. The heliographic distribution by flare importance is shown on Figure 1.

2.3 PCA-Flare Delay Time

Table 1B and Figure 2 show the PCA-flare delay time as a function of heliographic position and flare importance.

	PCA DELAY TIME HOURS						
Disk Position	≤1	>1 to ≤3	>3 to ≤6	>6 to ≤9	>9 to ≤12	>12	Total
E90 to E60	0	1	3	0	1	0	5
<E60 to E30	1	2	4	1	1	0	9
<E30 to CM	1	6	2	1	0	1	11
CM to <W30	4	4	3	1	0	1	13
W30 to <W60	5	4	2	1	0	0	12
≥W60	4	1	4	0	0	0	9
Total	15	18	18	4	2	2	59

TABLE 1B

PCA-Flare Delay Times with Solar Disk Distribution

Table 1B shows that approximately 86% of the PCA events followed the flare by six hours or less. The flare associated with a given PCA was chosen as the flare of highest importance that preceded the flare by less than twelve hours. If there were two or more flares of importance equal to or greater than 2+ preceding the PCA, the final decision was based on an analysis of the radio emissions in both the centimeter and meter wave lengths, and in some cases the previous activity of the sunspot groups and the importance of the short wave radio fadeout. Finally the association was checked against associations given in the scientific literature, and other things being equal the flare with the shortest delay time was chosen. If there were no major flares (importance $\gtrsim$ 2+) reported during the 12 hour period, all flares of importance $\lesssim$ 2 were examined in terms of their position, associated radio emissions, short wave fadeouts and the previous activity of the sunspot groups. In general this procedure led to a more or less unambiguous flare choice.

2.4 Prompt Flare Induced Phenomena

An examination of the associated data given in Tables 1 and 3 shows that every PCA flare was accompanied by a SWF, and all but three by a centimeter burst at one or more frequencies in the range from 2800 to 3750 Mc/s. All but three of the PCA flares were followed by a sudden commencement geomagnetic storm (SSC), or the SSC occurred within an acceptable time of two PCA flares (PCA numbers 12, 13; 43, 44; 50, 51; 52, 53; 54, 55). All but three of the PCA flares of importance 2+ or greater (importance based on the McMath-Hulbert working list) were followed by a Forbush decrease.

All but five of the shortwave radio fadeouts were of importance equal to or greater than 2, lasting for 30 minutes or more (PCA's 5, 14, 18, 22, and 24). In fact, 45 of the SWF's that accompanied a PCA flare lasted for more than 60 minutes.

Thirty-four of the centimeter bursts in the range 2800 to 3750 Mc/s had peak intensities greater than 1000×10^{-22}. $W(m^2 c/s)^{-1}$

These statistical relations are summarized in Tables 3A

Flare Imp.	No. Flares	SWF	All*	IV	10cm	SSC	Fd
1	1	1	1	1	1	1	1
2	13	13	3	8	11	11	5
2+	7	7	6	6	7	7	7
3	25	25	20	24	24	24	23
3+	13	13	13	13	13	13	13
Total	59	59	43	52	56	56	49

*All of the Solar and Terrestrial Effects: SWF, Spectral Emission, Type IV, Radio Emissions at Centimeter Wavelengths (at 2800, or 2980, or 3000, and/or 3750), SSC, and Forbush decrease (Fd)

TABLE 3A

Summary of Selected Phenomena Associated with the PCA Flares

Type II (slow drift bursts) are listed in Table 3, but were not included in Summary Table 3A, because of the lack of spectral observations at the time of a large percentage of PCA flares. The Type IV events include those observed either at Sydney DAPTO and/or Fort Davis and probable Type IV emissions on the basis of selected single frequency outbursts.

Flare Imp.	No. Flux Observations	<100	100 to 500	>500 to 1000	>1000 to 10000	>10000	Total
1	0	0	0	1	0	0	1
2	2	0	5	2	4	0	13
2+	0	1	2	1	2	1	7
3	1	1	3	3	15	2	25
3+	0	0	1	2	10	0	13
Total	3	2	11	9	31	3	59

TABLE 3B

The Distribution of Centimeter Flux From PCA Flares as a Function of Flare Importance

From Table 3 we see that 73% of the PCA flares produced peak flux at 2800 or 3750 Mc/s greater than $500 \times 10^{-22} W(m^2 c/s)^{-1}$. The distribution of flux intensity as a function of flare importance is shown in Table 3B. 92% of the importance 3+, and 80% of the importance 3 PCA flares produced peak flux greater than $500 \times 10^{-22} W(m^2 c/s)^{-1}$.

3.0 SUNSPOT GROUPS AND PCA EVENTS

3.1 Large Spot Groups

While we find that 53 of the important PCA events were associated with flares that occurred in large sun spot groups (22 large, 31 large and magnetically complex) these PCA sun spot groups represented only 34 (or 7%) of the 471 large spot groups that were reported during the years 1954 through 1963 (Table 4A).

Year	Large (Max. Area ≥ 500 millionths) with PCA	Number of PCAs	Total Spots	Large and γ or $\beta\gamma$ with PCA	Number of PCAs	Total Spots	Small Spots with PCAs Number
1954	0	0	1	0	0	0	0
1955	0	0	17	0	0	2	0
1956	0	0	81	3	3	9	1
1957	8	9	89	3	5	20	2
1958	8	11	80	0	0	19	0
1959	1	1	69	3	5	15	0
1960	0	0	19	5	11	14	2
1961	1	1	11	2	6	5	1
1962	0	0	8	0	0	4	0
1963	0	0	6	1	2	2	0
Totals	17	22	381	17	31	90	6

TABLE 4A

Sunspots with Maximum Areas ≥ 500 Millionths of the Solar Hemisphere and PCA Flare Distribution

34 of the PCA flares occurred in 20 different sun spot groups that during disk passage had maximum areas greater than 1000 millionths. (Table 4B) This represents only about 12 percent of the 153 sun spot groups in this category, as shown by years in Table 4B. 52 of these large spots had mean areas greater than 1000 millionths during the years 1954 through 1959. (Data are not available subsequent to 1959). While there appears to be a strong PCA-flares association with large sun spot groups, the probability that a

Year	Max. Area $\geq$ 1000	Mean Area $\geq$ 1000	Max. Area $\geq$ 1000 With PCA	Max. Area $\geq$ 1000 Total PCA
1954	0	0	0	0
1955	1	1	0	0
1956	29	8	1	1
1957	32	13	5	7
1958	38	13	4	9
1959	29	17	4	3
1960	15	-	3	7
1961	5	-	2	5
1962	3	-	0	0
1963	1	-	1	2
Total	153	52	20	34

TABLE 4B

Sunspot Groups with Maximum Area, and Mean Area $\geq$ 1000 Millionths

large sun spot group will, at some time during disk passage, be the source of a PCA flare is extremely small. Similarly there does not appear to be any real correlation between the morphology of sun spot groups, either large or small with the occurrence of a PCA flare. This is shown on Figure 5. where we have, among other parameters, plotted the daily area of all sun spot groups that had a maximum area $\geq$ 1000 millionths, during 1958. We have shown all flares of importance 3 associated with those sun spot group and the PCA flares.

We have also shown the daily areas of all sun spot groups with maximum areas $<$ 1000 millionth that were the source of an importance 3 flare or a PCA flare. The sun spot area data for the five days prior to the 32 PCA-flares through 1958 do not show any significant trend. We find:

2 - at the east limb
1 - formed on the disk the day before the flare
1 - intermittent
2 - small and variable
1 - large and variable
4 - decreasing
8 - increasing
13 - stable ± 10%

Corrected daily sun spot area data are not available for 1959 and subsequent years.

3.2 Magnetic and Zurich Classification

A similar situation exists in the case of both sun spot magnetic, and the Zurich classifications, even though there is a strong PCA flare association with γ or $\beta\gamma$ spot groups, and E, F, G, and H Zurich classes. This is shown on Table 4 where the PCA-flare day classifications are also shown.

The Zurich and magnetic classification of the PCA-flare sun spot groups on flare day are shown in Table 4C.

	E	F	G	H	J	A	C	D	Total
γ	7	2	0	6	0	0	0	0	15
$\beta\gamma$	14	6	2	0	0	0	0	0	22
β	8	1	1	1	0	0	1	3	15
α	0	0	1	0	3	0	1	0	5
?	0	0	0	0	1	1	0	0	2
Total	29	9	4	7	4	1	2	3	59

TABLE 4C

The Zurich and Magnetic Classification of Sunspots on PCA Flare Days

It should be pointed out that in those cases where the flare occurred at either the east or west limb, the Zurich and magnetic classification was extrapolated on the basis of the following or preceding days values.

30 of the PCA flares were definitely associated with γ or $\beta\gamma$ sunspot groups with an E, F, G, or H Zurich classification. Seven others may have belonged in this group based on extrapolation as mentioned above.

3.3 PCA Events Associated With Small Sunspot Groups

Six or 10% of the basic PCA events have been associated with flares from small sunspot groups (max. area < 500 millionths). These are shown in table 4D.

PCA Serial No.	Date	Abs. db	Delay Time	Flare Imp	CMD	Integrated Flux
2	3-10-56	3.5	$3^h\ 45^m$	2	E88	--
11	8-09-57	3.1	$4^h\ 50^m$	2	E76	--
20	9-26-57	2.0	$1^h\ 53^m$	3	E15	--
43	4-28-60	3.5	$1^h\ 00^m$	3	E34	5×10^6
46	5-06-60	16.0	$1^h\ 56^m$	3+	E07	4×10^6
57	9-28-61	3.3	$0^h\ 43^m$	3	E29	6×10^6

TABLE 4D

PCA Events From Small Sunspot Groups and Related Data

Except for the fact that the reported absorption for five of these PCA events was small, none of them show phenomena characteristics substantially different from those PCA events associated with large spot groups.

3.4 Heliographic Longitude Distribution of Proton Flare Sunspot Groups

The heliographic longitude of the sunspot group associated with the basic PCA flares is shown on Figure 3 divided into northern and southern hemisphere. When two or more flares occur in a single spot group, these multiple flare spots are considered as a single event and are shown without dividing lines. That is, Figure 3 shows 39 independent events, 26 or 67% of these events occur in the solar hemisphere between 320° and 140°.

It should be noted that 7 of the 17 PCA events that occurred between longitudes 140° and 320° produced integrated proton fluxes (protons/cm^2, energy $>$ 30 Mev) equal to or greater than 1.5×10^6 as shown below (see Table 6 also).

Event Number	1	11	26	30	31	32	38
Integrated Flux	$1.0x10^9$	$1.5x10^6$	$2.5x10^8$	$7.0x10^7$	$1.1x10^8$	$6.0x10^6$	$1.8x10^6$

The intensity of the flux for the remaining 10 has not been determined but the intensity of the absorption was greater than 3 db for 6 of the 10 events.

This clearly indicates that while there is only about a 33% probability that a PCA event will occur in the hemisphere between longitudes 140° and 320°, 19% of those events for which an integrated flux $>10^6$ has been determined, were produced by flares from that hemisphere.

Figure 4 shows the longitude distribution of the 106 proton events from Tables 1, 7, and 8, where we have shown them as 75 independent events, with 64% in the apparently favored hemisphere. This is in surprisingly good agreement with the percentage from the Figure 3 distribution since the PCA flare choice and consequently the sunspot group, for several of the events in Tables 7 and 8 may be questionable. These results are in reasonable agreement with those derived by Warwick (1965) where she found that 33 or 73% of her 45 independent proton events were in this same hemisphere.

4.0 PLAGE REGIONS

4.1 Plage Area and Brightness

A preliminary investigation (Table 5) shows that the probability that a large (area greater than 10,000 millionths of the area of the solar hemisphere) or bright (average intensity >3) region will be the source of a PCA-flare is very small. Forty-three of the 59 PCA flares occurred in plage regions with average maximum areas less than 10,000; in fact 23 of the PCA flares were associated with plage regions with average maximum area equal to 6,000 or less.

4.2 Flare Productivity

Flare productivity prior to the PCA flare has some significance. There are only nine cases where the number of flares from the PCA flare region was less than ten and in four of these cases the PCA-flare occurred near the east limb. Only one western quadrant PCA-flare region did not produce 10 or more flares prior to the PCA flare. Ten multiple PCA-flare regions accounted for 29 of the PCA flares. These multiple PCA-flare regions are shown on Tables 4 and 5.

5.0 FLARE IMPORTANCE

5.1 Major Flares and PCA Events

The distribution of PCA flares by importance is shown on Table 3A. Forty-five of the flares have importance $\geq$ 2+. The number of PCA flares of importance 2+, 3, and 3+ by years is shown in Table 1C together with the total number of flares reported in each of these categories based on the solar activity catalogue and the McMath-Hulbert working lists.

	All Reported Flares Importance			Flares with PCA's Importance		
	2+	3	3+	2+	3	3+
1954	0	0	0	0	0	0
1955	9	4	0	0	0	0
1956	38	21	1	0	2	0
1957	39	24	7	2	8	3
1958	58	17	3	2	3	3
1959	33	24	6	0	2	4
1960	22	15	4	3	5	2
1961	4	9	1	0	4	1
1962	3	2	0	0	0	0
1963	1	2	0	0	1	0
TOTAL	207	118	22	7	25	13
Table 7	(Small PCA)			2	2	1
Table 8	(Very small PCA)			2	5	2
TOTAL	207	118	22	11	32	16

TABLE 1C

ALL FLARES AND PCA FLARE WITH IMPORTANCE $\geq$ 2+

The number of PCA flares given in Table 1C by years is based on the major PCA events of Table 1. If we include the small PCA's from Table 7 and the Gregory PCA events from Table 8 for statistical purposes, we find that only 5.3% of the importances 2+ flares, 18.6% of the importance 3 flares, and 73% of the importance 3+ flares were followed by PCA events.

The importance 3+ flares are summarized in Tables 10A, 10B, and 10C and the six importance 3+ flares that were not followed by a PCA event are discussed in the appendix where it is concluded on the basis of associated phenomena that a PCA event would have been expected from two and not expected from the other four.

In the case of the very small PCA events, an analysis indicates that only one of the four had the potential of a major PCA event.

5.2 Flares with Importance 3+ by at Least One Observatory

A total of 53 flares were reported in the IAU Quarterly Bulletin and included in the Solar Activity Catalogue with an importance of 3+ by at least one solar observatory. Thirty of these flares were reduced to importance 3 or less in the McMath-Hulbert working lists as shown in Table 11A.

From Importance 3+ to:	Importance 3	2+	2	1	Total
1956	1	0	0	0	1
1957	5	0	0	0	5
1958	3	1	2	1	7
1959	5	0	1	0	6
1960	4	1	1	0	6
1961	3	2	0	0	5
TOTAL	21	4	4	1	30

TABLE 11A

IAU IMPORTANCE 3+ FLARES REDUCED TO IMPORTANCE ≤ 3 IN THE MCMATH-HULBERT WORKING LISTS

The 21 importance 3+ flares that were reduced to importance 3 in the McMath-Hulbert working list are listed in Table 11 together with the prompt flare associated data.

Nine of these flares (Numbers 1, 3, 4, 10, 14, 16, 18, 19, and 21) were followed by PCA eve... (Numbers 3, ..., 15, 33, 38, 47, 50, 53 55--Table 1). The remaining 22 flares with importance 3+ in the IAU Bulletin, the Solar Activity Catalogue, and the McMath-Hulbe... ...ing List are listed in Tables 10A, 10B, and 10C. Flares ... were followed by very small PCA events, or by no PCA are evaluated in detail.

5.3 Importance 3+ Flares Followed ... ...rge PCA Events

Twelve of the final list of impor... ...- flares (Table 10A) were followed within five hours by PCA's with total integrated flux greater than 10^6 protons/cm^2 with energies $>$ 30 Mev. These 12 flares occurred in ten different plage regions with average maximum area... ...t ranged from 4,000 to 15,000 millionths of the solar hemisphere, and average brightness of 3 (two cases), 3.5 (seven cases), and 4 (one case). Six of the ten associated sunspot groups had an average magnetic classification of γ, or $\beta\gamma$, two were bipolar (β) and two were unipolar (α).

All of these flares caused short wave r...dio fadeouts of importance 3 (5 cases) or 3+ (7 cases) lasting for 30 minutes or more (all but two lasted for more than two hours). All of these flares were accompanied by major radio bursts lasting for 30 minutes or more, at one or more of the frequencies 2800, 2980, 3000, or 3750 Mc/s and spectral emissions of Type IV.

5.4 Importance 3+ Flares Followed by Very Small PCA Events

Four of the importance 3+ flares were followed by very small PCA's (Table 10B). Three caused short wave radio fadeouts of importance 3 (two cases) and 3+ (one case) lasting for more than 30 minutes. Only one was accompanied by a major radio burst in the centimeter wave length (at 2980 Mc/s). From an analysis of the prompt flare associated phenomena (see Appendix 1, Section 1), only one of these flares (Number 3, Table 10B) satisfies the condition for an important PCA event. An integrated proton flux of $4 \times 10^5/cm^2$ for energies $>$ 30 Mev has been calculated for this event.

5.5 Importance 3+ Flares Not Followed by PCA Events

Table 10C lists six importance 3+ flares that were not followed by PCA events. Three were reported by the Sydney Observatory only and do not satisfy any of the conditions for PCA events. These flares and associated data are discussed in detail in Appendix 1, Section 2. Two of these flares (Numbers 5 and 6, Table 10C) meets the conditions for an important PCA event and must at the present time be considered as a false alarm.

Importance 3+ Flares	22
Important PCA's Expected	15
Important PCA's Reported	12
False Alarm Rate	1.3/1

5.6 PCA Intensity and Flare Importance

The distribution of PCA intensity with flare importance is shown in Table 1D. However, it must be pointed out that the maximum absorption is more qualitative than quantitative, since the total energy or total flux during a PCA event will depend on the rate of rise, recovery and the duration of the event. The integrated proton flux for protons with energies greater than 30 Mev is known for only 36 of the 59 events.

Flare Imp.	Weak	< 3	$3 \leq$ to 5	>5 to 10	≥ 10	Total
1	1	0	0	0	0	1
2	2	0	5	5	1	13
2+	0	2	3	1	1	7
3	2	6	11	1	5	25
3+	1	0	1	2	9	13
TOTAL	6	8	20	9	16	59

TABLE 1D

PCA INTENSITY AND FLARE IMPORTANCE

As a first approximation, from a comparison of the absorption in db with the events for which the integrated flux is known we find only four events with an integrated flux $> 10^6$ protons/cm^2 from events following flares of importance $<$2+, one is a flare at the west limb, the other at east 76.

A more complete evaluation of PCA events associated with flares of importance $\leq$ 2+, is desirable.

6.0 OTHER PROMPT PHENOMENA

6.1 Solar Radio Bursts at Centimeters Wavelength

The correlation analysis of solar radio bursts at 28,000, and 3750 Mc/s, with proton events was made by the Radiation and Fields Branch, MSC. That analysis was based on the original records from Ottawa (2800 Mc/s) and Nagoya (3750 Mc/s). More than 200 bursts were found with an integrated intensity greater than 10^{-18} joules $(m^2\ c/s)^{-1}$. In this study we have limited the investigation to the radio frequency bursts that occurred at the time of the PCA flares listed in Tables 1, 7 and 8. Peak fluxes or the smoothed flux (when the peak flux was not available) were used, at the frequencies 2800, 2980, 3000, or 3750 Mc/s. If a flux was not reported, an attempt was made to determine if observations were being made at the time of the flare. An examination of Tables 3 and 3A shows that a flux was reported at 2800, and 3750 Mc/s for 56 of the 59 PCA events listed in Table 1. The number of radio frequency bursts in several ranges of intensity are shown in Tables 3C, where flare importance has been used as a parameter. This shows, as was expected, a strong correlation between the major bursts (peak flux $> 500 \times 10^{-22}\ (m^2\ c/s)^{-1}$) and major flares (importance $\geq$ 2+).

A correlation of the integrated RF burst energy for all 56 cases shown in Tables 3 and 3B with the PCA intensity and, where available, the event integrated proton flux supplemented with data for 3000, and 2980 Mc/s should be carried out.

These data when combined with the other correlation studies may help to reduce the false alarm rate. In fact, since the SPAN telescopes will cover the frequencies 1420, 2695, and 4995 Mc/s, an analysis of the additional frequencies might be productive.

Observatory Code	Frequencies	Normal Observing Time, Hr. UT
HHI	1500	06-15
Syd	1420	21-07
Nag	2000	23-07
Tok	3000	00-06

Forty-three of the 59 PCA-flare events shown on Tables 1 and 3 occurred during the observing periods of one or more of these observatories. The six hours of the universal day (1500-2100) not patrolled by those observatories are covered by the normal patrol period at Ottawa.

In Table 3C we have listed the 12 PCA events where the peak or smoothed flux at 2800 Mc/s was less than 200, and those where the PCA-flare occurred outside the normal Ottawa observing time at 2800 Mc/s. In this table we have included all observing frequencies between 1420 and 3750 Mc/s.

PCA No.	Date	Flare Beg.	Frequencies Mc/s 2800	3750	1420	1500	2000	2980	3000
4	11-30-56	1430	(175)	*	*	**	*	*	**
5	1-20-57	1100	(184)	*	*	**	**	184	**
6	4-03-57	0825	*	*	*	(147)	*	22	**
14	8-29-57	1031	*	*	*	(151)	*	x	x
20	9-26-57	1907	(67)	*	*	*	*	*	*
22	2-10-58	9/2108	(>70)	*	{207 857}	*	*	*	*
25	6-06-58	0436	*	(360)	343	*	420	*	**
33	2-13-59	12/2301	*	(440)	**	*	(335)	*	*
39	3-29-60	0640	*	8250	x	*	4.9×10^4	**	**
44	4-29-60	0107	*	115	x	*	x	*	**
50	11-15-60	0207	*	11600	x	*	4950	*	**
58	9-20-63	2314	*	1400	**	*	1200	*	*

* Outside observing time ** Not observing
x No flux reported Bracket indicates smoothed flux

TABLE 3C

PCA Events with Very Low Flux at 2800 Mc/s or When the Flare Occurred Outside the Normal Ottawa Observing Time

It should be noted that the normal observing times both beginning and ending vary by one or two hours with the season.

6.2 Spectral Emissions - Broad Band Continuum - Type IV

Type IV spectral emissions were observed by either the Harvard or Sydney radio observatories or a type IV emission was derived by a number of investigators from single frequency observations for 52 of the 59 PCA events listed in Tables 1 and 3. The seven cases where no type IV was reported in the literature are summarized in table 3D .

PCA No.	Date	Flare Beg.	Flare Imp.	Type IV	2800	3750	Integrated Proton Flux
2	3-10-65	0515	2	*	850	*	--
5	1-20-57	1100	3	*	(184)	*	2×10^8
11	8-9-57	0617	2	**	246	(105)	1.5×10^6
13	8-29-57	28/2010	2+	x	(760)	*	1.2×10^8
14	8-29-57	1031	2	*	*	*	--
24	3-25-58	0557	2	xx	458	(106)	--
32	9-22-58	0738	2	*	336	(49)	6×10^6

* No observations
** No observations, Sydney stopped at 0616 UT
x None reported, Harvard observing
xx None reported, Sydney observing

TABLE 3D

PCA Events With No Reported Type IV Emissions

The study confirms the high correlation between PCA events and spectral emissions type IV. However, the 52 type IV emissions observed and derived and associated with a PCA flare represents a small percentage of the total number observed or derived during the years 1954 through 1963, as shown in table 3E.

	Total Obs.	Total Derived	With PCA Obs.	With PCA Derived
1954	0	0	0	0
1955	0	0	0	0
1956	1	28	0	3
1957	22	50	12	1
1958	21	26	8	1
1959	24	24	5	1
1960	42	8	10	3
1961	19	2	4	2
1962	8	2	0	0
1963	2	1	1	1
Total	139	141	40	12

TABLE 3E

Spectral Type IV Emissions, and PCA Events

Only 19 percent of the observed and derived type IV emissions occurred at the time of flares that were followed by PCA events.

A more complete analysis of spectral emissions, type II and type IV with emissions at fixed frequency in the range 1420 through 3750 Mc/s, and flare importance, may show a better correlation with PCA events.

6.3 Short Wave Radio Fadeout (SWF)

An inspection of tables 1, 3 and 3A shows that every PCA-flare was accompanied by a SWF, all but four of the SWF's were of importance equal to or greater than 2, lasting for 30 minutes or more. In fact 45 of the PCA flare-SWF's lasted for more than 60 minutes.

The significance of this PCA-flare, SWF correlation should be investigated further as a possible input parameter for the solar proton warning criteria.

6.4 Loop Prominence Systems

One of the most promising phenomena, which at this time has not been thoroughly evaluated because of lack of data, is the occurrence of loop prominences on the solar disk in association with a flare. A preliminary search for loop prominences reported in the IGY report series, combined with data published by Bruzek indicates a high probability that a disk flare which is associated with a loop prominence will be followed by a PCA event, and conversely the probability that a disk PCA-flare will have an associated loop prominence appears to be high. In any case the association is such that a careful evaluation should be made. The appearance of loop prominences at either the East of West limb does not appear to be as promising and must be taken into consideration before reliable conclusions can be made.

Table 6 shows the estimated PCA event proton flux (Protons/cm^2) for energies > 30 Mev., and those events for which loop prominence systems were reported in the literature or the IGY Solar Activity Report Series.

Table 6A summarizes the number of importance 3 and 3+ flares that were followed by an importance PCA event (from tables 1 and 6) and the number of Loop Prominences at the time of these major flares (3 and 3+). Seven additional Loop Prominences originated from PCA-flares with importance < 3 to give a total of at least 27 PCA events following flare with associated loop prominences.

	Flare Importance		LPS Bruzek or the IGY Rep. Series			
			Yes		No	
	3	3+	3	3+	3	3+
1956	2	0	0	0	2	0
1957	8	3	2	1	6	2
1958	3	3	1	1	2	2
1959	2	4	0	4	2	0
1960	5	2	4	2	1	0
1961	4	1	3	1	1	0
1962	0	0	0	0	0	0
1963	1	0	1	0	0	0
	25	13	11	9	14	4

TABLE 6A

Importance 3 and 3+ Flares
And Associated Loop Prominence Systems

7.0 DELAYED TERRESTRIAL EFFECTS

7.1 Effect of Disturbances in the Earth's Magnetic Field

The condition of the interplanetary magnetic field at the time of the PCA flare, as implied by the three hour planetary index K_p fails to show any significant correlation with the PCA flare delay time or the intensity of the PCA. This is shown for selected but typical events in Figures 6, 7, and 8. In addition to showing the three hour K_p for the four days preceding the PCA flare, we have shown all flares from the PCA flare sunspot group, and where available, the normalized neutron monitor two hours counting rate, the daily sunspot area, known loop prominences, and sudden commencement of geomagnetic storms. The length of the line or size of the box indicates the importance or intensity of the event.

We have included cases of major flares (importance $\geq$ 2+) not followed by known PCA events (Figures 8A, 8B and 8C), but with an associated loop prominence; moderate to intense PCA events (Figures 6 and 7) and a sequence of three very small PCA events (Figure 8D).

An indication of the condition of the earth's magnetic field on PCA day for the PCA events from Table 1 is shown in the first two columns of the last section of Table 3 (PCA Day Values), where the $\sum K_p$ and A_p are given.

This phase of the investigation will require a more complete analysis before firm conclusions can be made.

7.2 Geomagnetic Storms

Fifty-six of the basic PCA flares were followed by a sudden commencement geomagnetic storm or in a few cases where two or three PCA events occurred within a 24 or 48 hour period, we have considered that the two or three PCA flares were followed by an SSC even though they were the same storm. The maximum storm K_p and time delay between the PCA and the SSC are shown in Table 3. Table 3F shows the distribution of the storm maximum K_p as a function of the PCA flare importance.

PCA Flare Imp.	No. Storm	Maximum Storm K_p 5+	5+ to 6-	6o to 8-	8o	Total
1	0	0	0	1	0	1
2	2	0	1	7	3	13
2+	0	0	1	1	5	7
3	1	0	5	7	12	25
3+	0	0	1	6	6	13
TOTALS	3	0	8	22	26	59

TABLE 3F

THE DISTRIBUTION OF SSC MAXIMUM K_p WITH PCA FLARE IMPORTANCE

We see that a large percentage of the storms are moderate or severe more or less independent of the flare importance. The delay times from the start of the PCA to the start of the storm varies from four hours (PCA Number 4) to a maximum of 71 hours (PCA Number 49). In six cases the delay times were greater than 60 hours, and the PCA-SSC association might be questionable.

APPENDIX 1

IMPORTANCE 3+ FLARES FOLLOWED BY SMALL OR NO PCA EVENTS

The four importance 3+ flares that were followed by small PCA events (Table 10B) and six with no reported PCA events (Table 10C) are analyzed in considerable detail. It is concluded that an important PCA event would have been expected from the importance 3+ flare on September 18, 1957 this flare, followed by a small PCA, satisfied most of the conditions for a large PCA event. Similarly, the importance 3+ flare on June 18, 1959 was accompanied by the phenomena generally associated with the large PCA events.

1. IMPORTANCE 3+ FLARES FOLLOWED BY SMALL PCA EVENTS

1.1 Importance 3+ Flare, February 21, 1957

This flare at N20 W33 was followed in approximately two hours by a PCA (No. S3 Table 7) reported by several investigators on the basis of f_{min} data. The reported onset times ranged from 1800 UT on the 21st (Jelly and Collins) to 1600 UT on the 22nd (Besprozvannaya). Basler and Owrenlist this as two events, one on the 21st at 1800 UT, the other on the 22nd at 0500 UT.

The flare was reported in the IAU Bulletin from the Sacramento Peak Observatory in Region 46, but no importance was given. The flare is not included in Table 1, Volume 2 of the Solar Activity Catalogue. It is, however, reported as event 24 of Table VIII, Volume 2, with importance 3+ associated with sunspot 12140, plage 3856.

The plage, in its 4th rotation, was small (2800 millionths) moderately bright (average 2.5 intensity during disk passage) and was the source of only four flares (an importance 1 at 0530 UT the 21st, an importance 1+ at 0300 UT, the 22nd, and importance 1 on the 23rd).

This 3+ flare lasted for six hours with the reported maximum at 1930, nearly three and a half hours after the onset. No SWF is reported but a low intensity 10 cm burst (peak flux 19) starts at 1750 UT and lasts for four hours. Small bursts were reported at 200, and 167 Mc/s starting about 30 minutes after the flare beginning.

The association of this flare with a sunspot is questionable due to the intermittent appearance and disappearance of the three spots covered by the plage, (Mt. Wilson spots 12140 at N13, 12143 at N09, and 12150 at N09) and the location of the flare at N20 on the 21st two days after the disappearance of 12140. However, the association with an active region at heliographic longitude 10° is unquestionable. The spot (Greenwich No. 17876) attained a maximum area of 59 millionths on the 15th.

The other pair of spot groups (Mt. Wilson numbers 12143 and 12150) were located at N09. 12143, a three day spot, disappeared on the 16th while 12150 appeared on the 19th and was last seen on the 25th at W79. Greenwich spot 17875 was first seen on the 14th at E60, and was intermittent with a few small spots until the 16th (Mt. Wilson spot 12143). A new spot appeared on the 20th (Mt. Wilson spot 12150) with an area of 65 millionths. It developed rapidly and reached a maximum area of 729 millionths on the 23rd two days after the PCA flare. A major PCA event would not be expected.

1.2 Importance 3+ Flare, September 18, 1957

This small PCA was reported by two independent investigators, but is not included in Bailey's Catalogue. The reported start times range from 2000 UT on the 18th (Besprozvannaya) to 0400 on the 19th (Khocholava).

The flare that was probably responsible occurred in a large (area 1998 millionths on flare day) magnetically complex (d$\beta\gamma$1) sunspot group which was first seen on September 13 at E75. The group which formed from a few small spots developed rapidly into a large stream of normal type. The bright plage (number 4151) (intensity 3.5/4.0/3.0) had an average maximum area of 7500 millionths and was flare productive (83 flares during disk passage). In addition to the large spot group the plage contained two small groups that lasted for only three days (12637, dβ_pd, September 21-23, and 12632, dβ_pd, September 20-22).

The sunspot was the source of 32 flares of importance 1; 4 of importance 2; 1 importance 2+ and one importance 3, prior to the importance 3+ flare at 1658 on the 18th. The flare lasted for nearly 5 hours, caused a major short wave radio fadeout, (importance 3+ lasting for 150 minutes) small radio bursts at centimeter wave lengths, and an importance 3 spectral emission, type IV in the frequency range 580 - 100 Mc/s that lasted for more than 6 hours. There were major bursts of long duration at 167, 450, and 545 Mc/s. The flare was followed by a sudden commencement geomagnetic storm (max Kp = 7+) and a Forbush decrease of 6%.

This flare starting at 1658 UT on the 18th followed within slightly more than one hour of an importance 3 flare in the same plage and spot group which started at 1026 and ended at 1613. Both of these flares had resurgences (or double aspects) the earlier (importance 3) flare had maximum values at 1045, and 1325 with the two phases starting at 1026 and 1303 with major short wave radio fade outs at 1030 (importance 3 lasting 104 minutes) and 1245 (importance 3- lasting 95 minutes). The importance 3+ flare under discussion had maximum intensities at 1740 and 1840 with short wave fades at 1730 and 1823 both of importance 3+ and both lasting 150 minutes.

On the basis of the importance of the region, the flare associated phenomena and the central meridian position and the importance of the flares at 1026, 1303, 1658, and 1818. A solar proton event of major importance would have been expected.

1.3 Two Very Small PCA Events During 1960

Gregory reports 24 very small PCA events which he detected from an analysis of high sensitivity vertical-incidence back scatter sounding of the lower ionosphere at a frequency of 2.3 Mc/s at South 79° geomagnetic latitude, ionosond f_{min} data from high latitude stations confirm these events.

The 24 small events, Table 8 were not reported by other investigators. Two of these very small events were associated with importance 3+ flares (numbers G20 and G38 Table 8). These are analyzed in detail to determine, if possible, why large PCA events were not detected and the possible effect on a solar warning false alarm occurrence.

1.3.1 Importance 3+ Flare June 1, 1960

The flare at 0824 UT, N29 E46 on June 1, 1960 was observed by a record number of observatories (19 reported the flare) and ten gave it an importance of 3+. The flare lasted for five hours and seventeen minutes, and was accompanied by a short wave fade of importance 3 lasting for 75 minutes. There were great bursts at 2980 Mc/s, (lasting for 63 minutes with a peak flux greater than 3400) and 200 Mc/s (lasting for 75 minutes with a peak flux of 3100). Great bursts were also recorded at 9100, 1500, 600, 545, and 23 Mc/s. There was no sweep frequency spectral observation of the sun at the time of the flare, but because of the great bursts at single frequencies in both the centimeter and meter wave lengths, a type IV emission probable occurred throughout the complete frequency range of the radio spectrum. A Forbush decrease of 4.5 percent was reported by Chalk River starting at approximately 2200 UT on June 3. A sudden commencement geomagnetic storm started at 0248 on June 4, with a maximum three-hour Kp of 6+. Gregory reports a small PCA starting approximately five and a half hours after the flare, lasting for about 6 days. Jelly and Collins report a PCA commencing at 2000 UT on the 3rd lasting about 3 days.

Increased proton counting rates were reported in Explorer VII data during the northern high latitude passes on June 1, and again on June 4 (Table 6).

Although there were 11 importance 1, and 1+ flares between 0823 on the 1st and 1900 UT on the third, it is not probable that any of these small flares was responsible for the Jelly and Collins PCA. It is probable that the Jelly and Collins PCA, and the increased proton counting rates observed by Explorer VII were all from a plasma cloud ejected from the sun by the flare of June 1.

The flare occurred in a high latitude β type spot (N29) at heliographic longitude 343°. This spot is a return of the large (1800 millionths) magnetically complex (γ type) spot 14825 which crossed the visible disk at mean longitude 352°, which was the source of an importance 3 flare on May 13, followed by a great short wave fade and a polar cap absorption (number 47, Tables 1, 3, 4, and 5). The great flare on June 1 and sunspot were in a large (area 7000 millionths) moderately bright (average intensity equal to 3) and flare productive (34 flares importance $\geq$ 1 during disk passage) plage 5680.

While this flare did produce a small PCA (too small to be detected by the forward scatter technique or by Riometers), the characteristics of the flare and associated phenomena indicates that a high flux proton beam should have reached the vicinity of the earth within a few hours after the start of the flare. An integrated proton flux of 4×10^5 protons/cm^2 for energies $>$ 30 Mev has been calculated for this event by Webber.

1.3.2 The Importance 3+ Flare, December 5, 1960

This very small PCA found by Gregory, and not detectable on Riometer records or by the forward scatter technique, started approximately eleven hours after the importance 3+ flare at 1825 UT, N26 E68, on December 5. The flare was accompanied by a major SWF (importance 3 lasting 100 minutes) Type II and Type IV spectral emissions, a moderate burst at 2800 Mc/s (peak intensity 330), a major burst at 200 Mc/s (peak intensity greater than 1000) and small bursts at 545 and 108 Mc/s.

The flare occurred in the magnetically complex spot group ($1\beta\gamma1$) 15151, region 1434-38 at N28 and heliographic longitude 8°. The plage 5959 was moderate in area, (6500 millionths) and brightness, (average intensity 3), and was the location of 13 flares during disk passage.

Because of the eastern location of this flare on the solar disk (E68) and the low peak intensity of the 2800 Mc/s flux (330×10^{-22} wm^{-2} (S/C)$^{-1}$), this flare would not be classified for proton warning, but the region would be watched carefully during disk passage for later indications of a proton flare event. The plage in its fourth rotation was the return of plage 5925 which contained the large (area 1775 millionths) sunspot group 15114, which was the location of four very small PCA's on November 10, 11, 14, and 19, reported by Gregory only (numbers G31, G32, G34, and G36, Table 8) and the three major PCA events with ground level effects on November 12, 15 and 21. (Numbers 49, 50, and 51, Tables 1, 3, 4, and 5.)

2.0 IMPORTANCE 3+ FLARES WITH NO REPORTED PCA EVENT

2.1 Importance 3+ Flare, November 7, 1956

The importance 3+ flare at 1109 UT, S17 E32 occurred in the bright new plage 3751. The sunspot group 11949 crossed the visible disk between the 3rd and 15th November with β_p average magnetic classification, and a whole spot area on flare day of 929 millionths of the solar hemisphere. In spite of the large area of the sunspot only six importance 1 flares were reported prior to the importance 3+ flare. The first flare was reported on the 5th at E57. The sunspot was located at mean heliographic longitude 264°, which as seen from figures 3 and 4 is located in the region where PCA's are relatively rare.,

The region was relatively radio quiet and no emissions in the frequency range from 3750 to 2800 were reported at the time of the importance 3+ flare. The flare produced an importance 2 short wave radio fadeout which lasted for only 21 minutes. Six of the minor flares were accompanied by moderate radio bursts of short duration at centimeter and/or meter wave lengths. This flare was followed at 1313 by a loop prominence.

On the basis of the relatively minor SWF and lack of emissions in the centimeter wave lengths an importance PCA would not be expected. However, because of the associated loop prominence a state of alert should be considered.

2.2 Importance 3+ Flare, January 23, 1957

This importance 3+ flare at 2310, N17, W17, was reported by only one observatory (Sydney) in Region 19, sunspot 12089, plage 2823.

The flare occurred in the large, (16000) bright, (3.5, 3.5,3) flare productive (37 flares) plage region in its third rotation. The plage covered three sunspot groups. The sunspot in which the flare occurred (12089) had a maximum area of 1581 millionths, a mean area during disk passage of 778 millionths with an α_p magnetic classification and Zurich type H, at mean longitude 18°. There were no radio emissions at centimeter wave lengths reported at the time of the flare and no SWF was reported. A major burst was reported by NBS at 167 Mc/s with peak flux greater than 2100 x $10^{-22}Wm^{-2}$ $(c/s)^{-1}$.

Six importance 1, 4 importance 2, and 1 importance 2+ flares were reported in this region prior to the 3+ flare, the first flare (importance 1) occurred at E50 on January 18. No PCA would be expected from this flare.

2.3 Importance 3+ Flare, January 31, 1957

This importance 3+ flare at 0358 UT was also reported by only one observatory (Sydney) in Region 30, sunspot 12114, plage 3830.

This plage (in its second rotation) was of moderate size (8500), moderately bright (3/3/3). The plage contained two one day spots, one spot that was born and died on the visible disk and the flare-spot which was first seen on January 27 (Zurich and Greenwich) at E54 and mean longitude 257.4°. This small (mean area 160 millionths) stream of spots achieved a maximum area of 504 millionths on the 29th, but covered only 183 millionths of the solar hemisphere at the time of the flare on the 31st. It continued to decrease in size to 64 millionths by February 3 and to 40 millionths at W72 when it was last seen on February 5.

Only 3 flares were reported in this region, one of importance 1, and one of importance 2 on February 1, and the 3+ flare under evaluation. This flare was accompanied by small radio bursts at 9400 Mc/s (41 smoothed flux) and at 3000 Mc/s (234 peak flux). A minor SWF (importance 1) lasting for 84 minutes is associated with the flare. None of the characteristics or phenomena associated with this flare, except the reported importance, would indicate a PCA.

2.4 Importance 3+ Flare November 29, 1957

This flare at 0045 UT was followed by a Type II burst of short duration and a moderate burst (488 peak flux) at 9500 Mc/s. No associated SWF was reported. This flare occurred in a very small plage (4282) at very high latitude (N41) and near the east limb (E63). The plage contained no spots, this, the only known flare in the plage region, was reported by the Sydney observatory only. No PCA could be expected under these conditions, in fact, the reported flare importance would be questionable.

2.5 Importance 3+ Flare on April 5, 1959

This flare at 2316 UT, N16 W67, occurred in the bright (average intensity $>$ 3) flare productive (46 flares) plage, 5071, which is a fifth return region. This plage contained three spot groups that existed during the complete disk passage and two short lived groups. The flare occurred in the small (mean area 184 millionths) but magnetically complex ($\beta\gamma$) sunspot group 14020. An importance 3+ short wave fade lasting for 93 minutes started almost simultaneously with the start of the flare. There were no 2800 Mc/s observation at the time of the flare, and no Type II or Type IV dynamic emissions were reported. However, there were great bursts at 9500 Mc/s (2960 peak flux) 3750 Mc/s (smoothed flux 2300 lasting for 8 minutes) and at 2000 Mc/s (smoothed flux 580). No sudden commencement geomagnetic storm or Forbush decrease followed within three days after the flare, although a solar flare effect (magnetic crochet) was reported by 17 stations commencing at 2321 UT on the 5th. The four days prior to the flare were very quiet geomagnetically with a maximum 3-hour Kp of 3+ and Ap's of 6, 7, 12 and 6, respectively.

The flare was preceded by 24 minor flares and one importance 2+ flare. The first flare was reported at E48 on March 28.

The sunspot group was at mean longitude 273°. On the basis of this flare and the associated phenomena, including the SWF and burst at 3750 Mc/s. A PCA might be expected unless one considers that the region lies in the apparent region between Heliographic Longitudes 140° and 320° where very few PCA's have been reported.

2.6 Importance 3+ Flare in June 18, 1959

This flare at 1134 UT, N18 W67, occurred in a large, (area 9000 millionths), bright, (average intensity 3.5) and flare productive (96 flares during disk passage) plage 5204. The plage contained two spot groups that accompanied it across the east limb and a small one day spot. The flare occurred in the large (maximum area 1111 millionths, mean area 856 millionths) magnetically complex (γ type) sunspot group 14211 at heliographic longitude 330°. This spot was a Zurich type G on flare day and the source of 43 minor and 3 major flares prior to the 3+ flare on the 18th. The first flare (importance 2) occurred at the east limb on June 9 and was accompanied by a great shortwave fade of importance 3+ lasting for 180 minutes, two great bursts at 2800 Mc/s and a Type IV broad band continuum emission in the very low frequency range (50-25 Mc/s). This region was unusually active and radio noisy during disk passage.

The importance 3+ flare was accompanied by a SWF of importance 2+ that lasted for 52 minutes. Very large complex radio bursts were reported at centimeter wave length commencing simultaneously, the emission at 2800

Mc/s lasted for three hours with a smoothed flux of 1225 x 10^{-22} Wm^{-2} $(c/s)^{-1}$. No emissions were reported at meter wave lengths. The small PCA, observed by Riometers and from f_{min} data on June 13 (Number S17, Table 7) was associated with an importance 1 flare from this same region at E58, at a time of very quiet geomagnetic conditions, when except for a brief period (4th, 5th and 6th three-hour periods) on the 11th, the three hour Kp's remained less than 3o during the four days preceding the flare.

This is the one real failure among the importance 3+ flares since all of the flare-time related phenomena indicate a probable PCA of considerable magnitude. The sunspot longitude of 330° is in the apparent preferred hemisphere for PCA's.

It is interesting to note that during the next solar rotation the plage 5204 combined with 5218 to form the plage 5265, and sunspot 14211 returned as 14284 which was the source of the three high energy PCA flares on the 10th, 14th and 16th of July 1959 (Numbers 35, 36, and 37, Table 1).

SOURCES OF DATA

Polar Cap Absorption Events. The original sources used to compile the list of polar cap absorption events given in Tables 1, 7, and 8 are given in Table 3.

Solar and Terrestrial Phenomena used in the study of the PCA events were taken from Solar Activity Catalogue Volumes 1 through 5, prepared by F. C. Jonah, Helen Dodson-Prince and E. Ruth Hedeman under NASA Contract NAS 9-2469.

Sources used for the preparation of the Solar Activity Catalogue are listed in each volume of the catalogue.

Daily Sunspot Areas for the years 1954 through 1958 were obtained from Royal Greenwich Observatory Bulletins Photo Heliographic Results: 1955, published 1958 (no number); 1956 (Bulletin Number 14); 1957 (Bulletin Number 26); 1958 (Bulletin Number 60).

REFERENCES

Many sources of data on special solar events published in the scientific literature, not listed in Table 3, were consulted during this study.

No attempt is made to give a complete list of scientific papers, reporting special solar events. Only those directly related to polar cap absorption events have been included in the Bibliography.

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TABLE 1

PCA'S WITH ASSOCIATED FLARES AND SOURCES

No.	Date	PCA Beg.	Rise Time, hrs.	Duration hrs.	Abs. db.	Flare Onset	Flare Max.	Imp.	Position	Δt	Range Start Times	Original Sources	Others
	1956												
1.	Feb. 23	0400	18	123	13.0	0334	--	3	N23 W80	0^h23^m	23/0400-23/0600	B_1, B_2, Be, CJM, JP, S	M, Mo, WH
2.	Mar. 10	0900	38	160	3.5	0515	--	2	N16 E88	3^h45^m	10/0900-11/1600	B_1, Be, CJM	M
3.	Aug. 31	1430	14	69	4.9	1226	1246	3+(3)	N15 E15	2^h04^m	31/1430-31/1800	B_1, B_2, Be, CJM, JP, S	M, Mo, WH
4.	Nov. 13	2000	27	63	5.4	1430	1501	2	N16 W10	5^h30^m	13/1400-14/1600	B_1, B_2, Be, CJM	M, Mo, WH
	1957												
5.	Jan. 20	1500	16	86	4.1	1100	1119	3	S30 W18	4^h00^m	20/1500-21/1500	B_1, B_2, Be, CJM, DLP, S	BO, M, Mo, WH
6.	Apr. 3	1330	14	65	3.9	0825	0835	3	S14 W60	5^h05^m	02/2300-04/1200	B_1, B_2, Be, CJM, JP	BO, M, Mc, WH
7.	June 19	2215			Weak	1609	1613	2+(2)	N20 E45	6^h06^m	19/2215-19/2300	Be, JP, S	BO
8.	June 22	0500	44	115	5.0	0236	--	2	N23 E12	2^h24^m	22/0500-22/1000	B_1, B_2, K, RL, S	BO, M, WH
9.	July 3	0900	12	52	9.2	0712 0830	0745 0840	3+ 3+	N14 W40 N10 W42	1^h42^m 0^h30^m	03/0815-03/1030	B_1, B_2, Be, Bo, DLP, HG, HNS, H, JP, K, OH, PS, RL, S	BO, M, Mo, WH
10.	July 24	2015		27	2.0	1712 1801	1737 1828	3	S24 W27	3^h03^m	24/1000-24/2400	B_2, Bo, H, HG, HNS, JP, K, OH, PS, RL, S	BO, M, Mo, WH
11.	Aug. 9	1600	10	50	3.1	0617	0629	2	S09 E76	9^h43^m	09/1500-09/2400	B_1, Be, H, JC, K, PS	BO, M
12.	Aug. 28	1300			Weak	0810	0955	3+(3)	S30 E35	4^h50^m	28/0400-28/2300	A, Be, Bo, DLP, H, PS	BO, Mo
13.	Aug. 29	0000	7	27	3.2	28/2010	2024	3(2+)	S28 E30	3^h50^m	29/0000-29/0500	A, B_1, B_2, HG, HNS, OH, PS, S	BO, M, Mo, WH
14.	Aug. 29	1300	12	58	8.2	1031	1052	3(2)	S25 E20	3^h29^m	29/1300-29/1500	A, B_1, B_2, DLP, HG, HNS, K, OH, RL, S	BO, M, WH
15.	Aug. 31	1415	12	46	4.9	1257	1313	3+(3)	N25 W02	1^h18^m	31/1415-31/1530	A, B_1, B_2, H, K, S	BO, M, Mo, WH
16.	Sept. 02	1700	9	46	7.2	1313		3(2+)	S34 W36	3^h47^m	02/1500-02/2100	B_1, B_2, Bo, HNS, H, K, OH, RL, S	BO, M, Mo, WH
17.	Sept. 12	0200	13	57	0.5	11/0236	0300	3	N13 W02	23^h24^m	12/0200-12/2315	B_2, Be, Bo, DLP, HG, HNS, H, JP, K, Kh, OH, PS, RL, S	BO, M, Mo, WH
18.	Sept. 18	2000				18 1658 1818	1740 1840	3+	N23 E08	$3^h\ 02^m$ $1^h\ 42^m$	18/2000-19/0400	Be, DLP, H, Kh, PS	BO
19.	Sept. 21	1700	18	63	5.1	1330	1335	3	N10 W06	$3^h\ 30^m$	21/1200-21/2115	B, B_2, CJM, HG, HNS, H, K, OH, PS, RL, S	BO, M, Mo, WH
20.	Sept. 26	2100		31	2.0	1907	1952	3	N22 E15	$1^h\ 53^m$	26/2100-26/2315	B_1, Be, Bo, HG, HNS, H, K, Kh, OH, PS, RL, S	BO, M, WH
21.	Oct. 20	2100	22	64	7.8	1637	1642	3+	S26 W45	$4^h\ 23^m$	20/1700-21/1400	B_1, Be, Bo, CJM, DLP, HG, HNS, H, JP, K, Kh, OH, PS, RL, S	BO, M, Mo, WH
	1958												
22.	Feb. 10	0600	14	37	3.2	9/2108	2142	2+	S12 W14	$8^h\ 52^m$	10/0500-10/2400	B_1, B_2, Be, Bo, CJM, DLP, HG, HNS, K, Kh, OH, PS, RL, S	BO, M, Mo, WH
23.	Mar. 23	1500	34	53	3.2	0947	1005	3+	S14 E78	$5^h\ 13^m$	23/1500-23/1830	B_1, B_2, Bo	BO, M, Mo, WH
24.	Mar. 25	1530	13	122	10.0	0557		2	S15 E50	$9^h\ 33^m$	25/0100-25/1545	B_1, B_2, Be, CJM, DLP, HG, HNS, K, Kh, L, OH, PS, RL, S	BO, M, Mo, WH
25.	June 06	0600			Weak	0436	0448	3(2)	N16 W78	$1^h\ 12^m$	04/2300-06/1345	Be, Bo, DLP, HG, HNS, Kh, OH, PS, S	BO, M, WH
26.	July 07	0130	22	96	23.7	0020	0110	3+	N25 W08	$0^h\ 20^m$	07/0100-07/600	B_1, B_2, Be, Bo, CJM, DLP, HG, HNS, JP, K, Kh, L, OH, PS, RL, S	BO, M, Mo, WH
27.	July 29	0400		30	1.5	0259	0304	3	S14 W44	$1^h\ 01^m$	29/0400-29/0500	B_2, Be, Bo, DLP, HG, HNS, JP, K, Kh, OH, RL, S	BO, M, Mo, WH
28.	Aug. 16	0600	16 (2 db/hr)	71	>15.0	0433	0440	3+	S14 W50	$1^h\ 28^m$	29/0600-16/1200	B_1, B_2, Be, Bo, CJM, DLP, HG, HNS, JP, K, Kh, L, OH, PS, RL, S, ETV	BO, M, Mo, WH
29.	Aug. 21	1400	0.2 db/hr	19	3.0	20/0042	0045	3(2+)	N16 E17	13^h18^m	21/1400-21/1730	B_1, Be, DLP, HNS, K, Kh, L, RL, S	BO, M, WH
30.	Aug. 22	1530	11	84	10.6	1417	1450	3	N18 W10	$1^h\ 23^m$	22/1500-22/1745	B_1, B_2, Bo, CJM, DLP, HG, HNS, K, Kh, L, OH, PS, RL, S	BO, M, Mo, WH
31.	Aug. 26	0100	1 db/hr	89	16.6	0005	0027	3	N20 W54	$0^h\ 55^m$	26/0100-26/0400	B_1, B_2, Bo, CJM, DLP, HG, HNS, JP, K, Kh, L, OH, PS, RL, S	BO, M, Mo, WH
32.	Sept. 22	1400	22	80	5.0	0738	0750	2+(2)	S19 W42	$6^h\ 22^m$	22/0530-22/1730	B_1, B_2, Be, Bo, HG, HNS, JP, K, Kh, OH, PS, RL, S	BO, M, Mo, WH
	1959												
33.	Feb. 13	0800	12	74	2.6	12/2301	2325	3+(3)	N13 E48	$8^h\ 59^m$	13/0800-13/1400	B_1, Be, JC, JP	BO
34.	May 10	2300	3 db/hr	170	22.0	2055	2140	3+	N19 E47	$2^h\ 05^m$	10/2300-11/0300	B_1, B_2, Be, CJM, DH, DLP, HHO, JP, K, Kh, L, OH, RL, S, SL	BO, M, Mo, WH

PCA'S WITH ASSOCIATED FLARES AND SOURCES (cont.)

No.	Date	PCA Beg.	Rise Time, hrs.	Duration hrs.	Abs. db.	Flare Onset	Flare Max.	Imp.	Position	t	Range Start Times	Original Sources	Others
35.	July 10	0400	0.9 db/hr	360	20.0	0206	0230	3+	N20 E60	$1^h 54^m$	9/2000-10/1000	B_1, B_2, Be, CJM, DLP, EHO, K, Kh, L, OH, RL, S, SL	BO, M, Mo, WH
36.	July 14	0445	27	72	23.7	0325	0349 0527	3+	N17 E04	$1^h 20^m$	14/0445-14/0800	B_1, B_2, CJM, DLP, EHO, K, Kh, L, OH, RL, S,SL	BO, M, Mo, WH
37.	July 16	<2250	10	168	21.2	2114	2128	3+	N16 W30	$1^h 36^m$	16/2200-17/0600	B_1, B_2, CJM, DH, EHO, JP, K, Kh, L, OH, RL, S, SL	BO, Mo, WH
38.	Aug. 18	1100		60	3.0	1014	1030	3+(3)	N12 W33	$0^h 46^m$	18/1100-19/10xx	B_1, Be, DLP, JC, JP, K, S	BO
	1960												
39.	Mar. 29	0800	50	73	2.6	0640	0710	3(2+)	N13 E30	$1^h 20^m$	29/0800-29/1100	B_1, B_2, G	BO, Mo
40.	Mar. 30	2000		>36	5.0	1455	1540	3+(2)	N12 E13	$5^h 05^m$	30/1100-31/<0700	B_2, DH, EHO, GM, JP, K, L, S, Sat.	BO, M, Mo, WH
41.	Apr. 01	1000	6	73	3.6	0843	0859	3	N12 W11	$1^h 17^m$	01/0930-01/1000	B_1, B_2, G, GM, K, L, S, Sat	BO, M, Mo, WH
42.	Apr. 05	0400	>16	55	3.1	0215	0245	3(2)	N12 W62	$1^h 45^m$	05/0400-05/1400	B_1, B_2, EHO, G, GM, K, L, S, Sat.	BO, M, Mo, WH
43.	Apr. 28	0230	12	30	3.5	0130	0137	3	S05 E34	$1^h 0^m$	28/0200-28/1000	B_1, B_2, EHO, G, GM, JP, K, L, S, Sat	BO, M, Mo, WH
44.	Apr. 29	0400	0.4 db/hr	114	14.0	0107	0210 0359 0554	3(2+)	N14 W21	$2^h 53^m$	29/0200-29/700	B_1, B_2, EHO, G, GK. JP, K, L, S, Sat	BO, M, Mo, WH
45.	May 04	1030	3.2 db/hr	8	3.4	1000	1016	3	N13 W90	$0^h 30^m$	04/1030-04/1200	B_1, B_2, EHO, G, JP, K, L, S, Sat	BO, M, Mo, WH
46.	May 06	1600	0.15-0.33 db/hr	103	16.0	1404	1448	3+	S09 E07	$1^h 56^m$	06/1400-06/1800	B_1, B_2, EHO, G, JP, K, L, S	BO, M, Mo, WH
47.	May 13	0620	0.7 db/hr	65	4.5	0519	0532	3+(3)	N29 W67	$1^h 01^m$	13/0620-13/0800	B_1, B_2, EHO, G, JP, K, L, S, Sat	BO, M, Mo, WH
48.	Sept. 03	0500	31	89	2.7	0037	0108	3(2+)	N18 E88	$4^h 23^m$	03/0500-03/2300	B_1, B_2, EHO, G, JC, K, S	BO, M, Mo, WH
49.	Nov. 12	1400	16	73	21.2	1315	1330	3+	N27 W04	$0^h 45^m$	12/1400-12/1600	B_1, B_2, G, JP, K, S, Sat	BO, M, Mo, WH
50.	Nov. 15	0430	15	79	20.0	0207	0221	3+(3)	N26 W35	$2^h 23^m$	15/043-15/1200	B_1, B_2, G, JP, K, S, Sat.	BO, M, Mo, WH
51.	Nov. 21	0200	15	51	3.0	20/1955 20/2114	2020 2135	3(1) 3(2)	N25 W90 N28 W90	$6^h 05^m$ $4^h 46^m$	21/0000-21/1300	B_1, B_2, G, JP, S	BO, M, Mo, WH
	1961												
52.	July 11	2200	0.08 db/hr		1.3	1615	1659 1710	3	S07 E31	$5^h 45^m$	11/2200-11/2400	L, M, Sat	BO, M, Mo
53.	July 12	1900	0.8 db/hr	72	17.0	0950	1025	3+(3)	S07 E22	$9^h 10^m$	12/1300-12/2115	B_1, JP, L_2, Sat	BO, M, Mo, WH
54.	July 18	1130	8	55	10.0	0920	1005	3+	S07 W59	$2^h 10^m$	18/1130-18/1200	B_1, JP, L_2, Sat	BO, M, Mo, WH
55.	July 20	2200			Weak	1553 1633 1828	1600 1653 1847	3+(3)	S05 W90	$6^h 07^m$ $5^h 27^m$ $3^h 32^m$		L_2, Sat	BO, M, Mo, WH
56.	Sept. 10	2000	18	79	2.9	1555	1610	1	N10 W90	$4^h 05^m$	10/2000-10/2300	B_1, BO, Sat	M, Mo
57.	Sept. 28	2245	1.7 db/h pre-ssc 3.3 db/h post-ssc		3.3	2202	2223	3	N13 E29	$0^h 43^m$	10/2245-10/2335	B_1, L, L_2, Sat, Bal	BO, M, Mo, WH
	1963												
58.	Sept. 20	2400	15	54	3.1	2314	2403	2	N10 W09	$0^h 46^m$		B_1, BO,	
59.	Sept. 26	0745	8	89	4.6	0638	0717	3	N13 W78	$1^h 07^m$	26/0730-26/0745	B_1, BO	

TABLE 2

SOURCES USED FOR POLAR CAP ABSORPTION DATA

A	Anderson	J. Geophys. Res.	69	1964	1743-1753
B_1	Bailey	Planet. Space Sci.	12	1964	495-541
B_2	Bailey	J. Phys. Soc. Japan	17 A-1	1962	106-112
Be	Besprozvannaya	J. Phys. Soc. Japan	17 A-1	1962	146-150
Bo	Bookin	J. Phys. Soc. Japan	17 A-1	1962	150-151
BO	Basler & Owren	U. Alaska Geophys. Inst.	R-152	1962	189 pp.
CJM	Collins, Jelly & Matthews	Can. J. Phys.	39	1961	35-52
DH	Dodson & Hedeman	Ark. Geofysik	3	1962	469-470
DLP	Dvoryashin, Levitskii & Pankratov	Soviet Astron. A.J.	5	1961	311-325
EHO	Egeland, Hultqvist & Ortner	Ark. Geofysik	3	1962	481-488
FW	Freier & Webber	J. Geophys. Res.	68	1963	1605-1629
Go	Gosling	J. Geophys. Res.	69	1964	1233-1238
G	Gregory	J. Geophys. Res.	68	1963	3097-3107
GM	Greenstadt & Moreton	J. Geophys. Res.	67	1962	3299-3316
H	Hill	J. Phys. Soc. Japan	17 A-1	1962	97-102
HG	Hakura & Goh	J. Radio Res. Lab. Japan	6	1959	635-650
HNS	Hakura, Nagai & Sano	Rep. Ionosph. Space Res. Japan	15	1961	14-30
JC	Jelly & Collins	Can. J. Phys.	40	1962	706-718
JP	Jenkins & Paghis	Can. J. Phys.	41	1963	1056-1075
K	Kahle	U. Alaska Geophys. Inst.	R-129	1962	76 pp.
Kh	Khocholava	Geomag. Aeronomy.	2	1962	90-96, 907-913
			3	1963	735-740
L_1	Leinbach	U. Alaska Geophys. Inst.	R-127	1962	230 pp.
L_2	Leinbach	U. Alaska Geophys. Inst.	R-126	1962	16 pp.
M	Malitson	NASA TR	R-169	1963	109-117
MW	Malitson & Webber	NASA TR	R-169	1963	1-17
Mo	Modisette	Manned Spacecraft Center Eng. Des. & Oper, Ed.Purser, et.al.		1964	97-104
OH	Obayashi & Hakura	J. Geophys. Res.	65	1960	3143-3148
PS	Piggott & Shapley	Antarctica Res. Geophys. Mon.	7	1962	111-120
RL	Reid & Leinbach	J. Geophys. Res.	64	1959	1801-1805
S	Sinno	J. Geomag. Geoelect.	13	1961	1-10
SL	Shapley & Lincoln	Ann. IGY	16	1962	289 pp.
WH	Warwick & Haurwitz	J. Geophys. Res.	67	1962	1317-1332

TABLE 3

SUMMARY PCA EVENTS AND FLARE RELATED PHENOMENA

					Radio Emissions					Terr. Eff.				PCA Day Values					
	PCA	Flare Imp.	CMD	SHF	II	IV	3750	2800	200	SSC K_p	FWS	$\Delta t/\Delta t_1/\Delta t_2$	PCA db.	ΣK_p	A_p	Zurich Class	Mag Class	Area Umbra	Area Whole
	1956																		
1.*	2-23	3	W80	160/3+	0	(#)	(18000)	>4700	> 20000	8+	1.5	0.5/47/6.5	13.0	13-	7	(E)	(γ)	114	794
2.	3-10	2	E88	117/3-	-	-	-	850	x	6o	-	4.0/9/-	3.5	23-	20	A	-	-	-
3.*	8-31	3+(3)	E15	81/3	-	#	0	(>340)	22500	8o	6.5	2.0/35/1.5	4.9	23+	21	E	(γ)	97	837
4.*	11-13	2	W10	120/2+	-	#	0	(175)	x	8o	2.5	5.5/4/0.5	5.4	21+	16	G	βγ	46	338
5.	1957 1-20	3	W18	13/1+	-	-	0	(184)	x	9-	17.0	4.0/22/5.5	4.1	8+	4	E	(βp)	123	557
6.	4-03	3	W60	35/2+	-	#	0	0	> 10	6-	1.9	5.0/43/-14	3.9	26o	20	E	β	110	682
7.	6-19	2+(2)	E45	44/3	#	#	0	(2325)	>260	-	-	6.0/-/-	Weak	29o	26	J	αp	171	931
8.	6-22	2	E12	74/2	-	#	x	570	-	7o		2.5/68/-	5.0	23-	16	J	αp	167	816
9.	7-03	3+	W40	61/2+	-	#	0	>600	3400	7+	4.0	1.5/39/0.5	9.2	30o	30	H	γ	108	500
10.	7-24	3	W27	113/3	-	#	0	1275	385	-	-	3.0/-/-	2.0	20+	12	E	βγ	81	504
11.	8-09	2	E76	35/3-	-	-	(105)	246	110	-	-	9.5/-/-	3.1	23o	16	J	–	15	121
12.	8-28	3+(3)	E35	138/3	-	#	x	1192	100	7-	13.0	5.0/31/-	Weak	19+	10	E	γ	95	774
13.	8-29	3(2+)	E30	18/2+	#	-	0	(760)	>450			4.0/20/2	3.2	22-	28	E	γ	95	774
14.	8-29	3(2)	E20	16/1+	-	-	0	x	>230	7o	-	3.5/47/-	8.2	22-	28	E	γ	171	807
15.	8-31	3+(3)	W02	184/3+	-	#	0	(3900)	>1200	9-	4.5	1.5/37/9	4.9	30-	36	E	βγ	227	1317
16.	9-03	3(2+)	W36	68/2-	-	(#)	0	429	(250)	9o	2.1	4.0/48/?	7.2	54o	135	G	α	101	626
17.	9-12	3	W02	110/3	#	#	(373)	1110	520	9-	6.1	23.5/49/3	0.5	15o	7	E	βγ	132	701
18.	9-18	3+	E08	150/3+	-	#	0	(275)	> 293	7+	6.0	3.0/65/8	?	20-	12	F	βγ	376	1998
19.	9-21	3	W06	60/3-	-	#	0	(785)	>1250	9-	6.6	3.5/34/-	5.1	39o	74	E	βγ	136	491
20.	9-26	3	E15	100/2+	-	#	0	67	>384	9-	8	2.0/53/2	2.0	16o	8	C	αp	49	232
21.	10-20	3+	W45	196/3+	#	#	0	(4000)	>> 120	7-	8.2	4.5/30/1	7.8	19+	11	F	βf	399	2373
	1958																		
22.	2-10	2+	W14	20/1	-	#	0	> 70	>3000	9o	5.2	9.0/19/1.5	3.2	28-	24	D	βp	103	690
23.	3-23	3+	E78	196/3	-	#	0	>1340	1890	6o	11.1	5.0/54/2.5	3.2	27+	21	E	βp	192	1374
24.	3-25	2	E50	27/2	-	-	(106)	458		6o	IP	9.5/-/?	10.0	33+	33	E	βγ	268	1539
25.	6-06	3(2)	W78	50/2	-	#	x	x	650	8-	--	1.0/30/?		20+	18	HL	(β)	17	135
26.	7-07	3+	W08	125/3	#	#	1700	(3770)	4000	9o	7.8	0.5/31/1.5	23.7	23+	17	E	βf	136	686
27.	7-29	3	W44	120/3+	#	#	(2000)	>2100	(30000)	5+	2.0	1.0/59/2	1.5	11-	9	F	βγ	97	568
28.	8-16	3+	W50	168/3+	-	#	(5800)	5030	18000	7+	5.8	1.5/24.5/-0.5	15.0	20+	12	G	βγ	208	935
29.	8-21	3(2+)	E17	33/2+	#	(#)	(1450)	1260	155	6-	4.0	13.5/12.5/4.5	3.0	13o	6	E	βγ	203	1463
30.	8-22	3	W10	170/3+	-	#	0	(1500)	1400	8-	9.1	1.0/34/1.0	10.6	31+	34	E	βγ	112	1192
31.	8-26	3	W54	240/3+	#	#	(5050)	(5000)	85000	7-	3.8	1.0/26/2.0	16.6	23-	14	E	(βp)	116	776
32.	9-22	2+(2)	W42	35/2	0	0	(49)	336	x	7o	-	6.5/62/0	5.0	7-	4	E	(βp)	209	1087
	1959																		
33.	2-13	3+(3)	E48	40/2	-	#	(440)	x	470	6-	4.0	9.0/28/-2.0	2.6	27o	21	E	βp		
34.	5-10	3+	E47	560/3+	#	#	0	(2500)	1050	8+	14.8	2.0/24.5/1	22.0	23+	14	E	(βγ)		
35.	7-10	3+	E60	190/3+	#	(#)	(6300)	>1300	>1400	7-	9.9	2.0/36.5/1.0	20.0	20o	13	H	(γ)		
36.	7-14	3+	E04	180/3+	#	#	(6000)	1300	10000	9o	14.5	1.5/17/0	23.7	24-	16	H	(γ)		
37.*	7-16	3+	W30	177/3+	-	#	(1500)	6500	1100	9-	13.5	1.0/18.5/3	21.2	36+	47	H	(γ)		
38.	8-18	3+(3)	W33	120/3	#	#	0	985	6250	6-	6.8	1.0/41/0	3.0	31+	28	E	(γ)		1119
	1960																		
39.	3-29	3(2+)	E30	121/3+	-	(#)	8250	0	38000	9-	10.0	1.5/50/2.0	2.6	23+	18	E	(β)		
40.	3-30	3+(2)	E13	160/3	#	#	0	1750	6000	9-	4.0	5.0/31/45	5.0	26+	20	E	βγ		1650
41.	4-01	3	W11	57/3	-	(#)	0	>1000	4500	7+	5.5	1.5/37/1.0	3.6	65+	241	F	(βγ)		
42.	4-05	3(2)	W62	157/3+	#	#	x	2400	300	5+	-	2.0/59/-	3.1	31o	34	F	(γ)		
43.	4-28	3	E34	100/3+	#	#	260	512	x	9o	6.5	1.0/52/13	3.5	47o	84	D	(βp)		
44.	4-29	3(2+)	W21	110/2+	#	#	115	x	x			3.0/21.5/13	14.0	41o	55	H	γ		
45.*	5-04	3	W90	35/3	-	(#)	0	2650	x	7+	-	0.5/54.5/-	3.4	10+	5	HL	–		
46.	5-06	3+	E07	151/3	#	#	0	695	x	8+	11.3	2.0/36.5/0.5	16.0	39+	60	G	(βp)		
47.	5-13	3+(3)	W67	221/3+	#	#	3750	2065	x	6+	3.07	1.0/69.5/?	4.5	20+	11	F	γ		
48.*	9-03	3(2+)	E88	126/3+	#	#	12000	5600	>1000	8o	5.0	4.5/21.5/-31	2.7	31-	35	E	l (γ)		
49.*	11-12	3+	W04	154/3+	-	#	0	5500	>2000	8+	12.0	1.0/71/0.5	21.2	33+	67	F	(βγ)		
50.*	11-15	3+(3)	W35	253/3+	#	#	11600	x	>2700			2.5/8.5/0.5	20.0	42+	69	F	(βγ) l		
51.*	11-21	3(2)	>W90	82/3-	#	#	0	400	220	6o	2.0	6.0/4.5/-1.5 /82.5/-	3.0	36+	45	F	(βγ) l		
	1961																		
52.	7-11	3	E31	245/3+	#	#	0	1500	> 900	8+	12.0	6.0/37/1.0	1.3	17-	9	E	βγ		1400
53.	7-12	3+(3)	E22	97/3		(#)**	0	4100	22000			9.0/6/1.0	17.0	9+	5	E	(βδ)		
54.*	7-18	3+	W59	113/3	-	(#)**	0	2400	1000	6-	4.0	2.0/39.5/13	10.0	49o	93	E	(βδ)		
55.	7-20	3+(3)	W90	370/3+	#	#	0	1800	4000			5.0/SIP	Weak	24+	19	E	(βγ) l		
56.	9-10	1	W90	101/3	#	#	0	880	x	6o	3.0	4.0/68/-4	2.9	14o	7	E	(βp) l		
57.	9-28	3	E29	62/2	#	#	1690	800	>900	9-	7.0	1.0/46.5/0.5	3.3	8o	5	C	βf		
	1963																		
58.	9-20	2	W09	214/3	#	#	1400	x	>10000	9-	3.2	1.0/14/10	3.1	22+	13	E	(γ)		
59.	9-26	3	W78	102/3+	0	(#)**	1850	1008	260	6+	2.0	1.0/36/10	4.6	31-	27	E	βf l		

* Detected at ground level. ** Probable Type IV

TABLE 4

SUNSPOT DATA

FOR THE 5 DAYS BEFORE THE PCA FLARE

			Sunspot Group		Zurich Class Magnetic Class Field Strength						Sunspot Area Umbra, Whole Spot						Sunspot Position		
	PCA Date	Plage	Mt. W.	Gr.	0	-1	-2	-3	-4	-5	0	-1	-2	-3	-4	-5	L	B	CMP
	1956																		
*1.	2-23	3400	11462	17351	— — —	E — —	E (γ) —	E γ 13	F γ —	F (γ) —	114 794	155 1072	139 1113	203 1393	175 1058	264 1438	183.0	N21.6	2/17.29
2.	3-10	3431	11514	17389	A	A	Zurich shows Spot 9-17, Greenwich 14-17 Mt. Wilson 13-18, Tokyo 15-17										186.8	N17.1	3/15.33
*3.	8-31	3643	11777	17597	E (γ) —	E γ 22	E γ 20	E γ 15	E (γ) —	(b) — (x)	97 837	81 908	100 918	97 872	73 673	22 171	94.4	N18.3	9/01.71
4.	11-13	3753	11958	17723	G βγ 16	E (β) —	E (βγ) —	E βγ 15	E (β) —	E (β) —	46 338	60 627	105 607	123 768	131 814	143 785	222.7	N16.6	11/12.85
	1957																		
5.	1-20	3820	12085	17829	H — —	H (βp) —	H βp 15	H αp 17	H αp 26	H (αp) —	123 557	77 522	91 490	94 636	101 511	81 410	61.0	S27	1/18.77
6.	4-03	3907	12235	17935	E (β) —	E βp 15	D (β) —	A x —	B β 2	A αp 2	110 682	112 708	101 470	2 17	— —	1 6	219.0	S15	3/29.79
7.	6-19	4024	12415	18071	J αp 27	J αp 25	J (αp) —	J αp 14	ℓ (αp) —		171 931	175 1004	171 948	167 1062	24 244	EL	186.0	N16	6/21.96
8.	6-22				J αp 20	J αp 20	J αp 20	J αp 27	J αp 25	J (αp) —	167 816	153 769	156 936	171 931	175 1004	171 948			
9.	7-03	4039	12434	18084	H γ 18	H (x) —	G (x) —	G βp 34	G (αp) —	G αp 32	108 500	121 600	102 595	89 606	97 546	83 442	76.0	N11	6/30.23
10.	7-24	4070	12496	18122	E βγ 19	E βγ 23	G βγ 29	G βp 28	G βp 26	G βp 26	81 504	111 568	90 443	80 397	60 388	85 386	139.0	S23	6/22.71
11.	8-09	4099	12543	18159	ℓJ	East Limb					15 121 E75	Mean Area	(14 71	E75 - W60)			190.0	S10	8/14.89
12.	8-28	4125	12579	18181	E γ 18	E (γ) —	E γ 18	D (x) —	ℓ — —		95 774	127 654	93 585	85 629 E74	EL		335.0	S29	8/31.33
13. 14.	8-29				$\boxed{E\ \gamma\ 21}$	$\boxed{E\ \gamma\ 18}$	E (γ) —	E γ 18	D (x) —	ℓ — —	171 807	95 774	127 654	93 585	85 629 E74	EL —			
15.	8-31	4124	12580	18192	E βγ 24	E βγ 24	E βγ 24	E βγ 22	E (βγ) —	E βγ 16	227 1317	294 1726	383 1726	264 1450	244 1342	93 585	329.0	N25	8/31.83
16.	9-02	4125			G α 24	G (α) —	G α 25	G γ 22	E γ 21	E γ 18	101 626	103 681	113 682	113 629	171 807	95 774	335.0	S29	8/31.33
17.	9-12	4134	12596	18194	E (βγ) —	$\boxed{E\ \beta\gamma\ 22}$	E (βγ) —	E βγ 25	E βγ 26	E βγ 20	132 701	112 664	121 872	159 967	183 1102	181 1327	194.0	N11	9/11.01
18.	9-18	4151	12622	18209	F βγ 35	E (βγ) —	E βp 26	E βp 24	C βp 15	B βp 10	376 1998	244 1482	228 1327	203 1034	86 476	16 75 E75	85.0	N23	9/19.30
19.	9-21	4152	12634	18216	E βγ 26	B β 11	A(b) — —				136 491	12 49	Mean Area	(91 519	E14 - W85)		60.0	N10	9/21.21
20.	9-26	4159	12636	18223	C αp 25	J αp 24	J αp 27	C βp 25	J βp 23	J αp 12	49 232	48 249	43 251	47 264	50 246	39 220	338.0	N20	9/27.42
21.	10-20	4189	12689	18262	F — —	F βf 27	F βf 27	F βf 24	F βf 29	F (βf) —	399 2373	330 2074	397 2239	332 2304	454 2480	431 2344	70.0	S24	10/17.70
	1958																		
22.	2-10	4400	12997	18496	D (x) —	$\boxed{D\ (\beta p)\ —}$	E — —	E βp 17	E (βp) —	E βp —	93 633	103 690	81 633	119 630	92 672	128 789	44.0	S13	2/05.99
23.	3-23	4476	13103	18584	E βp	ℓ (β) —					192 1374	175 879	Mean Area	(184 1269	E81 - W83)		92.0	S13	3/28.96
24.	3-25				E βγ 20	E βp —	ℓ (β) —				268 1539	220 1311	192 1374	175 879	E.L.				
25.	6-06	4578	13275	18715	ℓ (β) —	D (β) —	E (β) —	E (β) —	E (β) —	E 15	16 134	62 436	89 764	102 686	114 728	96 583	341.0	N28	5/30.85
26.	7-07	4634	13356	18773	E βf 18	E (βf) —	D βf 20	A β —	A(b) —	(b) (x) —	136 686	96 689	56 510	36 196	5 19	3 15 W66	201.0	N27	6/07.62
27.	7-29	4659	13388	18796	F (βγ) —	F βγ 16	F βγ 16	E βp 16	E βp 15	D (β) —	97 568	108 489	79 375	67 290	50 235	44 237	315.0	S15	7/26.25
28.	8-16	4686	13434	18835	G βγ 31	G (βp) —	G βγ 34	G (βγ)	G βγ 32	G βγ 34	208 935	175 1022	197 1150	138 836	154 880	144 899	88.0	S13	8/12.38
29.	8-21	4708	13464	18857	E βγ 24	E (βγ) —	E βγ 23	E βγ 18	E βγ 17	D βp 13	203 1463	189 1381	149 1236	169 1134	110 910	136 945	322.0	N18	8/21.89
30.	8-22				E βγ 24	E βγ 24	E (βγ) —	E βγ 23	E βγ 18	E βγ 17	112 1192	203 1463	189 1381	149 1236	169 1134	110 910			
31.	8-26				E (βp) —	E βp 16	E βγ 21	E βγ 20	E βγ 24	E βγ 24	116 776	130 751	87 1010	123 1128	112 1192	203 1463			

TABLE 4

SUNSPOT DATA (continued)

	PCA Date	Flare	Sunspot Group Mt. W.	Sunspot Group Gr.	Zurich Class, Magnetic Class, Field Strength 0	-1	-2	-3	-4	-5	Sunspot Area Umbra, Whole Spot 0	-1	-2	-3	-4	-5	Sunspot Position L	φ	CMP
32.	9-22	4765	13544	18912	E βp 30	E βp 32	E βp 30	E βp 33	E βp 33	H βp —	209 1087	210 1200	200 1137	211 1268	262 1705	270 1775	303.0	S18	9/19.59
	1959																		
33.	2-13	5009	13929	19183	E βp —	$\boxed{\text{E (βp) —}}$	H — —	H (βp) —	ℓ (αp) —		Max. Area 1064, 2/15 Mean Area 142, 866						137.0	N08	2/15.82
34.	5-10	5148	14121	{19335 19336}	E (βγ) —	E (βγ) —	ℓ (βγ) —				Max. Area 806, 5/09; 1552, 5/11 Mean Area 76, 563; 136, 947						60 53	N15 N19	5/14.52 5/15.07
35.	7-10				H (γ)	H (γ)	ℓ (γ)												
36.	7-14	5265	14284	19448	H γ —	H γ —	H γ 21	H (γ) —	H (γ) —	H (γ) —	Max. Area 1981, 7/17 Mean Area 274, 1412						330	N16	7/14.66
*37.	7-16				H (γ) —	H (γ) —	H (γ) —	H (γ) —	H γ 21	H (γ) —									
38.	8-16	5323	14356	19498	E (γ) —	E (γ) —	E γ —	E (β) —	E (βp) —	E (βp) —	Max. Area 1119, 8/18 Mean Area 123, 745						266	N13	8/16.16
	1960																		
39.	3-29				E (β) —	H (βf) —	J βf 14	A (β) —	d — —										
40.	3-30				E βγ 29	E (β) —	H (βγ) —	J βf 14	A β —	d — —									
41.	4-01	5615	14778		F (βγ) —	F (βγ) —	E βγ 29	E (β) —	H (β) —	J βf 14	Max. Area 1650, 3/30						30	N12	3/31.5
42.	4-05				F (γ) —	F γ —	F (γ) —	F γ —	F (βγ) —	F (βγ) —									
43.	4-28	5645	14815		D βp —	J — —	J βp —	J βp 17	J (α) —	ℓ — —	Area Not Available						96	S06	4/30.4
44.	4-29	5642	14814		H (γ) —	H (γ) —	H — —	H (γ) —	H γ 23	H γ —	Max. Area 850, 4/22						133	N10	4/27.5
* 45.	5-04				ℓ — —	J — —	H (α) —	H α —	H (α) —	H γ —									
46.	5-06	5653	14823		G (βp) —	G βp 22	G — —	H — —	H (αp) —	H αp —	Not Available						7	S08	5/06.9
47.	5-13	5654	14825		F γ —	F (γ) —	F (γ) —	E βγ —	E βγ —	D (βγ) —	Max. Area 1800, 5/12						353	N28	5/08.2
* 48.	9-03	5838	15015		East Limb Spot Mean Values				{H ℓ γ ℓ}		Max. Area 800, 9/04						152	N19	9/09.3
* 49.	11-12				F — —	F βγ —	F βγ —	F (βγ) —	F βγ —	F (βγ) —									
* 50.	11-15	5925	15114		F βγ 25	F — —	F βγ —	F — —	F βγ —	F βγ —	Max. Area 1775, 11/14						28	N27	11/12.2
* 51.	11-21				30° Beyond W.L.														
	1961																		
52.	7-11				E βγ 26	H βγ 26	H βγ 27	d (x) —											
53.	7-12				E (βγ) —	E βγ 26	H βγ 26	H βγ 27	d (x) —										
*54.	7-18	6171	15353		E (βγ) —	E (βγ) —	E (βγ) —	E βγ 25	E (βγ) —	E βγ 28	Max. Area 1400, 7/11						48	S06	7/14.2
55.	7-20				ℓ (x) —	E βγ —	E (βγ) —	E (βγ) —	E (βγ) —	E βγ 25									
56.	9-10	6212	15411		ℓ — —	E (βp) —	E (βp) —	F βp —	F (β) —	F (β) —	Max. Area 1350, 8/31						76	N14	9/04.4
57.	9-28	6235	15435		C (βf)	C (x)	C (x)	J (x)	ℓ —		Area Not Available						87	N11	9/30.7
	1963																		
58.	9-20				E (γ) —	E — —	E — —	E — —	— (βf) —	H (βf) —									
59.	9-26	6964	15768		— ℓ —	— βγ —	E βγ —	E βγ —	E βγ —	— βγ —	Max. Area 1400, 9/15 Daily Areas not Available						309	N13	9/20.6

* Ground level effects

TABLE 5

PCA FLARE - PLAGE DATA

PCA		PLAGE						FLARE ACTIVITY						LIFE HISTORY	
				Position		Av. Max.	Brightness	Flare			Flares		First	Age	
No.	Day	No.	CMP	L		Area	E/C/W	Day	Imp.	CMD	Before	After	Flare	Rotat.	Plage Numbers Previous Rotations
	1956														
1.	2-23	3400	2/17	187	N20	16000	3/4/3.5	23	3	W80	28/3	0/0	E90/3	2	3379
2.	3-10	3431	3/16	178	N22	3500		10	2	E88	0/0	21/1	E88/2	2	Part of 3400
3.	8-31	3643	9/02	91	N16	10000	3.5/3.5/2.5	31	3	E15	21/0	6/0	E90/2-	3	3598 - 3565
4.	11-13	3753	11/13	221	N16	4000	3.5/3.5/3	13	2	W10	20/0	0/0	E90/2	2	3709
	1957														
5.	1-20	3820	1/19	58	S28	9000	3/3/2	20	3	W18	16/1	14/2	E70/3	3, 6	{3794 - 3767 {3797 - {3770 {3772} -3729 - {3686 {3689 - {3641 {3642
6.	4-03	3907	3/30.5	209	S13	5200	3/3.5/x	03	3	W60	12/0	12/0	E40/1	6	3872 - 3838 - 3813 - 3788 - {3755 {3757
7.	6-19	4024	6/22.5	179	N18	9000	3.5/3.5/3.5	19	2	E45	5/0	27/2	E57/1	2	{3989 {3991 (In position of 3958)
8.	6-22							22	2	E12	8/1	23/2			
9.	7-03	4039	6/30.0	79	N12	6000	4/4/3	7/03	3+	W40	42/3	0/0	E75/1	2	4001
10.	7-24	4070	7/22.0	148	S21	7000	2/3/2	24	3	W27	28/1	10/1	E58/1	3	4030 - 3993 (In position 3962)
11.	8-09	4099						09	2	E76	1/0	8/0	E90/1	2	{4066 {4072
12.	8-28							28	3	E35	17/0	32/5			
13.	8-29	4125	8/30.0	353	S27	8000	3.5/3.5/3.5	28	2+	E30	18/1	31/4	E87/1	3	4082 - 4044
14.	8-29							29	2	E20	21/2	28/3			
16.	9-02							02	2+	W36	40/5	9/0			
15.	8-31	4124	8/31.5	333	N22	21000	3.5/4/3.5	31	3	W02	42/0	68/0	E90/1	3	{4083 - 4057 {4084 - 4048 {4095 {4096
17.	9-12	4134	9/10.0	207	N12	9000	3.5/3.5/3.5	11	3	W02	20/2	15/2	E87/1	2, 6	{4098 - Part of 4065 {4023-3987-3966 {4024-{3989 {3991 {4028-4000 {4029-Part of 3991 {4100
18.	9-18	4151	9/19	89	N19	7800	3.5/4/3	18	3+	E08	30/3	39/2	E90	3, 5	4112 - {4075 - 4039 - 4001 {4078
19.	9-21	4152	9/20.5	69	N11	6000	3.5/4/3.5	21	3	W06	35/0	21/0	E73/2	2	4114
20.	9-26	4159	9/28.0		N20	19000	3.5/3/3.5	26	3	E15	16/0	45/1	E90/1	3, 4	4124 - {4083 - 4057 {4084 - 4048 {4095 {4096
21.	10-20	4189	10/17.5	73	S25	18000	3.5/3.5/3.5	20	3+	W45	58/3	23/2	E90/1	2	4155 (In position 4120)
	1958														
22.	2-10	4400	2/08.3	24	S12	25000	3.5/3.5/4	09	2+	W14	36/0	4/0	E70/1+	2, 3, 4	{4355 {4356 {4360 - 4313 {4362 - 4310 - 4245
23.	3-23	4476	3/28.5	98	S12	15000	3.5/3.5/3.5	23	3+	E78	5/0	81/4	E90/1	2	4442
24.	3-25							25	2	E50	15/1	71/4			
25.	6-06	4578	5/30	352	N24	8000	2.5/3/3.5	06	2	W78	42/2	1/0	E90/1	4, 6	4529 - {4484 - 4444 {4485 - 4446 - 4405 - 4359
26.	7-07	4634	7/07.5	203	N28	9000	2.5/3/3	07	3+	W08	6/0	16/0	E90/1	2	4596
27.	7-29	4659	7/26.5	311	S19	20000	3/3.5/3	29	3	W44	82/0	30/0	E89/1	3	4622-4581
28.	8-16	4686	8/12.5	86	S13	11000	3/3.5/3.5	16	3+	W50	59/1	12/0	E90/1	2	4653
29.	8-21							21	2+	E17	14/0	42/3			
30.	8-22	4708	8/22	321	N18	8000	4/3.5/3.5	22	3	W10	29/1	27/2	E87/1	3	4657 - 4623
31.	8-26							26	3	W54	47/3	9/0			
32.	9-22	4765	9/19.5	305	S18	17000	3.5/3.5/3.5	22	2	W42	52/1	3/0	E67/1	2, 5	{4712 {Part of 4710 - 4659 - 4622 - 4581

TABLE 5 (continued)

FCA FLARE - PLAGE DATA

FCA No.	FCA Day	Plage No.	Plage CMP	Plage Position L	Plage Position	Plage Av. Max. Area	Plage Brightness E/C/W	Flare Activity: Flare Day	Flare Imp.	CMD	Flares Before	Flares After	First Flare	Life History: Age Rotat.	Plage Numbers Previous Rotations
	1959														
33.	2-13	5009	2/16	134	N12	4000	3/3/3	12	3	E48	30/1	14/0	E90/2	1, 4	Mostly new; Part of 4969 - 4932 - (4901, 4902, 4892)
34.	5-10	5148	5/15	53	N14	14000	3.5/3.5/3	10	3+	E47	34/2	56/3	E80/1	.2, 10	5100; 5095 - 5058 - 5018 - 4976 - 4936 - 4744 - 4805 - 4854
35.	7-10							10	3+	E60	14/0	76/4			
36.	7-14	5265	7/14	339	N16	12000	3/3.5/3.5	14	3+	E04	34/3	56/2	E90/1	2, 5	5218; 5204 - 5175 - 5105 - 5070
37.	7-16							16	3+	W30	61/5	29/0			
38.	8-18	5323	8/16	263	N14	6000	3/3/3	18	3	W33	34/0	13/0	E90/1	5	5280 - 5219 - (5165, 5166) - 5120
	1960														
39.	3-29							29	2+	E30	5/0	63/1			
40.	3-30	5615	3/31.5	130	N11	3000	3.5/3.5/3	30	2	E13	16/1	52/1	E45/1	2	5594
41.	4-01							01	3	W11	28/1	40/0			
42.	4-05							05	2	W62	53/2	15/0			
43.	4-28	5645	4/30.5	94	S08	4500	3/3/2.5	28	3	E34	2/0	2/0	E79/1	2	5618
44.	4-29	5642	4/27.5	134	N27	4500	2.5/3/2.5	29	2+	W21	10/0	13/1	E90/1	3	5615 - 5594
45.	5-04							04	3	W90	23/1	0/0			
46.	5-06	5653	5/07	8	S07	4000	3/3/3	06	3+	E07	13/0	1/0	E90/1	2	5625
47.	5-13	5654	5/07	8	N29	2000	3/3/3.5	13	3	W67	31/0	7/0	E63/1	1	New
48.	9-03	5838, 5837	9/10	142	N24	10000	3.5/3/2.5	03	2+	E88	0/0	20/0	E88/2+	3	5794 - 5749 (5838 merged with 5837)
49.	11-12							12	3+	W04	34/2	57/2			
50.	11-15	5925	11/12	30	N24	9000	3.5/3.5/3.5	15	3	W35	52/4	39/1	E89/1	3	5894 - 5864
51.	11-21							20	2	W90	91/5	0/0			
	1961														
52.	7-11							11	3	E31	12/0	59/3			
53.	7-12	6171	7/14.5	44	S10	5600	3.5/3.5/3.5	12	3	E22	17/1	54/2	E55/1	3	6144 - 6121
54.	7-18							18	3+	W59	57/2	14/1			
55.	7-20							20	3	W90	71/3	0/0			
56.	9-10	6212	9/04.5	77	N15	6000	3.5/3.5/3.5	10	1	W90	66/0	1/0	E83/1	2	6197
57.	9-28	6235	10/01	87	N15	3600	3/3/3	28	3	E29	11/0	4/0	E90/1	3	6212 - 6197
	1962														
58.	9-20	6964	9/20.5	310	N14	4800	4/3.5/3.5	20	2	W09	65/2	17/1	E90/1	3	6931 -(Part of 6905)
59.	9-26							26	3	W78	82/2	1/0			

TABLE 6

ESTIMATED PCA EVENT PROTON FLUX

AND ASSOCIATED LOOP PROMINENCES

Serial No. Table 1	PCA			Integrated Flux	Flare				Loop Prominence * Time		
	Date	db	Δt	>30 Mev	Onset	Max	Imp.	CMD	Beg.	End	Type
	1956										
1.	2-23	13.0	0^h23^m	1.0×10^9	0334	--	3	W80	--	--	--
2.	3-10	3.5	3^h45^m	1.1×10^8	0515	--	2	E88			
3.	8-31	4.9	2^h04^m	2.5×10^7	1226	1246	3	E15			
4.	11-13	5.4	5^h30^m	--	1430	1501	2	W10			
	1957										
5.	1-20	4.1	4^h00^m	2.0×10^8	1100	1119	3	W18	1250	1320	A-1
6.	4-03	3.9	5^h05^m	--	0825	0835	3	W60			
7.	6-19	Weak	6^h06^m	--	1609	1613	2	E45			
8.	6-22	5.0	2^h27^m	--	0236	--	2	E12			
9.	7-03	9.2	1^h42^m 0^h30^m	2.0×10^7	0712 0830	0745 0840	3+ 3+	W40 W42	0830	0925	A-1
10.	7-24	2.0	3^h03^m	--	1712 1810	1737 1828	3	W27			
11.	8-09	3.1	9^h43^m 2^h30^m	1.5×10^6	0617 1330	0629 1355	2 1	E76 W77	1346 1437	1619** >2357	
12.	8-28	Weak	4^h50^m	--	0810	0955	3	E35			
13.	8-29	3.2	3^h50^m	1.2×10^8	28/2010	2024	2+	E30			
14.	8-29	8.2	3^h29^m		1031	1052	2	E20			
15.	8-31	4.9	1^h18^m	--	1257	1313	3	W02			
16.	9-02	7.2	3^h47^m	--	1313	--	2+	W36	1525** High Intensity		ADF
17.	9-12	0.5	23^h24^m		11/0236	0300	3	W02			
18.	9-18	Weak	3^h02^m 1^h42^m	--	1658 1818	1740 1840	3+	E08			
19.	9-21	5.1	3^h30^m	1.5×10^6	1330	1335	3	W06			
20.	9-26	2.0	1^h53^m	--	1907	1952	3	E15	2050**	Imp. 2	
21.	10-20	7.8	4^h23^m	5.0×10^7	1637	1642	3+	W45			
	1958										
22.	2-10	3.2	8^h52^m	1.0×10^7	9/2108	2142	2+	W14			
23.	3-23	3.2	5^h13^m	2.5×10^8	0947	1005	3+	E78	1030	2000	E, 1, 2
24.	3-25	10.0	9^h33^m	--	0557	--	2	E50			
25.	6-06	Weak	1^h12^m	--	0436	0448	2	W78			
26.	7-07	23.7	0^h20^m	2.5×10^8	0020	0110	3+	W08			
27.	7-29	1.5	1^h01^m	--	0259	0304	3	W44			
28.	8-16	>15.0	1^h28^m	4.0×10^7	0433	0440	3+	W50			
29.	8-21	3.0	13^h18^m	--	20/0042	0045	2+	E17			
30.	8-22	10.6	1^h23^m	7.0×10^7	1417	1450	3	W10	1610**		
31.	8-26	16.6	0^h55^m	1.1×10^8	0005	0027	3	W54			
32.	9-22	5.0	6^h22^m	6.0×10^6	0730	0750	2	W42			

TABLE 6 (cont.)

Serial No. Table 1	PCA			Integrated Flux >30 Mev	Flare				Loop Prominence* Time		
	Date	db	Δt		Onset	Max	Imp.	CMD	Beg.	End	Type
	1959										
33.	2-13	2.6	8^h59^m	—	12/2301	2325	3	E48			
34.	5-10	22.0	2^h05^m	9.6×10^8	2055	2140	3+	E47	2120	2232	EA, 2
35.	7-10	20.0	1^h54^m	1.0×10^9	0206	0230	3+	E60	0504	0900	A, 1
36.	7-14	23.7	1^h20^m	1.3×10^9	0325	{0349, 0527}	3+	E04	0530	0900	A, 1
37.	7-16	21.2	1^h36^m	9.1×10^8	2114	2128	3+	W30	2152	2310	A, 3
38.	8-18	3.0	0^h46^m	1.8×10^6	1014	1030	3	W33			
	1960										
39.	3-29	2.6	1^h20^m	--	0640	0710	2+	E30			
40.	3-30	5.0	5^h05^m	--	1455	1540	2	E13	1511	2040	A, 2, 3
41.	4-01	3.6	1^h17^m	5.0×10^6	0843	0859	3	W11	0937		E, 4
42.	4-05	3.1	1^h45^m	1.1×10^6	0215	0245	2	W62	0304	1617	E, 1, 2,5
43.	4-28	3.5	1^h00^m	5.0×10^6	0130	0137	3	E34			
44.	4-29	14.0	2^h53^m	9.0×10^6	0107	{0210, 0359}	2+	W21			
45.	5-04	3.4	0^h30^m	6.0×10^6	1000	1016	3	W90	1035 **	1314	
46.	5-06	16.0	1^h56^m	4.0×10^6	1404	1448	3+	E07	1540	1700	A, 2
47.	5-13	4.5	1^h01^m	4.0×10^6	0519	0532	3	W67	0546	2135	E, 1, 2,5
48.	9-03	2.7	4^h23^m	3.5×10^7	0037	0108	2+	E88	0215	1200	
49.	11-12	21.2	0^h45^m	1.3×10^9	1315	1330	3+	W04	1405	1940	A, 3
50.	11-15	20.0	2^h23^m	7.2×10^8	0207	0221	3	W35	0223	0300	E, 6
51.	11-21	3.0	{6^h05^m, 4^h46^m}	4.5×10^7	{20/1955, 20/2114}	2020, 2135	1, 2	W90, W90	20/2114**	2257	
	1961										
52.	7-11	1.3	5^h45^m	3.0×10^6	1615	{1659, 1710}	3	E31	1746	1816	E,2
53.	7-12	17.0	9^h10^m	4.0×10^7	0950	1025	3	E22	1207	1316	A, E, 1
54.	7-18	10.0	2^h10^m	3.0×10^8	0920	1005	3+	W59	1028	1200	E, 1
55.	7-20	Weak	{6^h07^m, 5^h27^m, 3^h32^m}	5.0×10^6	{1553, 1633, 1828}	{1600, 1653, 1847}	3	W90	1605 **	2330	
56.	9-12	2.9	4^h05^m	—	1555	1610	1	W90			
57.	9-28	3.3	0^h43^m	6.0×10^6	2202	2223	3	E29			
	1963										
58.	9-20	3.1	0^h46^m	—	2314	2403	2	W09	2400	2440	E, 2
59.	9-26	4.6	1^h07^m	—	0638	0717	3	W78	0742	2017	E, 1, 2

* From Bruzek, Ap. J. 140 (2) (1964), 746 ** Solar Activity Report Series; 1, 6, 19, 20

A, Seen in absorption E, Seen in emission

TABLE 7

SMALL PCA'S REPORTED BY TWO OR MORE INDEPENDENT OBSERVERS

No.	Date	PCA Beg.	Rise Time, hrs.	Duration hrs.	Abs. db.	Flare Onset	Max.	Imp.	Position	PCA Range Start Times	Original Sources	Plage	Sunspot	L	φ
	1955														
S1	1-16	1600		48	2	s,				16/1600-16/2230	B2, Be, JC	3065	11218	61	N36
	1956														
S2	4-27	2000		48		1546		1+	S14 E14	27/2000-27/2200	Be, JC	3477	11596	324	S15
	1957														
S3	2-21	1800		72-96		1605	1930	3+	N20 W30	21/1800-22/1600	Be, DLP, JC JP, S	3856	12140	10	N15
S4	4-06	0800	12	66	3.2	05/1433		1	S15 W90		B_1	3907	12235	219	S15
S5	4-12	1700				11/1722	1738	3(2+)	S23 E04	11/1300-12/1700	Be, JC, JP	3923	12254 12258	43	S22
S6	7-01	1200				f				01/ 000-01/1200	CJM, H				
S7	7-28	1500		24	Weak	1340	1402	2	S24 W83	28/1500-28/2100	H, JC, PS	4070	12496	139	S23
S8	9-22	1000				0643 *0732	 0750	1+ 2	N24 W32 N23 W38	22/1000-22/1200	H, PS	4151	12622	85	N23
S9	11-05	0030	10	46	2.6	04/0058 1058 1732	0102 1740	1 1 1	S20 W38 S24 W39 S25 W45	04/2300-05/0300	B_1, Be, DLP, H JC, PS	4207	12732	240	S24
S10	12-17	1300			Weak	0734	0737	2	N20 E41	17/0300-17/1600	H, JP, PS	4314	12855	313	N18
S11	12-28	2300		30	Weak	2229	2230	2	N25 W50	28/2300-28/2400	H, JC, PS	4321	12874	263	N22
	1958														
S12	3-11	0400			Weak	0030	0042	1	N11 E02	11/0300-11/1000	Be, JC, PS, S	4449	13076	307	N11
S13	3-14	2200				1454	1507	2	S21 W84	14/1500-14/2200	Be, CJM, JP,PS,S	4445	13063	15	S18
S14	3-31	1600				*31/0005 30/2345 31/0038 31/0025	0014 2349 0052 0031	2 1 2 2	S17 W22 S10 W31 S08 W23 N37 E59	31/NTG -31/1600	JC, JP	4476 4484	13103 13110 13110 13118	92	S13
S15	4-10	0900	9	68	4.4	f					B_1, B_2, Be, CJM JP, K, L_1, PS, RL,S				
	1959														
S16	1-26	1500				0842	0900	3	N16 W61		JC, JP	4969	13878	106	N17
S17	6-13	1330			1.5	0357	0358	1	N17 E58	13/0800-13/1330	Be, JC, K	5204	14211	330	N17
S18	9-02	0400		48	Very small ~1.5	*1923 1648 1947 02/0310	1938 1704 1953 0434	2+ 2+ 1+ 1+	N12 E60 S12 W52 N09 W15 N17 E21		B_2, NHO, C	5354 5340 5344 534C	14414	355	N12
	1960														
S19	1-11	2200		96	VS	2040	2126	3	N22 E03	11/2200-12/0700 13/1600-13/2000	B_1, G JC, S	5527	14660	101	N19
S20	9-26	0900		120	2 db	0525	0537	1+	S22 W64	25/2100-26/2300	G, JC, JP, K	5858	15043	353	S19
	1961														
S21	11-10	1500			2 db	1434	1444	1+	N19 W90	10/1500-10/1600	B_1, Ba, BO	6264	15461	5	N09
	1962														
S22	2-01	2030			1-2db	0901	0907	2	N10 W36		BO, Sat	6326	15507	298	N10
	1963														
S23	4-15	1200				1034	1125	2	S11 W06		BO, Ma	6766	15714	246	S12

* Most probable flare
f No reasonable flare or region association
s Sunspot and plage associations reasonable

TABLE 8

PCA'S REPORTED BY GREGORY ONLY DURING 1960

	PCA			Flare						Solar Active Region					
No.	Date	UT Hrs	Duration Days	Beginning	Max	Importance	Position	Delay Hours	Source Station	Plage	Region	No.	L		Plage Age
***															
G2	1-15	03	1	1334		2	S20 W68	14	HLS	5525	1422-45	14657	121	S17	New
G3	2-7	07	4	*06/1340 06/1426	1344	1 2	S13 W81 S15 W03	17.5	Scott B.	5551	1423-3	14701	196	S13	4
G4	2-15	10	4	**											
G5	2-29	16	8	*1522 0140	1546	1 2	N22 E04 S32 W56	<1	Scott B.	5586	1424-21	14738	172	N24	2, 5
G6	3-10	18	2.5	1716	1720	1	N25 E08	1	HLS	5592	1424-39	14751	41	N25	3
G7	3-17	18	3	1616	1620	1	N05 W32	1	HLS	5597	1425-1		349	N06	5
****															
G11	4-15	10	4	*0717 0950	0719 0957	1 1	N12 W17 N23 E68	2.5	HLS	5627	1426-11	14796	313	N11	New
****															
G16	5-09	08	> 3	0704	0734	3	S16 E55	1	HLS	5657	1427-11	14831	279	S09	3
****															
G18	5-17	15	2	*0418 1414	0425 1418	1+ 1-	S09 E33 N18 W08	11	HLS	5663	1427-28	14840	197	S12	3
G19	5-26	10	3	0818	0928	2+	N16 W15	2	HLS	5669	1427-40	14849	126	N13	4
G20	6-01	14	6	0824	0900	3+	N28 E39	6	HLS	5680	1428-02	14867	343	N30	2
G21	6-15	10	2	0635	0653	2	S09 E08	4	HLS	5695	1428-22	14888	199	S12	4
G22	6-25	17	> 2	1131	1215	3	N19 E04	6	HLS						
G23	6-27	23	>1	2140	2156	3	N17 W23	1.5	HLS	5713	1428-39	14908	69	N20	New
G24	6-28	19	1.5	*1214 1815	1217 1825	1 1	N21 W37 N08 E68	7	HLS						
G25	8-11	24	5	1916	1929	2+	N22 E27	5	HLS	5794	1430-13	14981	143	N20	2
G26	8-26	10	5	0847	0852	1	N17 W90	1	HLS	5802	1430-23	14989	68	N17	3
****															
***															
G29	10-3	16	10	**					HLS						
G30	10-29	12	8	1026	1030	3	N14 E25	1.3	HLS	5909	1433-19	15099	185	N12	New
G31	11-10	18	>1	1009	1023	3	N28 E28	8							
G32	11-11	04	>1	0305	0340	2	N28 E12	1	HLS	5925	1433-39	15114	28	N27	3
****															
G34	11-14	22	>1	2114	2120	1+	N35 W27	1	All						
****															
G36	11-19	12	>2	1001	1059	1	N25 W90	2	Southern						
****															
G38	12-06	05	6	5/1825	1839	3+	N26 E68	11	HLS	5959	1434-38	15151	8	N25	4

* Preferred Flare
** No Reasonable Flare Association
*** PCA's Reported by Gregory and Others:
For: G1, 28
See Table 7: G19, 20
**** For: G-8, 9, 10, 12, 13, 14, 15, 17, 27, 33, 35, 37
See Tables
1- 5 : 39, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51

TABLE 9

ANALYSIS OF PCA EVENTS DURING 1960 AND EXPLORER VII DATA

No.	Date	Hr.	Duration	db	Integrated Flux	Δt^{hr}	Flux	Δt^{hr}	Flux	Duration
S-19, G1	1-11	2200	96h	VS	--	-11.5	0.4	29	2.0	> 74.5
* (1) G2	1-15	0300	24h	VS						
(2) G3	2-07	0700	4d	VS						
G4	2-15	1000	4d							
G5	2-29	1600	8d							
G6	3-10	1800	60h							
G7	3-17	1800	72	VS		- 3.5	0	70.5	0.6	104.0
39, G8	3-29	0800	73	2.6		3.5	0.3	20.0	0.6	43.5
40	3-30	2000	> 36	5.0		11.5	0	26.0	0.7	27.5
(3) 41, G9	4-01	1000	73	3.6	$5x10^6$	- 1.5	-0.5			
						- 0.5	+1.6	1.0	220±30	47.0
42, G10	4-05	0400	55	3.1	$1.1x10^6$	3.0	0.7	5.0	> 5.4	
(4) G11	4-15	1000	96	VS						
43,G12	4-28	0230	30	3.5	$5x10^6$	1.0	0.7	16.0	> 33.0	39.5
(5) 44, G13	4-29	0400	114	14.0	$7x10^6$	~15.0	10.0	3.5	17.0	< 23.0
(6) 45	5-04	1030	8	3.4	$6x10^6$	5.0	3.7	3.5	> 41	~10.0
(7) 46	5-06	1600	103	11.0	$4x10^6$	< - 1.5	4.3	< 4.0	14	11.0
(8) G16	5-09	0800	72	VS						
47, G17	5-13	0620	65	4.5	$4x10^6$	7.0	2.3	1.5	51	29.5
(9) G18	5-17	1500	48	VS		1.0	0	21.0	1.5	70.0
(10) G19	5-26	1000	72	VS		0	1.3	0	1.3	26.0
(11) G20	6-01	1400	144	VS		< - 3.5	0.6	1.5	5.0	51.0
(12) G21	6-15	1000	48	VS						
G22	6-25	1700	> 48	VS						
G23	6-27	2300	> 24	VS						
G24	6-28	1900	36	VS						
(13) G25	8-11	2400	120	VS		< 12.5	> 2.0	0	> 2.0	> 95.5
(14) G26	8-26	1000	120	VS						
(15) 48, G27	9-03	0500	89	2.7	$3.5x10^7$	< 8.5	141±14	2.5	255±29	> 143.5
(16) S20, G28	9-26	0900	120	2.0						
(17) G29	10-3	1600	240							
G30	10-29	1200	172							
(18) G31	11-10	1800	> 1							
G32	11-11	0400	> 1							

* ( ) See Notes, Appendix 2

TABLE 10A

IMPORTANCE 3+ FLARES FOLLOWED

BY MAJOR PCA EVENTS

			FLARE DATA				SUNSPOT			SWF	RADIO EMISSION		PCA		Integ.	Table 1
Serial	Date	Flare CMD	Area	Ave. Bright	Total Flares	Age Rot.	Mag. Class	Zurich Class	L.	Dur. Min./Imp.	Dur. Obs#/Flux/Min.	Spectral	Δt hr.	db	Flux/cm² >30 Mev	Serial No.
	1957															
1.	7-03	W40	6000	4.0	43	2	1γp1	E	76	44/3	Nag/(736)/25 Ned/585/31 Gor/285/30	IV	1.5	9.2	1.0×10^7	9
2.	10-20	W45	18000	3.5	92	2	1βp1	F	70	156/3+	Ott/(4000)/51	II, IV	4.5	7.8	5.0×10^7	21
	1958															
3.	3-23	E78	15000	3.5	90	2	1βf1	E	92	196/3	Ned/>1340/>110 Jod/>1190/10	IV	5.0	3.2	2.9×10^8	23
4.	7-07	W08	9000	3.0	23	2	4βp1	E	201	125/3	Tok/3770/100 Nag/(990)/10 Nag/(1700)/30 Ott/(875)/8.5	II, IV	0.5	23.7	2.5×10^8	26
5.	8-16	W50	11000	3.5	72	2	1βf1	G	88	168/3+	Tok/5030/70 Nag/(5800)/60	(IV)	1.5	>15.0	4.0×10^7	28
	1959															
6.	5-10	E47	14000	3.5	97	2, 10	1βf1	E	60	560/3+	Ott/(2500)/160	II, IV	2.0	22.0	9.6×10^8	34
7.	7-10	E63								190/3+	Nag/(6300)/38	II, (IV)	2.0	20.0	1.0×10^9	35
8.	7-14	E04	12000	3.5	96	2, 5	1γ1	E	330	180/3+	Nag/(6000)/100	II, IV	1.5	23.7	1.3×10^9	36
9.	7-16	W31								177/3+	Ott/(6500)/180 Nag/(1500)/60	IV	1.0	21.2	9.1×10^8	37
	1960															
10.	5-06	E07	4000	3.0	14	2	2γp1	G	7	151/3	Ned/>620/28 Ott/695/90	II, IV	2.0	16.0	4.0×10^6	46
11.	11-12	W04	9000	3.5	98	3	1βf1	F	28	154/3+	Ott/5500/340	IV	1.0	21.2	1.3×10^9	49
	1961															
12.	7-18	W59	5600	3.5	79	3	4βf1	E	48	113/3	Ned/2400/65	(IV)	2.0	10.2	3.0×10^8	54

TABLE 10B

IMPORTANCE 3+ FLARES FOLLOWED

BY SMALL PCA EVENTS

Serial	Date	Flare CMD	Area	Ave. Bright	Total Flares	Age Rot.	Mag. Class	Zurich Class	L.	Dur. Min./Imp.	Dur. Obs#/Flux/Min.	Spectral	Δt hr.	db	Integ. Flux/cm² >30 Mev	Table 1 Serial No.
	1957															
1.	*2-21	W30	2800	2.5	4	4	4βp1		10	--	Ott/19/240	II	2.0	Weak		7/53 **
2.	9-18	E08	7800	3.5	83	5	4βf1	F	85	43/3+	Ott/(275)/40	IV	3.0	Weak		1/18
	1960															
3.	***6-01	E46	7000	3.0	34	2	1β1		343	75/3	Ned/3400/60	(IV)	6.0	V. small	4×10^5	8/020
4.	12-05	E68	6500	3.0	13	4	1βf1	C	17	100/3	Ott/330/27	II, IV	11.0	V. small		8/038

* Flare Reported by Sacramento Peak only

** Table/Serial No.

*** An important PCA would be expected

TABLE 10C

IMPORTANCE 3+ FLARES NOT FOLLOWED

BY A PCA EVENT

Serial	Date	Flare CMD	Area	Ave. Bright	Total Flares	Age Rot.	Mag. Class	Zurich Class	L.	Dur. Min./Imp.	Dur. Obs#/Flux/Min.	Spectral	PCA	Table 1 Serial No.
	1956													
1.	11-07	E32	4000	3.5	21	New	1γp1	E	264	21/2		(IV)	No PCA expected	
	1957													
2.	*1-23	W17	16000	3.5	37	3	4γp1	E	18	None	None reported		No PCA expected.	
3.	*1-31	E05	8500	3.0	3	2	4γp1	C	257	84/1	Tok/234/>120	II	No PCA expected.	
4.	*11-29	E63	1000	1.5	1	2	No spot			None	None reported	II	No PCA expected.	
	1959													
5.	4-05	W67	6000	3.5	46	5	1βf1	D	273	93/3+	Nag/(2300)/8		A PCA might be expected.	
6.	6-18	W12	9000	3.5	69	4	1γ1	G	330	22/2+	Ott/(1225)/180	(IV)	A PCA would be expected.	

* Flare reported by Sydney only

#		
Ott	Ottawa	2800 Mc/s
Ned	Nederhorst	2980
Gor	Gorky	3000
Jod	Jodrell Bank	3000
Tok	Tokyo	3000
Nag	Nagoya	3750

TABLE 11

FLARES WITH IMPORTANCE 3+ BY AT LEAST ONE OBSERVATORY,

REDUCED TO IMPORTANCE 3 IN THE McMATH-HULBERT WORKING LISTS

					PLAGE DATA				SUNSPOT				RADIO EMISSIONS*		PCA			
No.	Date	Flare CMD	Plage Region	No.rep/ No.3+	Area	Ave.Max. Bright	Total Flares	Age	Mag. Class.	Zur. Class.	L	SWF	Min. Obs/Flux/Dur.	Spectral	Δt	db	Integrated Flux	Serial No.
	1956																	
1.	8-31	E15	3643	11/1	10000	3.5	30	3	1γ1	E	94	81/3	Ott/(340)/39	(IV)	2.0	4.9	2.5x10^{7}	3
	1957																	
2.	1-06	E40	3813	6/1	19000	3.5	27	3	1βp1	H	183							
3.	8-28	E33	4125	11/2	8000	3.5	61	3	1γ1	E	335	138/3	Ned/1192/40	(IV)		Weak		12
4.	8-31	W02	4124	8/1	21000	3.5	110	2, 3	1βγ1	E	329	184/3+	Ott/(3900)/65	IV		4.9		15
5.	9-19	E02	4151	5/1	7800	3.5	83	5	4βγ1	F	85	54/3	Nag/(1080)/11 Tok/1410/10	IV				
6.	11-24	E37	4263	7/1	8900	3.5	38	4	1βp1	G	263	32/3-	Ned/>998/40	IV				
	1958																	
7.	1-25	W69	4372	17/1	3500	2.0	10	4, 6	4β1	E	269	74/3	HHI/358/83 Ned/278/40					
8.	3-01	W46	4436	5/1	1400	3.5	15	New	4βp1	E	146	12/2+	Ned/458/2 Ned/296/4					
9.	3-03	E60	4445	8/1	10000	3.0	45	3,4,5	1βp1	F	15	95/3+	Ned/1338/28	(IV)				
	1959																	
10.	2-12	E48	5009	2/1	4000	3.0	43	1, 4	1βp1	E	137	40/2	Nag/(440)/70	IV		2.6		33
11.	5-11	E41	5148	4/1	14000	3.5	97	2, 10	1βγ1	E	96	67/3-	Ott/(900)/200	II, IV	This is the region of very large PCA on May 10			
12.	7-14	E37	5273	14/1	4000	3.0	12	2	1γ4	D	296	105/2+	Ott/(85)/30					
13.	7-16**	W27	5265	8/1	12000	3.5	96	2, 5	1γ1	H	330	28/2-	Ott/(350)/9	II	This is in the region of the large PCA on the 10, 14, and16th			
14.	8-18	W33	5323	17/2	6000	3.0	48	4	1βγ1	E	260	120/3	HHI/621/106 Sim/720/23 Ned/985/23	(IV)		3.0	1.8x10^{6}	38
	1960																	
15.	5-09	E52	5657	7/1	4000	3.0	7	3	1α1	J	279	98/2	None reported					
16.	5-13	W67	5654	6/1	2000	3.0	38	New.	1γ1	F	353	221/3+	Nag/3750/105 Tok/2065/101	II, IV		4.5	4x10^{6}	47
17.	11-10***	E29	5985	9/1	9000	3.5	98	3	1βγ1	F	28	90/2	Ned/360/12 Ned/>600/33					
18.	11-15	W08		2/1								253/3+	Nag/11600/80	II, IV		20.0	7.2x10^{8}	50
	1961																	
19.	7-12***	E22	6171	19/4	5600	3.5	78	3	1βγ1	E	48	97/3	Ned/4100/87 Ott/45/225	(IV)		17.0	4x10^{7}	53
20.	7-15	E15	6172	8/1	5000	3.0	5	2, 3	1αp1	G	14	113/3	Ott/54/458 Ned/61/8	IV				
21.	7-20	W90	6171	3/1	5600	3.5	78	3	1βγ1	E	48	370/3+	Ott/1800/42 Ott/250/222	II, IV		Weak	5x10^{6}	55

* Ott Ottawa 2800 Mc/s
Ned Nederhorst 2980
HHI Heinrich Hertz, Simferopol, Tokyo 3000
Sim Simferopol
Tok Tokyo
Nag Nagoya 3750

** The PCA and ground level effect on July 16, 1959 is generally associated with the 3+ flare at 2114 UT N16 W32 (No. 9 Table 11A, No. 37 Table 1). These events probably should be considered in the combined effect of the importance 3 flare at 1525 (No. 13, Table 10) and the 3+ flare at 2114.

*** Flares Numbers 17 and 18 are from same region; Plage 5985.
Flares 19 and 21 are from the same region; Plage 6171.

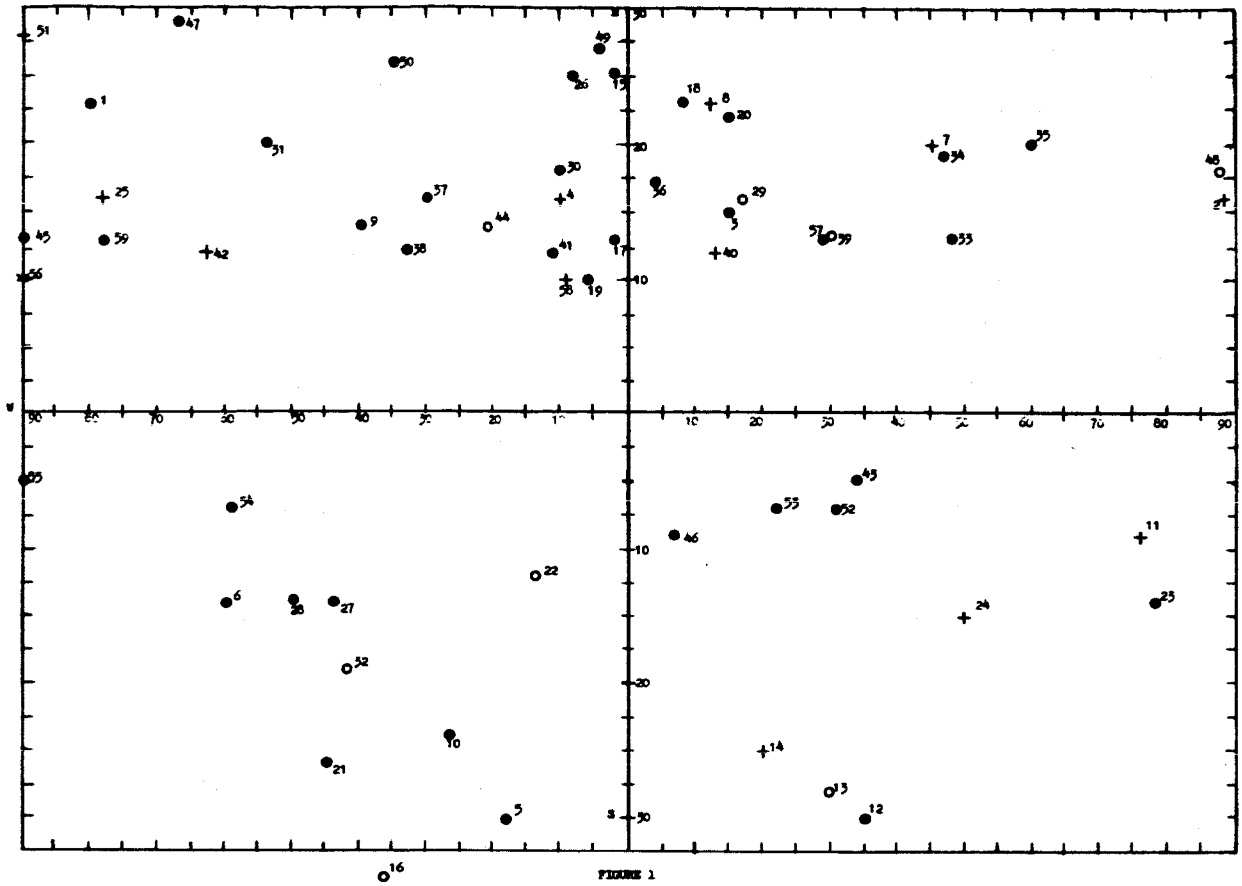


FIGURE 1

HELIOGRAPHIC POSITION OF PCA FLARES

3+, 3, 2+, 2, ≤1

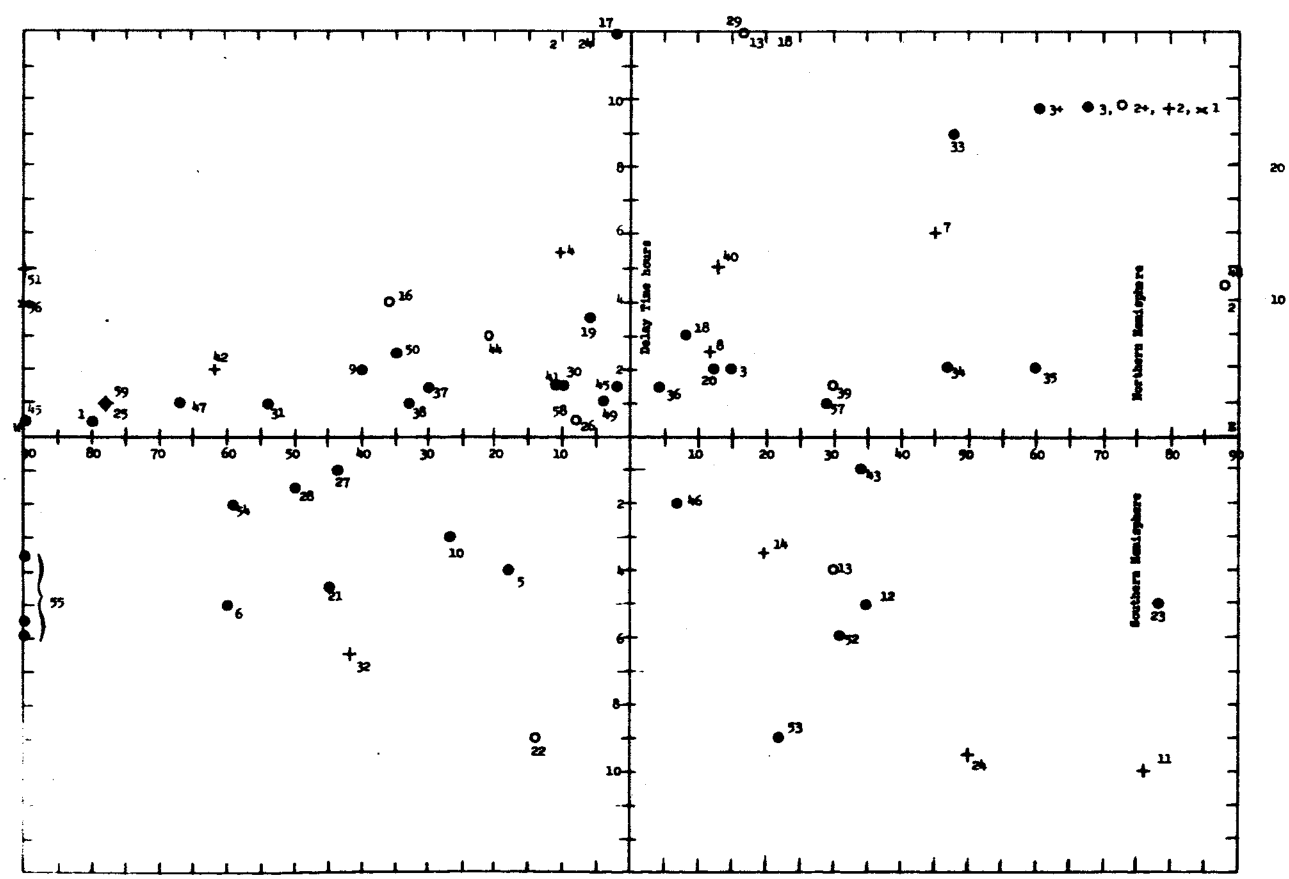


FIGURE 2

FLARE TO PCA TIME DELAY AS A FUNCTION

OF THE FLARE CENTRAL MERIDIAN DISTANCE

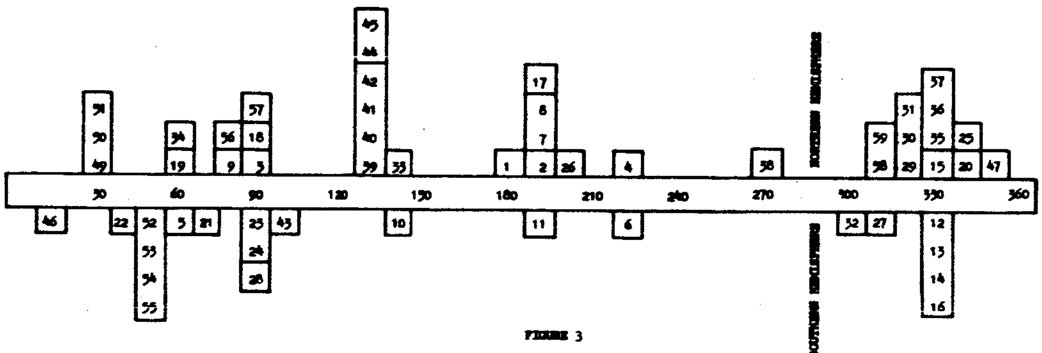


FIGURE 3

HELIOGRAPHIC LONGITUDE DISTRIBUTION

OF PCA FLARE SUNSPOTS

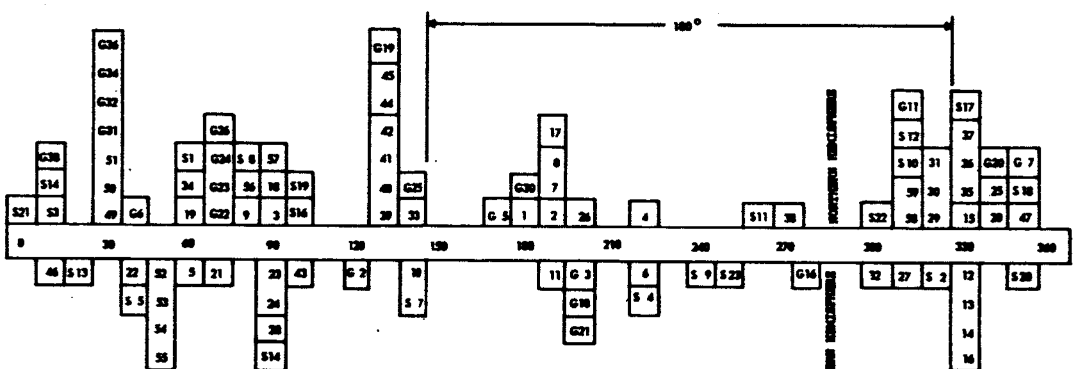


FIGURE 4

SUNSPOT HELIOGRAPHIC LONGITUDE DISTRIBUTIONS

ALL PCA'S REPORTED IN THE LITERATURE

AND LISTED IN TABLES 1, 7, AND 8

FIGURE 5 SOLAR ACTIVITY DURING 1958

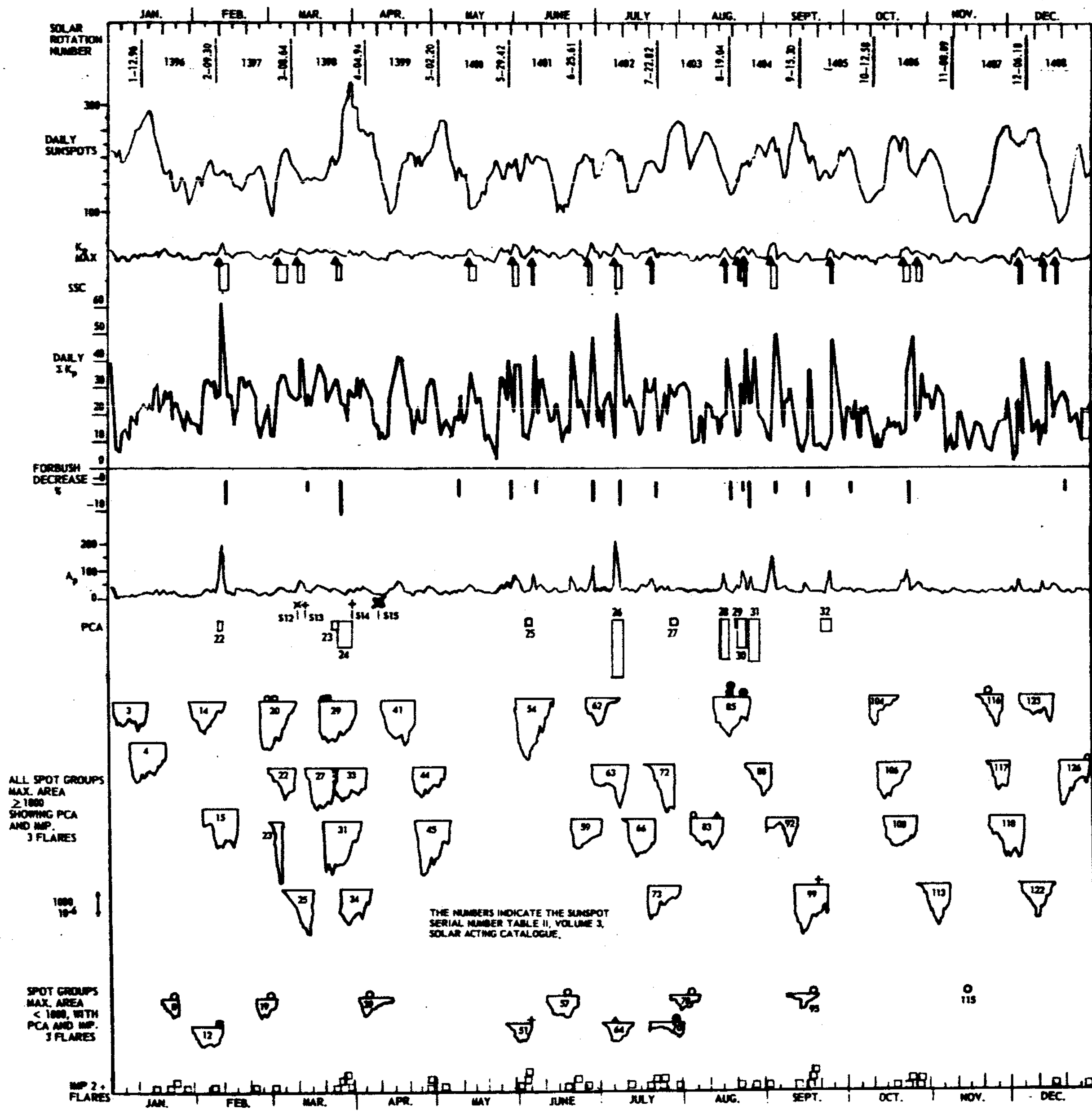


FIGURE 6A PCA NO. 11 AUG. 09, 1957 1600 UT

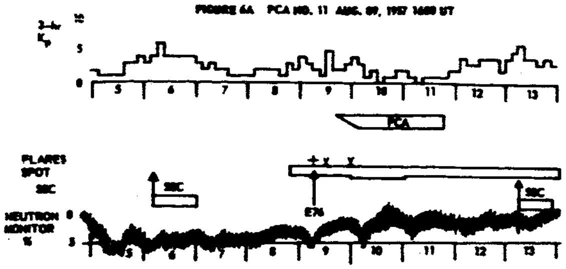


FIGURE 6C PCA NO. 26 JULY 07, 1958, 0130 UT.

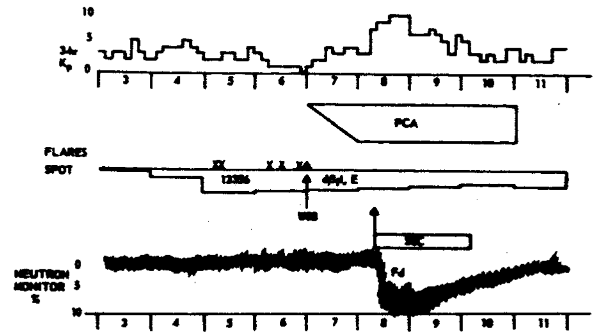


FIGURE 6B PCA NO. 4 NOV. 13, 1956, 2000 UT.

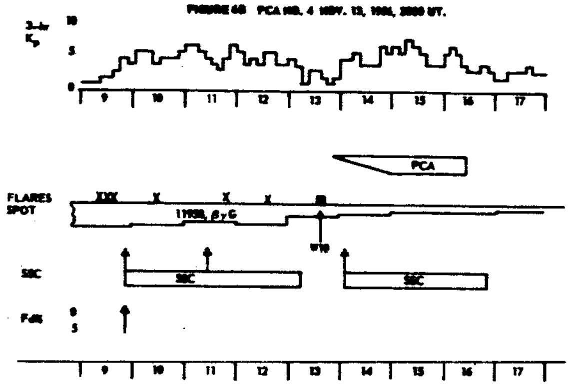


FIGURE 6D PCA NO. 22 FEB. 10, 1958, 0600 UT

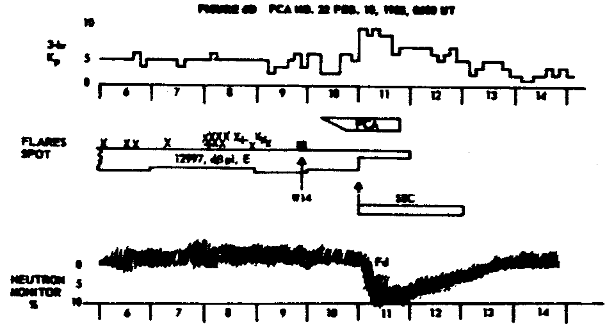


FIGURE 7A PCA'S NO. 35, 36, 37 JULY 10, 14, 16, 1959, 0400, 0445, & 2230 RESPECTIVELY

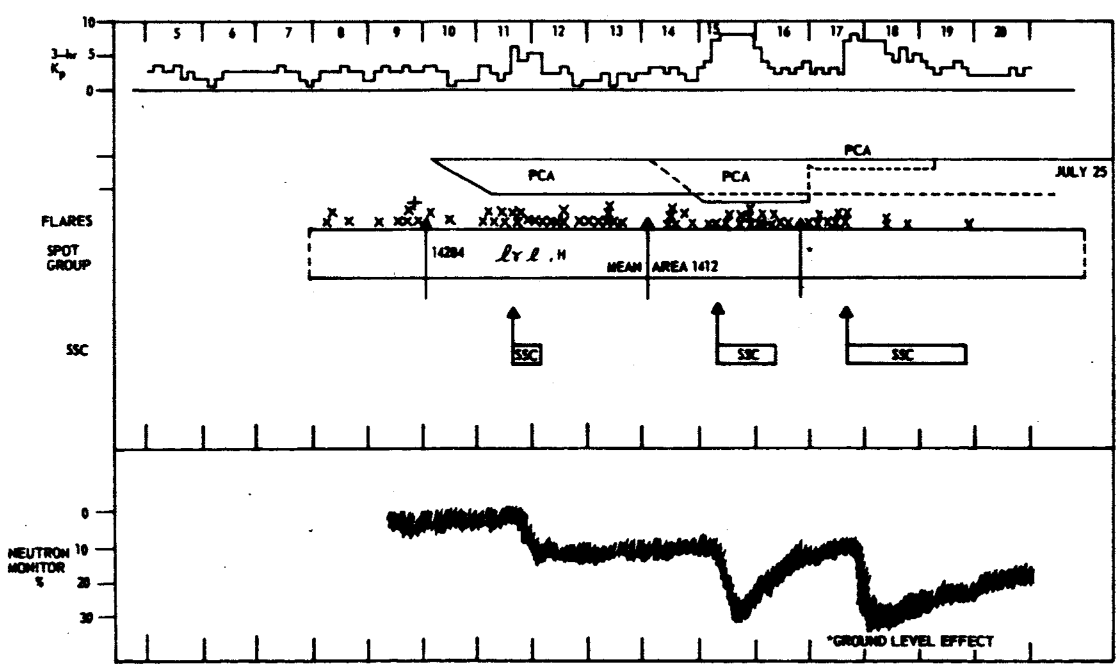


FIGURE 7B. PCA'S NOS. 29, 30, 31 – AUG. 21, 22, 26, 1958

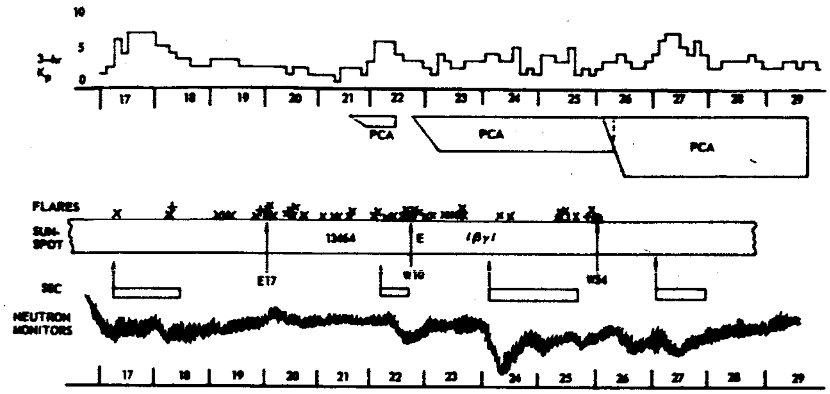


FIGURE 8A FLARE NOV. 07, 1956, 1109 UT. IMP. 3+, NO PCA, WITH LOOP PROMINENCE 1313 UT.

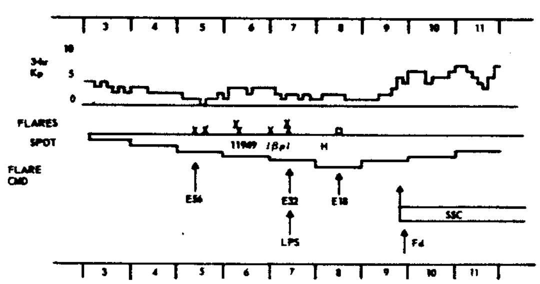


FIGURE 8C IMPORTANCE 3 FLARE MARCH 3, 1958 WITH LOOP PROMINENCE, NO PCA

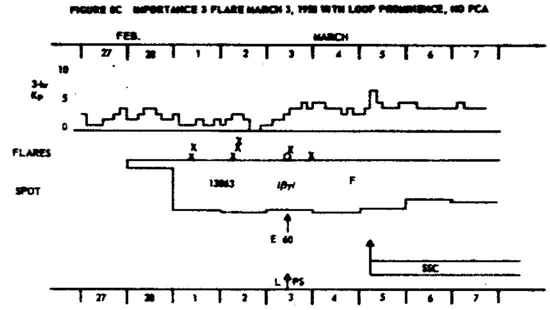


FIGURE 8B FLARE APRIL 16, 1957, 1040 UT. IMP 3, NO PCA, WITH LOOP PROMINENCE 1056 – 2404

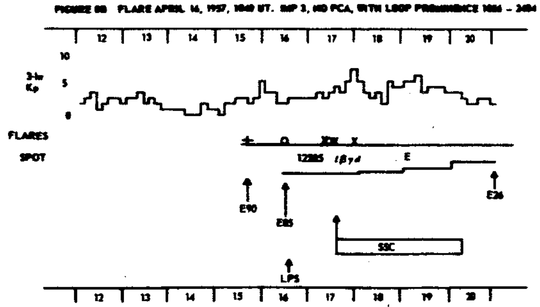
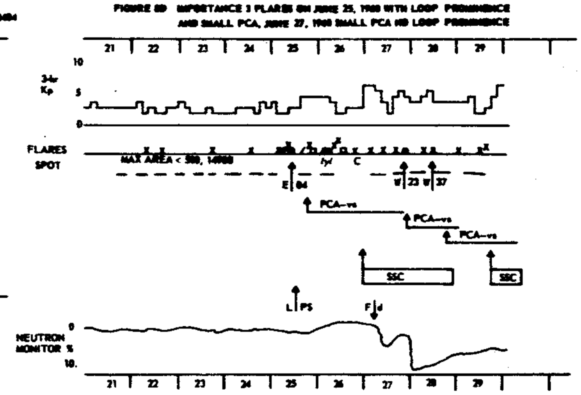


FIGURE 8D IMPORTANCE 3 FLARES ON JUNE 25, 1958 WITH LOOP PROMINENCE AND SMALL PCA, JUNE 27, 1958 SMALL PCA NO LOOP PROMINENCE



CODE USED FOR FLARES

IMPORTANCE 3+	▲	WITH PCA	▲
3	○		●
2+	□		■
2	+		+
1	x		x