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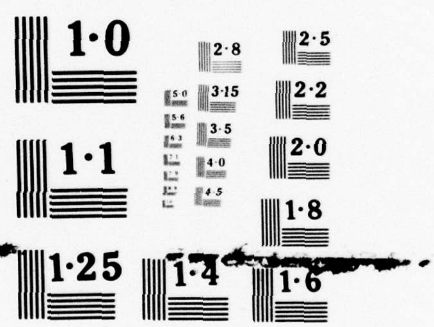

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SURVEY AND COMPARISON OF SOLAR ACTIVITY AND ENERGETIC PARTICLE EMISSION IN 1970

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Solar activity in 1970 was at a relatively high level with the number of "major" flares and important centers of activity reaching maximum numbers for all of cycle 20. Satellite data, primarily from Explorer 41, provided evidence for at least 152 distinct energetic particle enhancements during the year. These events have been compared with concurrent solar activity. All but one of the 13 particle events associated with Polar Cap Absorption

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) in 1970 have been identified with specific solar flares. For the 50 proton events with energies 19-80 or >60 MEV, 72% have reasonably sure solar or geophysical sources. Of the 59 purely low energy particle events (1-10 MEV) only 39% could be assigned probable solar associations. For the numerous low-energy particle events without confident solar associations, there were assorted time coincidences with geomagnetic storms, sector boundary passages, the development of new regions on the disk, and the central meridian passage of significant centers of activity. At the present time, the significance of these solar and geophysical phenomena for particle enhancement is not known.

Although the intervals of lowest solar activity, September and October 1970, corresponded to the times of lowest levels in observed particle enhancement, identification of the five greatest centers of activity in 1970 did not lead directly to the solar sources associated with the majority of the most energetic particle (19-80 and/or >30 MEV) enhancements at earth in that year. Strong solar magnetic fields and interplanetary circumstances apparently influenced significantly the propagation of energetic particles from sun to earth. In spite of this situation, the 23 "greatest" flares (CFI ≥11) formed a class of solar phenomena in 1970 that were associated with the onset or continuation of increased particle enhancement in the neighborhood of the earth regardless of all other circumstances.

SURVEY AND COMPARISON OF SOLAR ACTIVITY AND ENERGETIC PARTICLE EMISSION IN 1970

I. Scope of the Survey

Energetic-particle records for 1970 have been examined and distinctive particle events have been tabulated by Ms. M. A. Shea and Mr. Don Smart of AFGL. Summaries of the recognized particle events were given to Miss E. R. Hedeman, Dr. H. D. Prince and Dr. O. C. Mohler for study in conjunction with the organized solar data at the McMath-Hulbert Observatory. The particle data included times of start, maximum, and duration for each event, and information relating to levels of energy detection and multiple spacecraft response. The solar data considered in comparison to the particle data included not only flare-occurrence, but also the formation, growth and disk transit of major centers of activity and the activation of large filaments. The occurrence of geomagnetic disturbance and the passage of interplanetary sector boundaries also were included in the evaluation of the probable or possible causes of observed particle enhancements. The conventions and symbols used in the published "Catalogue of Solar Particle Events, 1955-1969" (Z. Svestka and P. Simon, editors) have been followed in the present study of 1970 particle enhancements. The symbols used for flare and other associations are given below:

- ● Flare association is certain
- ⊙ Flare association is probable
- ○ Flare association is possible
- ⊘ The flare is probably a "contributor"
- ☐ Possible flare on invisible hemisphere
- △ Time-associated with a sudden commencement or an SC storm
- ◊ A modulation effect, including geomagnetic disturbance, and CM transit of an active region.

The principal results of the study are summarized in Table 1 and its appendix. Table 1 presents information relating to all proton enhancements in 1970 with assured flare associations. It includes both particle and flare data as well as numerous remarks which relate to the dynamic radio spectrum, X-ray flux, electron data when known, and other interesting or pertinent comments. More than 150 particle enhancements in 1970 have been studied but only 67 had sufficiently confident flare associations for inclusion in this tabulation.

An appendix to Table 1 has been prepared which shows the dates of all of the remaining large proton events (19-80 or >60 MEV or with PCA).

in 1970 for which confident flare associations could not be established. Possible flare associations and other types of solar or geophysical causes are suggested. This tabulation includes 15 entries. Together, Table 1 and its appendix, account for approximately 55% of the identified energetic particle events in 1970. The remaining 45% of the events were confined to the lower particle energies and were without assured flare associations.

II. General Description of Solar Activity in 1970

The "maximum" in solar cycle 20, according to the 13-month smoothed Zurich sunspot numbers, occurred in November 1968. The year 1970 therefore began just one year and one month after "maximum," and it is not surprising that the level of solar activity at that time was still very high. Actually, monthly values for Zurich sunspot number, Area x Intensity for calcium plages, and number of flares with importance ≥ 1, all show that January-July 1970 constituted one of the intervals of highest activity in all of cycle 20. See Figure 1.

The number of flares evaluated as "major" on the basis of their ionizing, optical and radio frequency emission also reached maximum numbers in 1970. See Dodson and Hedeman 1975, and Table 2.

"Major" flare occurrence was greatest in March 1970, with June, July, and November also being flare-rich months. See Table 3 and Figures 2 and 3. There was only one flare of Hα importance 3 in 1970, the large flare on November 5 in a region with only very small spots. This flare at E35° was clearly associated with one of the most energetic and long enduring particle enhancements of the year. Of the 151 "major" flares in 1970, 23 had indices ≥ 11 indicating very great flares, again the largest number of such flares for any year in the cycle. It may be of interest that 16 of the 23 greatest flares in 1970 took place in the eastern half of the solar disk. It is possible that this circumstance introduced special propagation situations that in some instances tended to mask relationships between flare occurrence and the subsequent onset of particle enhancement.

In addition, there were more centers of activity designated as "major" in 1970 than in any other year in Cycle 20. See Table 2. A center of activity is considered to be "major" if it is judged to be significantly above average in any one of the following characteristics: flare production, ionizing radiation (SID's), size and complexity of spots, centimetric radiation, or metric radiation. An Active Region Index (ARI) has been derived for all "major" centers of activity in the following manner:

ARI = A + B + C + D + E, where

A (0-5) is based on number of flares

B (0-4) is based on number of associated SID's

C (0-3) is determined by size and magnetic complexity of spots

D (O-5) attempts to evaluate the relative magnitude of the centimetric radiation associated with the region

E (O-4) attempts to evaluate the relative magnitude of metric radiation associated with the region

There were 41 centers of activity in 1970 that were considered to be "major" and for 5 of these regions the indices were $\gtrsim 10$. See Tables 2 and 3 and the lower halves of Figures 2 and 3.

The months of September and October 1970 were times of relatively low solar activity. No "major" flares were observed between September 27 and October 21. Figure 3 shows that during this interval 1-10 MEV flux was the lowest for the year and no particle enhancement with energy as great as 19-80 or >30 MEV was observed. See Table 1.

III. General Description of the Particle Data for 1970

There are 152 particle events in the list prepared by Smart and Shea for the year 1970. In general, they cover energy ranges from 1.0-10 MEV up to 19-80 MEV or > 60 MEV. Of these events, 127 included proton enhancements observed near the earth by the Explorer 41 satellite, 23 were recorded only on other satellites, primarily Pioneers 8 and 9, and there were 2 cases of electron emission without observed proton increases. Thirteen instances of Polar Cap Absorption were reported in 1970. See Tables 1 and 3. A total of 50 proton enhancements showed increases in the 19-80, >30, or > 60 MEV ranges while 59 of the events appeared on only the lowest, 1-10 MEV record.

In 1970, the energetic particle emission from the sun, as exemplified by the low energy ~1-10 MEV flux data from Explorer 41, is a record of almost constantly changing intensity. The many distinct enhancements ranged in duration from ~ one day to more than two weeks. The sensitivity limit for the record was ~0.1 for 1-10 MEV proton flux $(cm^2 Sec\ Ster)^{-1}$. The distinct particle events in the 1-10 MEV flux constituted increases from <1 to >5 orders of magnitude. See Figures 2 and 3. There were 22 times in 1970 when the 1-10 MEV proton flux rose above the 10 unit level for a sustained interval of time. For 20 of these events there also were concomitant increases in more energetic particle fluxes.

All of the PCA events occurred during times when the 1-10 MEV record showed sustained flux greater than 10 units and more energetic particle enhancements also had been detected.

Thirty-four, or 68%, of the events with energy as great as 19-80 MEV occurred at the beginning of or during sustained 1-10 MEV enhancements >10 flux units. Accordingly, the 1-10 MEV record shown in Figures 2 and 3 appears to give reasonably trustworthy guidance to the times in 1970 when significant energetic particle enhancements were observed in the neighborhood of the earth.

In 1970 there was only one extended interval with consistently low energetic particle flux. For Carrington rotations 1565 and 1566, from ~August 27 to October 21, energetic particle emission was primarily low, and no instances of PCA or events with energy as great as 19-80 MEV were recorded. See Table 1. The intervals with the most sustained and energetic particle emissions occurred during the end of January, early and late March, early and late June, late July, mid-August, early November, and mid-December. Table 5, with its distribution of all distinctive particle enhancements in 1970 by time and by maximum detected energy, reflects these intervals.

IV. Summary for 1970

A. General Relationships in 1970 between Solar Activity and Particle Events

1. Comments on Earlier Years in the Cycle

In addition to the detailed intercomparison of individual particle enhancements with specifically time-associated flares and other solar phenomena as shown in Table 1, one can and perhaps should ask if, in general, the greatest particle enhancements were concomitant with times of the greatest observed solar activity. Conversely, one can try to evaluate the generality of energetic particle detection in the neighborhood of the earth with the occurrence of significantly above average levels of observed activity on the sun.

Unpublished, preliminary studies of this type for the years 1965-1967 indicate that when the sun was showing relatively low levels of activity, as in 1965 and 1966, there was a gratifying agreement in time between the occurrence of above average solar activity in the western hemisphere of the sun (centers of activity and flares) and the detection of enhanced proton emission in the neighborhood of the earth. Although the principal particle enhancements in these relatively quiet years were confidently associated with observed solar phenomena, there were a few well defined increases in protons and a large number of weak, low energy, short duration particle events without apparent solar associations.

The increased activity of 1967 introduced less clear cut agreement between observed solar phenomena and energetic particle enhancements in the neighborhood of the earth. In 1967, more of the great centers of activity (Active Region Indices $\gtrsim 10$) traversed the disk without leading to unusually great particle events at earth. The very strong, closed local magnetic fields represented by these regions and/or propagation difficulties of the interplanetary medium apparently inhibited the transport to earth of particles from these regions and their flares. Furthermore, the greatest particle event in 1967 apparently stemmed from a flare far on the invisible hemisphere. This work for the earlier, less active years in cycle 20 leads one to expect in 1970 only a modest degree of accord between highest levels of observed solar activity and the resultant particle enhancements at the earth. This expectation is borne out by detailed comparison of the records.

2. Comparison of Highest Levels of Solar Activity in 1970 with Observed Particle Enhancements Near Earth

a. *Great Centers of Activity*

In 1970 there were five centers of activity with Active Region Indices $\geq$10. See Table 4. For only one of these regions, McMath 10845 with CMP July 24, did its flares and the time of disk crossing result in an outstandingly great series of particle events at earth. Ten particle events have been associated with this region. This is the largest number of particle events for any center of activity in 1970. Furthermore, McMath 10845 was the only one of the five "greatest" centers of activity to produce a PCA-associated flare out of a total of 13 PCA events in 1970. Table 6 and Figures 2 and 3 summarize the particle activity associated with these five great regions. It is somewhat surprising that of the 50 most energetic particle enhancements in 1970 (i.e. $\geq$ 19-80, $>$30 MEV), only five have been confidently identified as coming from flares in these "greatest" regions. Consideration of the 41 "major" centers of activity in 1970 leads to the recognition of two additional centers with above average association with distinctive particle events. McMath 10808, (ARI = 9) with CMP July 1, had five confidently and two possibly associated events. Likewise "major" region 11002, CMP October 29 (ARI = 10), becomes one of the more particle-rich regions if, in addition to its two confidently associated particle flares, one adds five "possible" events, some of which are considered to stem from activity in this region when it was beyond the west limb.

Carrington Rotation 1567, (October 20-November 17) was the only rotation in 1970 to include the CMP of two of the centers of activity with indices $\geq$10, and it was a rotation that included one of the intervals of greatest particle enhancement and PCA in the entire year, viz November 5-14. See Figure 3. However, this outstanding particle event in November was associated, not with phenomena taking place in either of the two great regions, but with the large, isolated flare of Hα importance 3 in McMath 11019, a region with a large bright plage but only small spots and none of the usual aspects of above average activity. See Figure 3.

In 1970 recognition of the five "major" solar centers of activity with the greatest number of flares, the largest and most complex spots, and the highest levels of radio frequency emission, does not, in general, lead directly to the solar sources associated with the majority of the greatest particle enhancements at earth in that year.

b. Important Flares

Let us now consider the frequency of particle enhancements with the greatest of the observed solar flares (i.e. CFI $\geq$ 11). There were 23 "major" flares in 1970 with Comprehensive Indices as great as eleven. See UAG 52, Table 3, and Figures 2 and 3. Nineteen of these flares have been confidently associated with the observed onset of energetic particle enhancements in the neighborhood of the earth. See Table 1. The other four great flares occurred during particle enhancements. This close association between great flares and energetic particle enhancement took place even though twelve of the nineteen particle flares developed in the eastern hemisphere of the sun. One of these flares, on August 12 at 20^h15^m U.T., was directly at the east limb. It was associated with particles in all energy classes up to > 60 MEV. Apparently, if the flares are sufficiently great, even far eastern longitudes will not prevent the propagation of energetic particles to the earth. It can be said that in 1970 "major" flares with Comprehensive Indices $\geq$11 formed a class of solar phenomena that were associated with the onset or continuation of increased particle enhancement in the neighborhood of the earth regardless of all other circumstances. The magnitude of the resultant particle enhancements, however, varied markedly from flare to flare

B. Consideration of Principal Problem Particle Events or Circumstances and Atypical Solar Regions and Flares

In 1970, although there were many low energy particle enhancements without identifiable solar associations, and although numerous ambiguities remain between multiple solar flares possibly associated with certain more energetic events, there were, in truth, relatively few instances of significant particle enhancement without records of prior, above average solar flares. See Table 5. Thirty-seven, or 74%, of the 50 events with > 19 MEV enhancements have confident probable associations with specific solar or geophysical phenomena. This is the case for only 23, or 39%, of the purely low-energy 1-10 MEV enhancements. The principal "problem" particle enhancement is probably the one that began at low energies on December 23, accompanied by PCA and high energy particles on December 24. The enhancement lasted for more than a week. There were no appropriate prior flares. McMath region 11084 (ARI = 2) with numerous subflares was traversing the western hemisphere of the solar disk. Active region 11077 was on the invisible hemisphere. There was a +/- sector boundary crossing on December 23, and the geomagnetic index "Cg" became as great as 4. This geomagnetically disturbed day apparently marked the first "member" of the first well-defined series of 27-day recurrent geomagnetic storms in the post-maximum phase of solar cycle 20. Is there any relationship between these assorted phenomena and this "problem" particle enhancement of late December 1970?

From the solar point of view, there were in 1970 numerous somewhat atypical situations. It already has been pointed out (Sect. IV, A, 2) that high values of the Active Region Index did not, in general, identify the principal particle producing solar regions. The center of activity with the highest index (ARI = 14) in 1970 was region 11029 with CMP on November 14. This region produced numerous "major" flares during its western transit which were indeed time-associated with particle enhancements but only with enhancements at the lowest energy levels. See Figure 3 and Tables 1 and 6. Did the very strong closed magnetic fields, probably associated with this region and its large spot group, prove too binding for the successful propagation of the more energetic particles even from a flare with CFI of 13 at W22° on November 16? The same query probably applies to regions 10918 (CMP September 5, ARI = 8) and 11002 (CMP October 29, ARI = 10). Conversely, one can ask if the relative weakness of the magnetic fields of centers of activity with only small or no spots plays some part in permitting the escape of flare-accelerated particles from such areas. In 1970, five of the relatively rare "major" flares in such "spotless" regions (including the great event on November 5) were confidently associated with particle enhancements in the neighborhood of the earth. These isolated, "major" flares in 1970 were generally associated in time with the disappearance of neighboring filaments which, in turn, implies changes in the local magnetic fields. The occurrence of particle events at the earth apparently reflects both the magnitude of the flare-event on the sun and the ease of particle escape and propagation to the earth.

A last survey of Figures 2 and 3 leads one to ask again what led to the several "problem" increases in particle enhancement between August 3 and 9. Was it continued activity in region 10845-10882 while on the invisible hemisphere? Or did the greatest of all 1970 filament disappearances on August 5-6 play some part in these events and in the magnitude of the long enduring enhancement centered on August 15-16? An equally vexing query comes to mind as one sees on March 1, six "major" flares, some in the east and some in the west and only minor particle enhancements. Why did all of this important solar activity lead to such relatively limited particle increases at the earth?

A sector boundary had just passed the earth the day before and a moderate geomagnetic storm was in progress.

In spite of the fair degree of accord that has been found in 1970 between observed solar phenomena and energetic particle enhancements in the neighborhood of the earth, many unresolved problems remain. Progress in solving these problems probably will come only after there has been significantly improved understanding of the solar phenomena themselves and their inter-relationships, and after the role of the interplanetary medium in particle propagation has been more clearly determined. It is hoped, however, that additional survey-studies of energetic particle enhancements for other years in solar cycle 20 will provide further insight into the general problems, which may in turn lead to improved understanding of the solar causes of energetic particle emission in the neighborhood of the earth.

V. References

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"Experimental Comprehensive Solar Flare Indices for Certain Flares, 1970-1974" H. W. Dodson and E. R. Hedeman, Report UAG-52, World Data Center A for Solar Terrestrial Physics; Boulder, Colorado, 1975

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TABLE I *

PARTICLE DATA Time 1970	MEV	PCA		FLARE DATA Time	Imp.	Coord.	Plage No.	Profile	CFI	OTHER COMMENTS
Jan 3^d21^h	19-80/.0004		●	3^d1914	1n	N13W16	10508	11120	5	Is + cont.(M) + filament disappearance
Jan 5^d04^h	1-10/15.3		● {	5^d0407	1f	S14W77	10503	01010	2	II(M) Flare Ambiguous.
				5^d0415	2n	N15W45	(10506-10508)	02010	3	Second is a "spotless" flare. Major D.B./imp.2, Jan 4-5.
Jan 28^d15^h	19-80/.0031 >30/.08		●	28^d1022	1b	S16W26	10542	21000	3	+ electrons 13^h30^m UT.
			+							
			Ø	28^d1910	2b	S14W34	10542	32300	8	10cm G.B., In(M) 1-8A(X)=4900/>3hr Contributes to particle Max.28^d23^h UT
Jan 29^d13^h	>60/0.75 19-80/.042	0.8	●	29^d1022	1b	S13W41	10542	11000	2	+ EL. 12^h55^m UT Is(M), 1-8A(X)=210
			+							
			Ø	29^d2011	1n	S14W45	10542	21000	3	1-8A(X)=390 Contributes to particle max. 30^d00^h UT.
Jan 31^d16^h	>60/1.85 19-80/.170	3.0	●	31^d1515	2b	S22W63	10542	22130	8	II & IV (M,DKM) 1-8A(X)=390/6 hr.
			+							
			△	1^d1956	(GMS Effect)					SC storm begins, contributing to particle max. 1^d22^h UT.
Feb 16^d07^h	19-80/.00021 1-10/7.8		●	16^d0202	2n	S13W82	10567	02010	3	II(M) A "spotless" flare, preceded by D.B. Feb 15-16.
Mar 1^d06^h	1-10/.290		●	1^d0500	sb	N05E52	10607	10233	9	II(M) & IV (DCM,M) 1-8A(X)=470
			+							
			Ø	1^d0936	1b	N05E48	10607	31234	13	II(M) & IV (DCM) 1-8A(X)=3200/1 hr. contributes to particle max.1^d11^hUT
Mar 1^d17^h	1-10/4.7		⊙	1^d1529	1n	N05E46	10607	21233	11	II(M,DKM) & IV (DCM,M,DKM) 2-12A(X)=630
			+							
			Ø {	1^d1400	1n	N23W57	10592	21203	8	IIIg (DCM,M,DKM) } All could contribute to particle onset
				1^d1158	1n	N07E50	10607	11133	9	IV (DKM) } All could contribute to particle onset
				1^d1127	2b	N13W31	10595	12233	11	II(M) & IV (M & DKM) 1-8A(X)=940/>2.5 hr. } All could contribute to particle onset

* Explanation of table contents is found on p. 29

TABLE I (continued)

PARTICLE DATA: Time 1970	MEV	PCA		FLARE DATA: Time	Imp.	Coord.	Plage No.	Profile	CFI	OTHER COMMENTS
March 1^d23^h	>10/.14		●	1^d1955	2b	N15W37	10595	22213	10	II(M) 1-8A(X)=2200/1.5 hr.
			+	1^d2023	2b	N07E43	10607	12002	5	All could contribute to particle onset, and max. at 2^d01^h UT.
			⊘	1^d2335	1b	N07E39	10607	11122	7	Cont.(M,DKM)
				2^d0012	1b	N06E39	10607	21112	7	II(M) 1-8A(X)=340
Mar 4^d21^h	19-80/.00013 1-10/12.7		●	4^d1822	1b	N14W79	10595	11234	11	II(M) & IV(M & DKM)+ El.4^d19^h(HEOS) 1-8A(X)=390
			+ ⊘ +	5^d0407 <0430	1n 1n	S14E73 N15W87	10618 10595	31100	5	1-8A(X)=770/6 hr. - possibly contributes to particle max. at 5^d04^hUT
			△	5^d0805	(GMS effect)					SC storm begins, contributing to duration (>40^h) of particle event
Mar 6^d14^h	19-80/.032 >30/0.33	$6^d1.0$ $7^d5.1$ and 3.8	⊙	6^d0935	(no flare)		10595	30201	6	SID/imp.3,bright surges,spray and loops, NW limb 1-8A(X)=470/2 hr.
			+	6^d1319	1n	S14E60	10618	31132	10	IV(M)+ El.13^h30^m UT 1-8A(X)=340/5 hr.
			⊘	7^d0140	2b	S11E09	10614	22113	9	II(M) 1-8A(X)=510/2 hr. A "spotless" flare and possibly a contributor to low energy max. at 7^d02^hUT
Mar 7^d<13^h	19-80/.20 >10/37.3	?	●	7^d1122	1b	S14E49	10618	21200	5	El.<13^hUT 1-8A(X)=210 PCA (Thule Riom.) begins ~1100 UT.
Mar 7^d20^h	>30/.93 19-80/0.2		⊙	7^d1601	1n	S14E45	10618	21202	7	I(DCM) 1-8A(X)>170/2.5 hr.
			+ ◇	(GMS effect)						Major GMS in progress, increases in intensity after 7^d18^h UT.
Mar 12^d14^h	19-80/.003 >10/.65		●	12^d0306	2n	S14W46	10614	22101	6	III G(DCM,M) + El. 03^h25^mUT 1-8A(X)=600/1.5 hr. A "spotless" flare. Also major D.B.'s (imp.2 and 1+) Mar 11-12 & Mar 13-14.

Mar 18^d23^h	1-10/.75		●	18^d1656	1n	S04W75	10630	11032	7	II(M) & IV(M,DKM) 1-8A(X)=64/1 hr.
Mar 21^d07^h	19-80/.00089 1-10/9.8		● +	21^d0035	2f	N19E66	10641	12110	5	II(M), I(M) 1-8A(X)=170/2,5 hr.
			◇	Region Transit						Disk transit of region 10641 (Mar 18-31) contributes to long period of increased flux (~13 days)
Mar 23^d19^h	>60/.23 19-80/.063	0.5	⊙	23^d1544	1n	N18W62	10638	21100	4	III G (DCM) 1-8A(X)=390/2 hr.
			⊙	(" 1700) (" 1758)	(No Flares)		10638?	00030	3	IV(DKM) II(M)+ cont.(M & DKM) } + El. 18^h15^mUT McM-H observers' notes report- 1653 UT: "Prom. loops off W.Limb" 1712 UT: 10638 now "Brighter south of spot."
Mar 25^d22^h	19-80/.04 >10/1.40		●	25^d1202	1b	N14E10	10641	31232	11	II & IV(M,DKM) + El. 21^h30^mUT 1-8A(X)=1000/3.5 hr.
Mar 29^d01^h	>60/6.47 19-80/.40	1.8	● +	29^d0010	2b	N14W37	10641	22334	14	IV(DCM,M,DKM) + El. 00^h15^mUT 10 CM. G.B., 1-8A(X)=1700/3 hr.
			◇	GMS Effect						SC storm begins 31^d0529UT, contributing to long duration of particle event (≥ 5 days)
Apr 7^d09^h	>10/.27 6-19/.14		⊙	7^d0723	1n	S11E24	10669	11000	2	III b(M) + El. 10^h30^mUT 1-8A(X)=130/1 hr.
			+ ⊘	6^d1953	1n	S13E30	10669	31220	8	Cont.(DCM,M,DKM) 1-8A(X)=390/5.5 hr. } These flares could contribute to particle onset, and to max. ~8^d01^hUT.
			⊘	7^d1554	1b	S10E20	10669	21102	6	Ic(DCM) in prog. 1-8A(X)=390/5 hr.
Apr 9^d13^h	6-19/.083 1-10/32.3		⊙	8^d2324	sn	N16E55	10675	20132	8	II(M,DKM) & IV(DCM,M,DKM) 1-8A(X)=860/2 hr.

TABLE 1 (continued)

PARTICLE DATA			FLARE DATA						OTHER COMMENTS
Time 1970	MEV	PCA	Time	Imp.	Coord.	Plage No.	Profile	CFI	
Apr 15^d08^h	19-80/.00048 >10/.09	0.6	● 15^d0413	2b	N13W85	10670	32333	14	10 cm.G.B., II(M) & IV(DCM,M) + El. 04^h40^mUT 1-8A(X)=2300/>4hr.
Apr 25^d04^h	1-10/.40		● 25^d0037	1b	N05W73	10684	21202	7	IIIg(DCM,M,DKM) + El. (Heos) 1-8A(X)=690/1.5 hr.
May 5^d05^h	19-80/- >10/.27		● 4^d2222	2f	N31E08	(10714-10722)	02010	3	II(M,DKM) + El. $5^d02^h10^m$UT 1-8A(X)=~30/3.5 hr. A "spotless" flare related to a filament between two regions. Fil. becomes D.B./imp.2+, May 4-5.
May 6^d14^h	1-10/71.2		● 6^d1225	1n	N14E46	10725	11100	3	1-8A(X)=170
May 8^d07^h	1-10/95.8 0.9-1.5/125		⊙ 7^d2225	1n	S10W88	10709	21100	4	IIIb(M) 1-8A(X)>61/~1hr.
			+ ⊘ 8^d0656	2b	N14E23	10725	22100	5	1-8A(X)=640/2 hr.
May 30^d09^h	>30/.90 19-80/.06	1.9	● 30^d0226	2b	S08W31	10760	32101	7	Is(M) + El. 05^h20^mUT 1-8A(X)≥430/5.5 hr.
			+ ⊘ 31^d1107	1n	S05W58	10760	21103	7	III G(M) 1-8A(X)=170
Jun 2^d10^h	19-80/.00069 >10/.24		● 2^d0618	2n	S08W76	10760	22132	10	II & IV(M) 1-8A(X)≥210/>9 hr.
Jun 5^d06^h	1-10/5.4		⊡ 4^d2347	(No Flare)		10760?	00012	3	II(DCM,M) Active region 10760 is on invisible hemisphere, about 2 days beyond west limb. Also - D.B./imp. 1+, June 4-5.
Jun 5^d19^h	1-10/8.2		⊡ 5^d1043	(No Flare)		10760?	00112	4	II(M) 1-8A(X)=38/>5 hr. Possibly 10760 on invisible hemisphere, ~2 days beyond west limb.

Jun 14^d17^h	19-80/.0034 >30/.09		●	14^d1321	2b	N20E42	10789	12233	11	II(M,DKM),IV(DCM,M,DKM)+ El.17^h00^mUT 1-8A(X)=1300/2.5 hr.
			+	14^d0503	2b	N19E42	10789	32211	9	II(M) 1-8A(X)=5100/1.5 hr.
			⊘	14^d1659	1b	N18E35	10789	31200	6	IIIG & V(DCM), IN(DCM) 1-8A(X)=5000/2 hr.
				15^d1304 15^d1316	1n 2b	N18E22 N15E08	10789 10781	21222	9	IIIG(DCM,M,DKM)& cont.(M,DKM) 1-8A(X)=2500/2 hr. These flares are possible "contributors" to particle onset, and to particle maximum. Many important flares occurred in region 10789 during long rise to particle max.on 16^d23^hUT.
Jun 25^d15^h	>10/.38 6-19/.033	0.8	●	25^d0712	2n	S06W26	10798	02101	4	IIIG(M) 1-8A(X)≳130/7 hr. A "Spotless" flare.
Jun 26^d02^h	>30/.93 19-80/.0063		● +	25^d1834	2b	N10E12	10801	12202	7	UNCL(DCM) + El. $26^d01^h00^m$UT 1-8A(X)=300/1 hr.
Jun 27^d06^h	19-80/.0004 >10/1.6		▲	27^d0606	(GMS Effect)					SC storm begins, following event on June 25.
Jun 28^d23^h	19-80/.00026 1-10/1.01		●	28^d1945	1b	N21E22	10808	31232	11	II(M,DKM) & IV(DCM,DKM) 1-8A(X)=3300/2 hr.
Jul 1^d17^h	6-19/.56 1-10/97.3		● +	1^d1058	1n	N19W12	10808	21103	7	IIIG(M,DKM) + Major D.B./imp.2 2-12A(X)~100 between July 1-2.
			⊘	1^d2021	1n	N18W17	10808	11132	8	II(M) & IV(M,DKM) 1-8A(X)=79
Jul 2^d19^h	19-80/~.0004 >10/.11		●	2^d1758	1b	N19W29	10808	11133	9	II & IV(M,DKM) 1-8A(X)≥90/1.5 hr.

TABLE 1 (Continued)

PARTICLE DATA			FLARE DATA							OTHER COMMENTS
Time 1970	MEV	PCA		Time	Imp.	Coord.	Plage No.	Profile	CFI	
Jul 6^d23^h	19-80/.002 >10/.01		●	6^d2137	1b	N22W90	10808	21112	7	II(M) + El. 22^h00^mUT 1-8A(X)=860/∼1.5 hr. + Major D.B./imp. 2 between July 6-7.
Jul 7^d18^h	>60/0.31 19-80/.04		⊙	{7^d1654 1711}	Type II bursts with following sub-flares					
				7^d1648	sf	N24W90	10808	20112	6	II(M,DKM) + El. 17^h15^mUT 1-8A(X)=600/2.5 hr. McM-H observers' notes indicate considerable west limb activity between 1650-1830 UT: "Bulges;""bright surge;" "bright arch structures." Sub-flares in 10813 and 10815 are called "small bright points."
				1652	sf	N10W56	10813			
				1654	sf	S09W14	10815			
				(Possibly Ambiguous)						
Jul $8^d15^h20^m$	0.5-1.5/1.4 (electrons)		●	8^d1515	sn	S10W20	10815	00000	0	A "pure electron" event - no proton enhancement IIIG(M,DKM)
Jul 20^d15^h	1-10/.40		●	20^d1109	2b	N08E55	10845	32333	14	10 cm G.B., IV(M,DKM) 1-8A(X) > 4900/3.5 hr.
			+							
			⊘	20^d2030	sn	N05E43	10845	10131	6	IV(DCM) 1-8A(X)=340∼2.5 hr. A possible contributor to particle max. at 21^d00^h UT.
Jul 21^d07^h	19-80/.0015 ≥10/.52		⊙	21^d0437	1n	N09E45	10845	21131	8	IV(M) + El. 06^h30^m UT. 1-8A(X)>210/2 hr.
			+							
			⊘	22^d0023	1b	N08E33	10845	21332	11	10 cm G.B., IV(DCM,M) 1-8A(X)≥1400/1.5 hr.
			+							
			△	21^d0732	(GMS effect)					GMS in progress since 20^d19^hUT, SC 21^d0732UT and increase in storm intensity.
Jul 23^d00^h	1-10/9.1		●	22^d1940	sb	N06E18	10845	10213	7	II(DKM) + El. 23^d00^hUT 1-8A(X)=87/3.5 hr.
Jul 23^d<12^h	19-80/.001 1-10/67.3		●	23^d1029	1n	N10E13	10845	31133	11	IV(DKM)(or cont.) 1-8A(X)=300/1.5 hr.

Jul 23^d21^h	$\gtrsim$30/.50 19-80/.056	3.6	●	23^d1832	1b	N09E09	10845	21333	12	10 cm G.B., IV(DCM,M) + El. 18^h45^mUT 1-8A(X)=2000/2 hr.
Jul 27^d15^h	1-10/81.4		●	27^d0717	1n	N11W38	10845	31222	10	IS & cont.(M) + El. 07^h30^m UT. 1-8A(X)=390/1 hr.
Aug 1^d21^h	1-10/.65		⊙ or □?	1^d1025	2b	N06W43	10851 10845?	22100	5	1-8A(X)=390/3.5 hr. Active region 10845 is 1 day behind west limb, on invisible hemisphere. Sector boundary passage occurred July 31-Aug. 1.
Aug 13^d01^h	>60/.15 19-80/.01		●	12^d2015	1b	N11E90	10882	31334	14	10 cm G.B., II(M,DKM) & IV(DCM,DKM) 1-8A(X)=4900/>4 hr. + El. $12^d23^h00^m$UT
Aug 14^d22^h	>60/.28 19-80/.26	2.6	● {	14^d1602	1b	N10E74	10882	31233	12	IV(DCM,M) + El. Max 15^d10^hUT 1-8A(X)=4400/6 hr.
				14^d1604 1710	sn 1b	N16W75	10865	31232	11	Simultaneous flaring in two separate active regions.
Sep 8^d18^h	1-10/.54		●	8^d1227	1b	N13W47	10918	21233	11	IV(DKM) 1-8A(X)=390
Sep 11^d21^h	1-10/1.42		⊙ +	11^d1750	sn	N12W89	10918	00121	4	Cont.(M)
			⊘	11^d2305	sn	N13W83	10918	10002	3	IIIg(DCM,M,DKM) 1-8A(X)>170/~1 hr.
Sep 23^d23^h	1-10/.08		●	23^d1817	sn	N13E36	10959	10020	3	II(M,DKM), Cont.(M) 1-8A(X)=30/1 hr.
Sep 24^d20^h	1-10/.80		●	24^d1612	1f	N09W11	10948	01020	3	II(DKM), Cont.(M) A "spotless" flare 1-8A(X)=20/2 hr.
Oct 28^d<21^h	1-10/.45		●	28^d1232	2b	N21E21	11002	32234	14	II(M) & IV(M,DKM) 1-8A(X)>390/5 hr.
Nov 1^d14^h	19-80.00058 1-10/1.4		●	1^d1210	sb	N16W50	11002	10111	4	II(M) + El.<14^h30^m UT 1-8A(X)=210/2.5 hr.

TABLE 1 (continued)

PARTICLE DATA			FLARE DATA							OTHER COMMENTS
Time 1970	MEV	PCA		Time	Imp.	Coord.	Plage No.	Profile	CFI	
Nov 5^d05^h	>60/.38	3.5	●	5^d0307	3b	S13E35	11019	33332	14	10 cm G.B., II(M) & IV(DCM,M) + El. 04^h30^mUT.
	19-80/.075									1-8A(X)=2300/12 hr. A great event in an almost spotless region.
Nov 15^d14^h	>10/.80		● +	15^d0625	2b	N15W12	11029	222_2	≥8	1-8A(X)=4100/7 hr. + El.06^hUT.
			⊘	15^d1754	1b	N16W18	11029	31100	5	IV(DKM) & Cont.(M,DKM) in progress all day (1320-2330 UT) 1-8A(X)=1700/5 hr.
Nov $16^d<10^h$	>10/.60		●	16^d0042	2b	N16W22	11029	32332	12	10 cm.G.B., II(M) & IV(DCM,M) + El. 07^hUT. 1-8A(X)>1800/5 hr.
Nov 17^d04^h	1-10/1.5		⊙	16^d2142	1n	N16W33	11029	21102	6	1-8A(X)>690/3 hr. } Flare
			+	17^d0121	1b	N15W35	11029	21100	4	2-12A(X)=360/1 hr.} Ambiguous
			⊘	17^d0542	1n	N17W38	11029	11103	6	1-8A(X)=510/1 hr. - Possibly a "contributor" to particle max.
Nov 17^d11^h	1-10/3.6		●	17^d0732	2b	N16W38	11029	32200	7	1-8A(X)>4900/3 hr. + El.08^hUT
Nov 20^d01^h	19-80/.00015		⊙	19^d2246	1n	N01W19	11035	21112	7	II(M) 1-8A(X)=300/<1 hr.
Nov 21^d14^h	1-10/3.6		⊙	21^d1322	1n	N05W46	11035	21100	4	1-8A(X)=130/2 hr.
			+	21^d1512	1b	N07W40	11035	11212	7	II(M) & IV(DCM(6^m)) 1-8A(X)=510/2.5 hr.
			◇		(GMS effect)					A moderate GMS is in progress (Began with an SC 21^d0622UT)
Dec $4^d<23^h$	1-10/2.2		●	4^d0953	2n	N21E90	11073	22102	7	UNCL. + V(M) 1-8A(X)=510/0.5 hr.
Dec 6^d02^h	19-80/.0003 1-10/8.2		●	5^d2259	1n	N15W46	11060	11110	4	II(M) 1-8A(X)=130/3,5 hr. Flare-associated, but ambiguous.
				5^d2315	sn	S17W18	11063			

Dec 11^d20^h	19-80/.000045		●	11^d1025	1b	N10E36	11077	31233	12	II & IV(M) 2-12A(X)=1310/1.5 hr.
Dec 12^d04^h	19-80/.0056 >30/.14	0.8	●	11^d2205	1n	N16W01	11073	11332	10	10 cm.G.B., II(M) & IV(DCM,M) + El.03^h00^m UT & 10^h30^m UT
			+							1-8A(X)=700/8 hr.
			⊘	12^d0901	1b	N10E23	11077	31133	11?	IV(M)(7 min. dur.) 1-8A(X)~1200/<1 hr. A "Contributor" to the second electron event.
Dec 13^d22^h	>10/1.8 19-80/.0050		⊙ +	13^d1831	sb	N10E04	11077	10133	8?	II(M) & IV(DKM(6 min.)) + El. 21^hUT 1-8A(X)=390/-
			Δ	14^d0154	(GMS Effect)					SC storm begins.

TABLE I - APPENDIX

PARTICLE DATA			FLARE DATA							OTHER COMMENTS
Time 1970	MEV	PCA		Time	Imp.	Coord.	Plage No.	Profile	CFI	
Feb 26^d14^h	19-80/.00089		○ +	26^d<0857	1b	N09E74	10607	01001	2	Flare-ambig.,SGDB. Data + El.13^h30^mUT
				26^d<1247	Sn	N14E11	10595	00002	2	1-8A(X)=70/>6hr.
			⊘	27^d2318	2b	N07E69	10607	32133	12	II & IV(DCM,M,DKM) 1-8A(X)=1700 Contributes to long duration of particle event.
Apr 16^d<22^h	19-80/.0013		○	16^d1915	Sn	S08E49	10684	00000	0	IIIg(M,DKM) + El.19^h43^mUT(VELA)
			or □?				10670 ?			Active region 10670 is one day beyond west limb.
			or ◇	(GMS effect)						A gradual storm begins 16^d15^hUT
Jun 17^d11^h	19-80/.0034		⊙	17^d<1154	Sn	N19W03	10789	20120	5	Continuum (DKM)+ El. 12^hUT 1-8A(X)=170/1.5 Hr.
			or ◇	(Region modulation)						Active region 10789 is at C.M.
			or △	(GMS effect)						Moderate SC storm begins, $17^d07^h50^m$UT.
Jun 25^d04^h	19-80/.005		□ ?				10789?			El. 04^h30^mUT Active region 10789 is on invisible hemisphere, 1 day beyond west limb.
Jun 27^d09^h	19-80/.003		⊙	27^d0732	Sn	N21E43	10808	10002	3	IIIg(M) + El. 09^h30^mUT 1-8A(X)= 130
			or △	(GMS effect)						Geomag. storm began with SC $27^d06^h06^m$UT.
July 8^d15^h	0.5-1.5/1.4 (electrons)		●	8^d1515	Sn	S10W20	10815	00000	0	El.15^h20^mUT. III G (M,DKM) A "pure" electron event - no proton enhancement.

TABLE I - APPENDIX (cont'd)

PARTICLE DATA			FLARE DATA							OTHER COMMENTS
Time 1970	MEV	PCA		Time	Imp.	Coord.	Plage No.	Profile	CFI	
Jul 24^d19^h	19-80/.40 >60/.10		▲	(GMS effect)						No flares or sub-flares. SC storm in progress since $24^d11^h26^m$UT, + second SC at $24^d23^h50^m$UT. Related to earlier flares on 23^{rd}(in Table I).
Aug 9^d21^h	19-80/.00017			(A problem)						Not flare-associated. Start of a gradual increase in particle flux. (El. rise 9^d18^hUT). A "Zone" of bright plages crosses C.M. between Aug.8-12. Active region 10882 is on invisible hemisphere, about 3 days before east limb passage.
Aug 23^d07^h	19-80/.0031		○ or ◇	{23^d0508 {23^d0415	Sf Sf	N19E15 N11W37	10894 10882	00000 00000	0 0	IIIg(M)} + El. 05^h30^mUT. IIIG(M)} (Flares from SGDB.) Also, a small new bright plage appears on 23^{rd} near NW limb.
Nov 5^d23^h	19-80/.12		□?				11002?			El. in prog. $5^d<24^h$UT. No flares reported. Active region 11002 is on invisible hemisphere, just beyond west limb.
Nov 6^d10^h	19-80/.082 >60/.23		□?	6^d0649UT - II(M), but no known flare				00010	1	El. 09^h30^mUT. Active region 11002 is 2 days beyond west limb.
Nov 7^d06^h	>60/.17		▲ +	(GMS effect)						El. 7^d01^hUT SC Storm begins, $7^d00^h46^m$UT.
			⊠?	7^d0402UT - II (M) but no known flare				00010	1	Perhaps active region 11002 on invisible hemisphere, and a "contributor" to particle maximum at $7^d\sim05^h$UT.

TABLE I - APPENDIX (cont'd)

PARTICLE DATA			FLARE DATA							OTHER COMMENTS
Time 1970	MEV	PCA		Time	Imp.	Coord.	Plage No.	Profile	CFI	
			⊙	18^d2318	Sn	N05W01	11035	10102	4	IIIG (DCM,M)
Nov 19^d01^h	19-80/.00021			18^d1510	1n	N07W02	11035	11100	3	IIIG (M), 1-8A(X) ≥170/4.5 hr.
				18^d1406	Sn	N04W02	11035	10122	6	IIIG + cont.(DCM,M,DKM)
			or							1-8A(X)= 130
			◇	(GMS effect)						A moderately severe geomagnetic storm has been in progress since $18^d12^h25^m$UT. A D.B. of imp. 1+ occurs between Nov. 18-19.
Nov 23^d14^h	19-80/.0032		O	23^d1054	1n	N09W66	11035	11000	2	1-8A(X)= 210. + El. 12^h40^mUT. A weak geomagnetic disturbance is in progress. A sequential sector boundary occurs between Nov. 23-24.
Dec 24^d07^h	19-80/.018 >60/.31	0.6		(A problem)						No suitable flares, although region 11084 has been active with numerous sub-flares. Active region 11077 is on invisible hemisphere, 3 days beyond west limb. A moderate and brief geomagnetic disturbance occurs on Dec. 24.

NOTES FOR TABLE 1 AND APPENDIX

Particle Data

Column

1. Date and hour of onset of proton enhancement.
2. Highest range, and maximum value, of proton flux reported. Explorer 41 fluxes at 19-80 and 6-19 MEV are measured in units of number of particles/sec.-cm^2-SR-MEV/NUC. Fluxes at >60, >30, >10 and 1-10 MEV are measured in number of particles/cm^2-sec-ster.
4. Polar cap absorption (when known), and maximum value in db.

Flare Data

5. Date and time (UT) of flare, plus confidence association with particle event (●, ⊙ or ∅) or date and time (UT) of onset of geomagnetic storm (▲ or △ = SC storm). ◇ = modulation due to geomagnetic disturbance in progress, or to effect of central meridian transit of an active region.
5. Flare importance.
6. Location of flare on disk.
7. McMath Plage Number.

8 & 9. Components of and value of comprehensive flare index for the flare.

Other Comments

10. Remarks, which include:
    (1) Data about the dynamic spectrum events accompanying the flare.
    (2) Electron data (0.5-1.1 MEV), when known.
    (3) 1-8A X-ray maximum flux (ergs/cm^2 sec x 10^4) and duration.
    (4) Other interesting or pertinent comments concerning occurrence of important D.B.s (Disparition Brusque), "spotless" flares, major flare "contributors" to particle events already in progress, geomagnetic storm onsets, etc.

The particle data in the above tables have been supplied by Ms. Shea and Mr. Smart of the Air Force Geophysics Laboratory. The flare data have been taken from the Quarterly Bulletin on Solar Activity supplemented by the Solar Geophysical Data Bulletins and UAG Report 52. Radio frequency, X-ray, and geomagnetic storm information came primarily from Solar Geophysical Data Bulletins.

TABLE 2

NUMBER OF "MAJOR" FLARES AND IMPORTANT CENTERS OF ACTIVITY IN SOLAR CYCLE 20

	"MAJOR" FLARES†		"Major" Centers of Activity Δ	
	Total Number	CFI ≥ 11*	Total Number	ARI ≥ 10
1964	2	1	5	0
1965	6	0	8	0
1966	63	10	16	4
1967	93	8	30	6
1968	106	8	33	4
1969	103	17	34	7
1970	151	23	41	5
1971	60	4	17	1
1972	96	13	18	4
1973	74	7	18	0
1974	71	8	11	3

† A flare is considered to be "major" if it satisfied any one of the following criteria:

Short wave fade (or Sudden Ionospheric Disturbance), importance ≥ 3.

Hα Flare, importance ≥ 3.

10cm flux, ≥ 500 X $10^{-22}Wm^{-2}Hz^{-1}$

Type II burst

Type IV radio emission, duration >10 minutes

* The Comprehensive Flare Index (CFI) is the sum of the following 5 parameters:

SID importance (Scale 1-3)

Hα importance (Scale 0-3)

Magnitude of ~10cm flux (characteristic of log of flux in units of $10^{-22}Wm^{-2}Hz^{-1}$)

Dynamic Spectrum (Type II = 1, Continuum = 2, Type IV with duration > 10 minutes = 3)

Magnitude of ~200 MHz flux (characteristic of log of flux in units of $10^{-22}WM^{-2}Hz^{-1}$)

Δ See text for description of Active Region Index (ARI)

TABLE 3

SUMMARY OF SOLAR AND PARTICLE DATA FOR 1970

1970	Number of Flares				Number of "Major" Centers of Activity		Number of Particle Events Explorer 41				
	Imp.3	Imp.2	"Major"	CF 1 ≥ 11	Total	ARI 1 ≥ 10	Total	>60, >30 19-80MEV	>10 6-19MEV	1-10MEV	With PCA
Jan.		6	6		3		8	4	1	3	2
Feb.		5	10	1	5		3	2		1	
March		13	26	8	4		15	8	1	6	3
April		2	8	1	3	1	8	2	2	4	1
May		4	7		5		9	2		7	1
June		7	16	2	3	1	13	8	1	4	1
July		1	21	4	5	1	19[a]	7	3	9	1
Aug.		1	11	2	3		13	4	3	6	1
Sept.		2	9	1	2		6			6	
Oct.		4	7	1	3	1	6		1	5	
Nov.	1	5	20	2	2	1	14	8	2	4	1
Dec.		1	10	1	3		13	5	4	4	2
TOTAL	1	51	151	23	41	5	127[b]	50	18	59	13

[a] excludes 2 pure electron events

[b] excludes 2 pure electron events and 23 proton events observed on other satellites

TABLE 4

"MAJOR" CENTERS OF ACTIVITY IN 1970

Rotation	Region†	CMP (1970)	Lat.	Long.	Profile Index (ABCDE)*	(API)
1556	10508	Jan. 3	N13	241	10101	3
"	10527	Jan. 17	S13	50	00100	1
1557	10542	Jan. 27	S20	285	22210	7
"	10568	Feb. 10	N16	94	24110	8
"	10579	Feb. 17	S13	2	12100	4
1558	10581	Feb. 19	S23	335	01200	3
"	10584	Feb. 22	S15	296	22000	4
"	10595	Feb. 27	N16	237	23200	7
"	10607	Mar. 5	N08	158	24102	9
"	10618	Mar. 10	S15	85	12210	6
"	10630	Mar. 15	S02	19	01100	2
1559	10641	Mar. 25	N16	247	33010	7
"	10652	Apr. 1	N07	162	01100	2
"	10669	Apr. 9	S15	49	13321	10
"	10675	Apr. 13	N16	3	23200	7
1560	10709	May 2	S13	112	11100	3
"	10725	May 10	N15	6	13210	7
1561	10740	May 14	S10	307	14210	8
"	10743	May 18	N16	254	03320	8
"	10760	May 28	S09	128	24200	8
1562	10781	June 14	N18	257	13201	7
"	10789	June 17	N19	217	34310	11
"	10801	June 27	N12	91	02000	2
"	10808	July 1	N24	38	24210	9
1563	10812	July 4	S11	358	02211	6
"	10845	July 24	N12	94	14212	10
"	10851	July 29	N06	21	02001	3
"	10853	July 31	S13	1	0100-	1
1564	10865	Aug. 9	N18	236	0421-	7
"	10868	Aug. 12	N20	203	0310-	4
"	10882	Aug. 20	N08	97	02100	3
1565	10918	Sept. 5	N18	239	02312	8
"	10922	Sept. 8	N22	199	02000	2
1566	10965	Oct. 2	N19	243	01100	2
"	10987	Oct. 16	N07	58	01100	2
1567	11002	Oct. 29	N18	253	23311	10
"	11029	Nov. 14	N15	35	24323	14
1568	11035	Nov. 18	N09	343	13111	7
"	11073	Dec. 11	N15	40	12200	5
"	11077	Dec. 14	N10	0	13200	6
1569	11084	Dec. 20	N18	288	01001	2

* An evaluation of the following parameters:

A. Number of flares
B. Number of SID's
C. Size and complexity of spots
D. Centimeter radiation
E. Meter radiation

† Brackets indicate returns of related active regions.

TABLE 5

ALL PARTICLE EVENTS IN 1970 WITH INDICATION OF THEIR PROBABLE SOURCE OR CAUSE

1970	No. of Events: Total	No. of Events: With PCA	✓Maximum Energy of Protons (EXPL. 41): >60MEV	>30 and/or 19-80MEV	>10 and/or 6-19MEV	1-10MEV	Observed only on Other Satellites
Jan.	10	2	2 ●+ ●+	2 ● ⊙	1 ●	3 ? ? ○	2 ○ ○
Feb.	3			2 ● ○		1 ?	
Mar.	18	3	2 ⊙+ ●+	6 ⊙ ● ⊙ ● ● ●+	1 ●	6 ● ⊙ ● ● ○ ?	3 ● ? ●
Apr.	9	1		2 ●+ ⊙	2 ⊙ ⊙	4 ? ? ? ●	1 ●
May	11	1		2 ●+ ●		7 ? ● ? ⊙ ? ○ ○	2 ? ●
June	17	1		8 ● ● ? □ ● ▲ ? ●	1 ●+	4 ⊡ ⊡ ○ ▲	4 ○ ○ ○ ?
July	25*	1	2 ⊙ ▲	5 ● ● ⊙ ● ●+	3 ● ○ ●	9 ? ○ □ □ ● ● ? ● ○	4 ? ○ ○ ○
Aug.	17	1	2 ● ●+	2 ? ○	3 ○ ? ○	6 ⊙ ○ ? ○ □ ◇	4 ○ ○ ○ ?
Sept.	7					6 ● ⊙ ⊙ ● ● ?	1 ?
Oct.	8				1 ?	5 ○ □ ○ ? ○	2 ? ?
Nov.	14	1	3 □ ? ●+	5 ● □ ? ⊙ ?	2 ● ⊙	4 ● ⊙ ● ○	
Dec.	13	2	1 ?+	4 ⊙ ●+ ⊙ ●	4 ○ ○ ? ?	4 ● ? ? ?	
TOTAL	152*	13	12	38	18	59	23

+ indicates the occurrence of PCA

* includes 2 cases of electron enhancement without observed proton increase

✓ see page 5 for explanation of symbols used

TABLE 6

SUMMARY OF PARTICLE EVENTS PROBABLY ASSOCIATED WITH THE FIVE GREATEST CENTERS OF ACTIVITY IN 1970

McMath Plage Number	"ARI"	Date of CMP	Associated Particle Events Date	MEV		Flare Data or Comments Date Imp. Long.	"CFI"
10669	10	Apr. 9	Apr.7^{d}10^{h}30^m	>10	⊙	Apr.7^{d}0723, 1n, E24	(2)
10789	11	June 17	Jun.14^{d}17^{h}00^m	>30	● + ⊘	Jun.14^{d}1321,2b, E42	(11)
			Jun.25^{d}04^{h}30^m	19-80	□	Region 1 day beyond west limb	
10845	10	July 24	Jul.20^{d}15^h	1-10	●	Jul.20^{d}1109,2b, E55	(14)
			Jul.21^{d}06^{h}30^m	19-80	⊙ + ⊘	Jul.21^{d}0437,1n, E45	(8)
			Jul.23^{d}00^{h}30^m	1-10	●	Jul.22^{d}1940,Sb, E18	(7)
			Jul.23^d<12^h	19-80	●	Jul.23^{d}1029,1n, E13	(11)
			Jul.23^{d}18^{h}45^m	19-80 PCA	●	Jul.23^{d}1832,1b, E09	(12)
			Jul.27^{d}07^{h}30^m	1-10	●	Jul.27^{d}0717,1n, W38	(10)
			Jul.28^d~15^h	1-10	○	Jul.28^{d}1259,Sn, W53	(3)
			Jul.30^{d}19^h	1-10	○	Jul.30^{d}1243,1n, W83	(2)
			Aug.1^{d}21^{h}30^m	1-10	□	Region 1 day beyond west limb	
			Aug.3^{d}08^h	1-10	□	Region ~ 3 days beyond west limb	
11002	10	Oct. 29	Oct.25^{d}06^h	1-10	○	Oct.24^{d}0450,2n, E75 plus later subflares	(≥4)
			Oct.27^{d}05^h	1-10	○	Oct.26^{d}2159,1n, E41	(5)
			Oct.28^d<21^h	1-10	●	Oct.28^{d}1232,2b, E21	(14)
			Nov.1^{d}14^h	19-80	●	Nov.1^{d}1210, Sb, W50	(4)
			Nov.6^d~00^h	>30	□	Region is just beyond west limb	
			Nov.6^{d}10^h	>60	□	Region is ~2 days beyond west limb	
			Nov.7^{d}01^h	>60	□	Region is ~3 days beyond west limb	
11029	14	Nov. 14	Nov.15^{d}14^h	>10	●	Nov.15^{d}0625,2b, W12	(≥8)
			Nov.16^d~07^h	1-10	●	Nov.16^{d}0042,2b, W22	(13)
			Nov.17^{d}04^h	1-10	⊙ + ⊘	Nov.16^{d}2142,1n, W33	(6)
			Nov.17^{d}08^h	1-10	●	Nov.17^{d}0732,2b, W38	(7)

FIGURE CAPTIONS

Figure 1 Flare, Calcium Plage, and Sunspot Data for Solar Cycle 20.

Figure 2 and 3 Comparison of 1-10 MEV Proton Flux (Explorer 41) with Flares, Major Centers of Activity, Filament Disruptions, and Newly Formed Regions as Functions of Time and Carrington Longitude for the Year 1970. (Figure 2, January-June; Figure 3, July-December.)

Notes for Figures 2 and 3

The upper half of the charts shows the following information:

Carrington Rotations

Dates of interplanetary sector boundary passages

Geomagnetic storms and sudden commencements

Onset or continuation of proton events confidently or probably associated with specific solar flares, ● ⊙ ☐ ⊘

Trace of 1-10 MEV flux, adapted from Explorer 41 data

All known PCA events

The onset of proton events, at low energies only (L)

Known electron increases (E)

The lower half of the charts shows the principal solar events as functions of both heliographic longitude and time. The following phenomena are included:

All "major" centers of activity with McMath plage numbers and Active Region Index. Latitude north or south is indicated by N and S.

All flares of Hα importance 2 or 3 (written above the region line)

Comprehensive Flare Indices for all "major" flares (written below the region line)

All flares considered as probably associated with the onset or continuation of a proton enhancement (enclosed in circles)

All disappearances of filaments of above average size (black square)

All newly formed or resurgent regions that were above average size (the letters N or R appear at the appropriate date and longitude on the disk)

Parallel, diagonal lines indicate the relationship between time and Carrington Longitude (scale at right) for east limb, central meridian, and west limb.

Dotted lines, in general, indicate the passage of regions across the invisible hemisphere

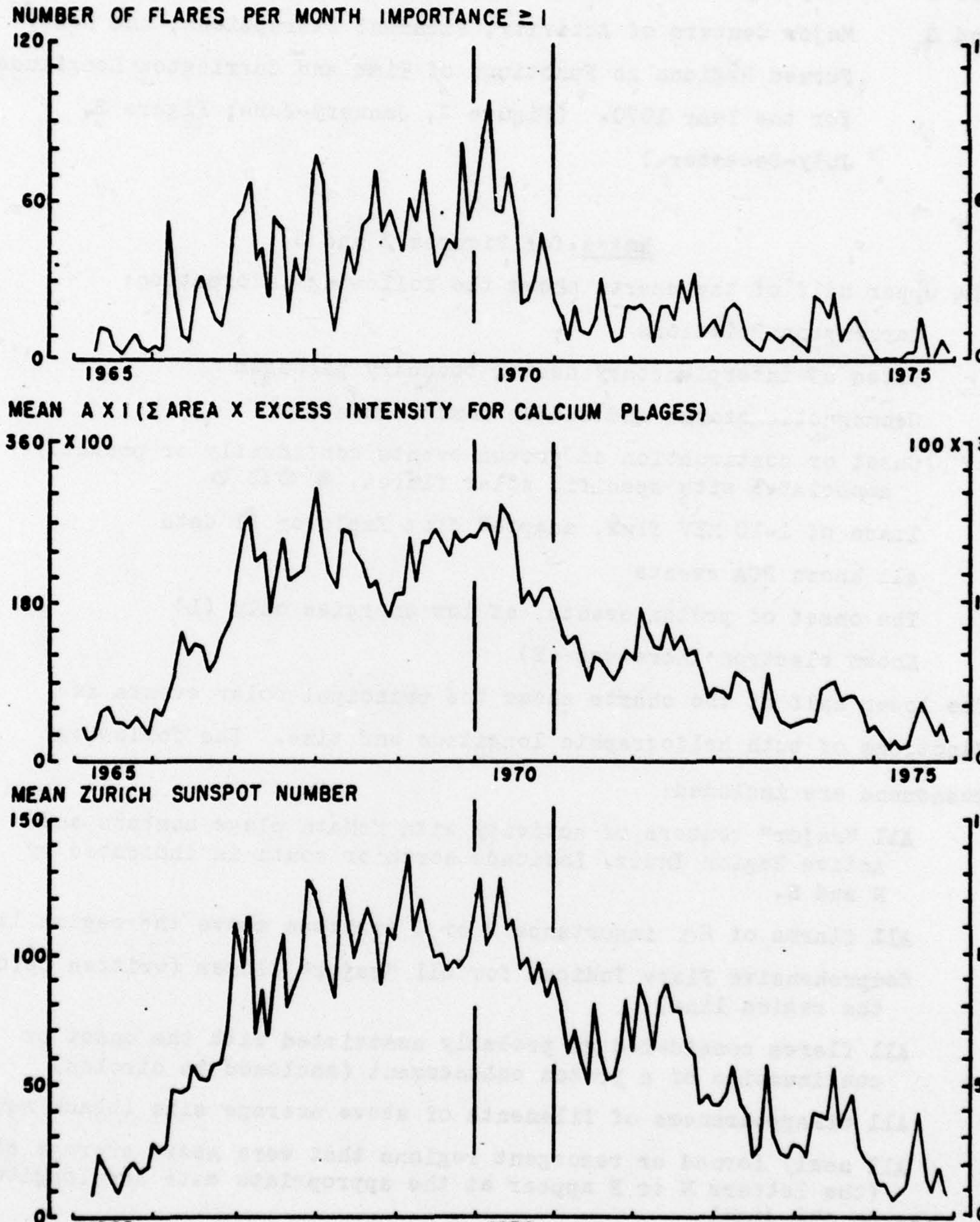
NUMBER OF FLARES PER MONTH IMPORTANCE ≥ 1
120
60
0
1965
1970
1975
MEAN A X I (Σ AREA X EXCESS INTENSITY FOR CALCIUM PLAGES)
360 X 100
100 X 360
180
0
1965
1970
1975
MEAN ZURICH SUNSPOT NUMBER
150
100
50
0
1965
1970
1975

Fig. 1

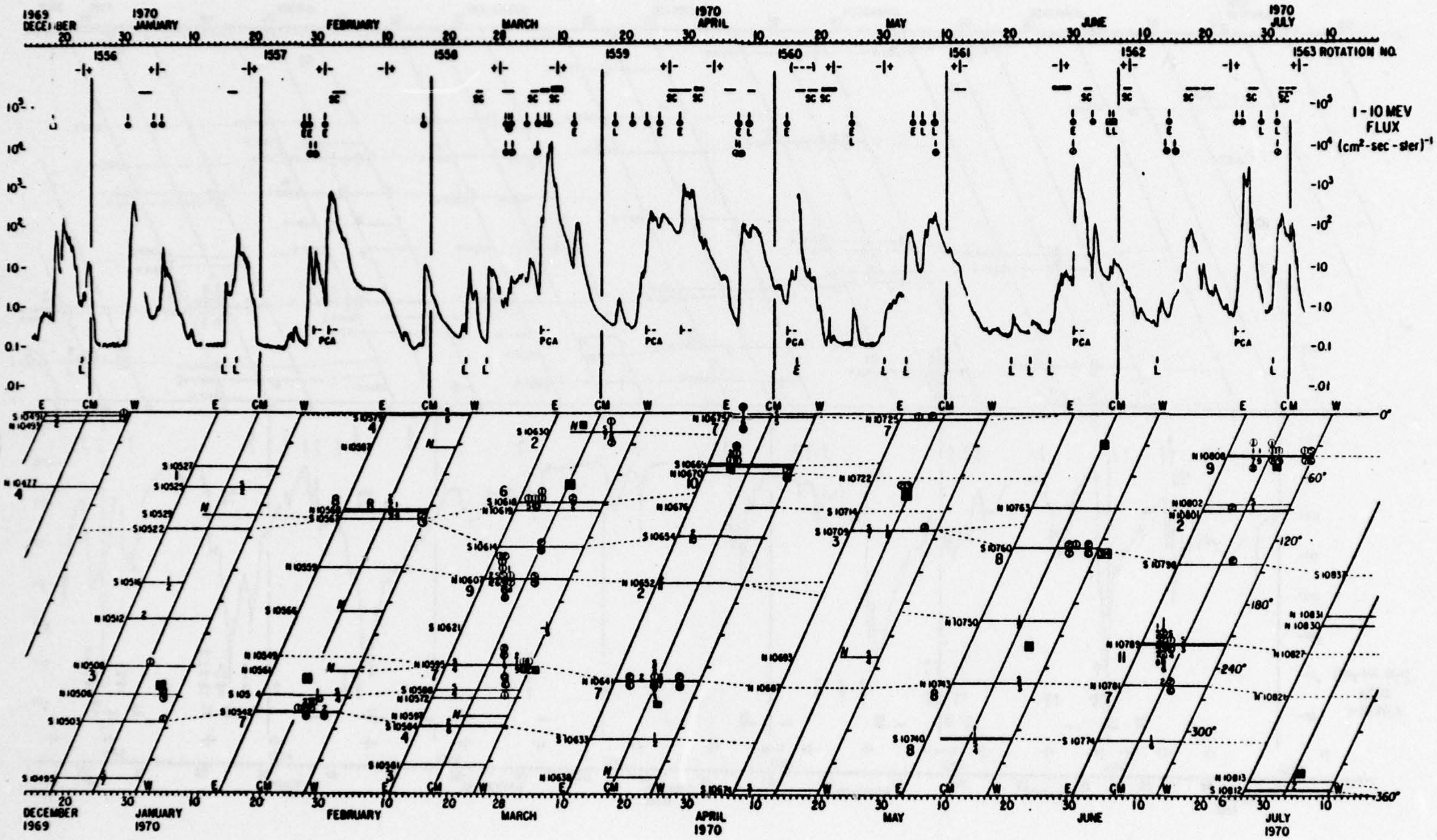
1969 DECEMBER
1970 JANUARY
FEBRUARY
MARCH
1970 APRIL
MAY
JUNE
1970 JULY
1556
1557
1558
1559
1560
1561
1562
1563 ROTATION NO.
1-10 MEV
FLUX
(cm²-sec-ster)⁻¹
PCA
SC
E
CM
W
0°
60°
120°
180°
240°
300°
360°
DECEMBER 1969
JANUARY 1970
FEBRUARY
MARCH
APRIL 1970
MAY
JUNE
JULY 1970

Fig. 2

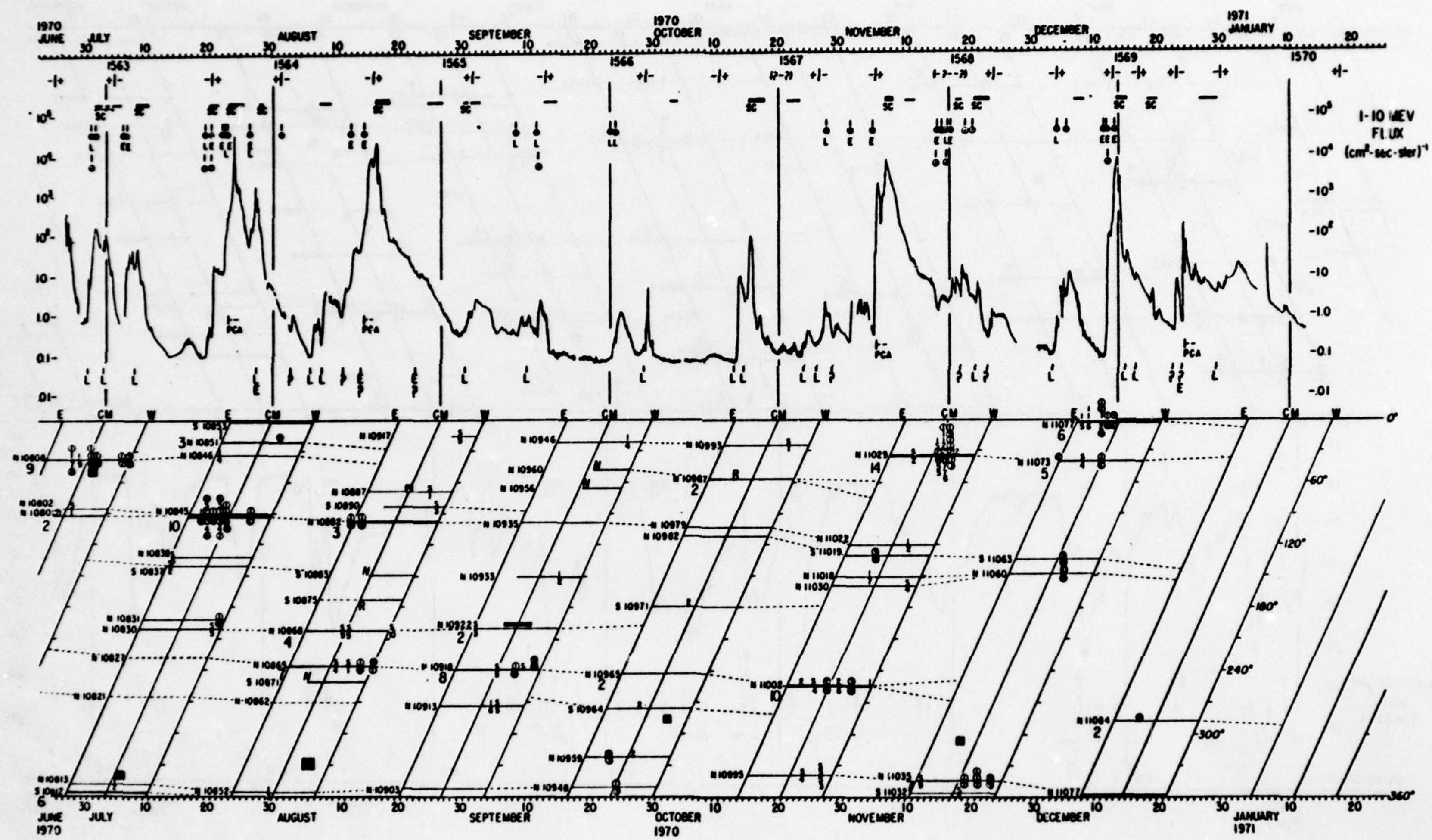
1-10 MEV
FLUX
(cm²-sec-ster)⁻¹
JUNE 1970
JULY
AUGUST
SEPTEMBER
OCTOBER 1970
NOVEMBER
DECEMBER
JANUARY 1971
1563
1564
1565
1566
1567
1568
1569
1570
PCA
E
CM
W

Fig. 3