THE UNIVERSITY OF MICHIGAN

COLLEGE OF LITERATURE, SCIENCE, AND THE ARTS
Department of Astronomy
COLLEGE OF ENGINEERING
Department of Aeronautical and Astronautical Engineering

Quarterly Reports

ORA PROJECTS 03941 AND 039

James L. Amick
Research Engineer

Helen Dodson Prince
Professor of Astronomy

under contract with:

DEPARTMENT OF THE NAVY
BUREAU OF WEAPONS
CONTRACT NO. NOrd-16595
WASHINGTON, D.C.

administered through:

OFFICE OF RESEARCH ADMINISTRATION ANN ARBOR

May 1961

ORA PROJECT 03941

STUDIES OF VARIATIONS IN THE EARTH'S MAGNETIC FIELD DUE TO SOLAR ACTIVITY

PERSONNEL

Mr. Frederick Stewart is employed on this project.

INSTRUMENTS

The APL-5Mc WWV recorder continues to supply records of interest and value.

STUDIES

Recurrent Geomagnetic Storms

Geomagnetic records for January-March, 1961, supplement those of March-December, 1960, and emphasize anew the need for improved understanding of geomagnetic storms that are neither obviously flare-associated nor obviously 27-day recurrent storms. These storms, currently taking place, are providing new problems, as well as new data, for those who would try to predict with greater accuracy the occurrence of geomagnetic disturbances.

Examination of the geomagnetic data for 1960 suggests that a recurrence pattern may exist in the data for the last three quarters of the year, but that it follows a 26-day interval somewhat better than the usual 27-day value. Evidence for recurrence intervals systematically different from 27 days can be found in data for the last solar cycle. For example, in the easily recognizable series of recurrent storms, December 1950-July 1951, Δt is < 27 days for the first four members of the sequence. Later in the sequence $\Delta t \geqslant 27$ days (see Fig. 1).

For 1960, the geomagnetic indices suggest that a "change" occurred in March during rotation No. 1734. Furthermore, examination of the Chalk River* neutron counts for 1960 shows that the Forbush decrease starting on March 31 was very great. It apparently was exceeded in depth and duration only by the events of November 12-20. Accordingly, we have selected March 31, 1960, as day "0" for calculations of superposed values of K_p. These calculations provide evidence for recurrent geomagnetic storms in the latter part of 1960. The results of the calculations, plotted in Figs. 2 and 3, show the following circumstances:

---

* or Deep River

(1) Average values of K_p for 11 superposed rotations prior to March 31, 1960, yield only scattered points, for $\Delta t = 27$ days and for $\Delta t = 26$ days.

(2) Average values of K_p for 11 superposed rotations including and following March 31 show systematic trends in the values. For $\Delta t = 27$ days, two maxima occur. For $\Delta t = 26$ days, the second maximum is less distinct and the interval of relatively high values of $\overline{K_p}$ is well defined and of long duration.

The curve of mean K_p for $\Delta t = 26$ days, for the 11 rotations following and including March 31, 1960, resembles closely a mirror image of the great Forbush decrease that began on March 31, 1960 (see Fig. 3).

Studies still in progress of optical and radio-frequency aspects of solar activity indicate that in July, 1960, there occurred phenomena similar to those previously noted in connection with the onset of sequential storms in the last solar cycle. The July rotation seems to represent a "transition" from the flare-associated to the recurrent type of storm in the sequence of storms here studied. Consideration of whether the ejection of an extensive plasma cloud from the sun (as indicated by the occurrence of the great Forbush decrease on March 31, 1960) bears any real relation to the future development of sequential geomagnetic storms must await further analysis of more abundant data.

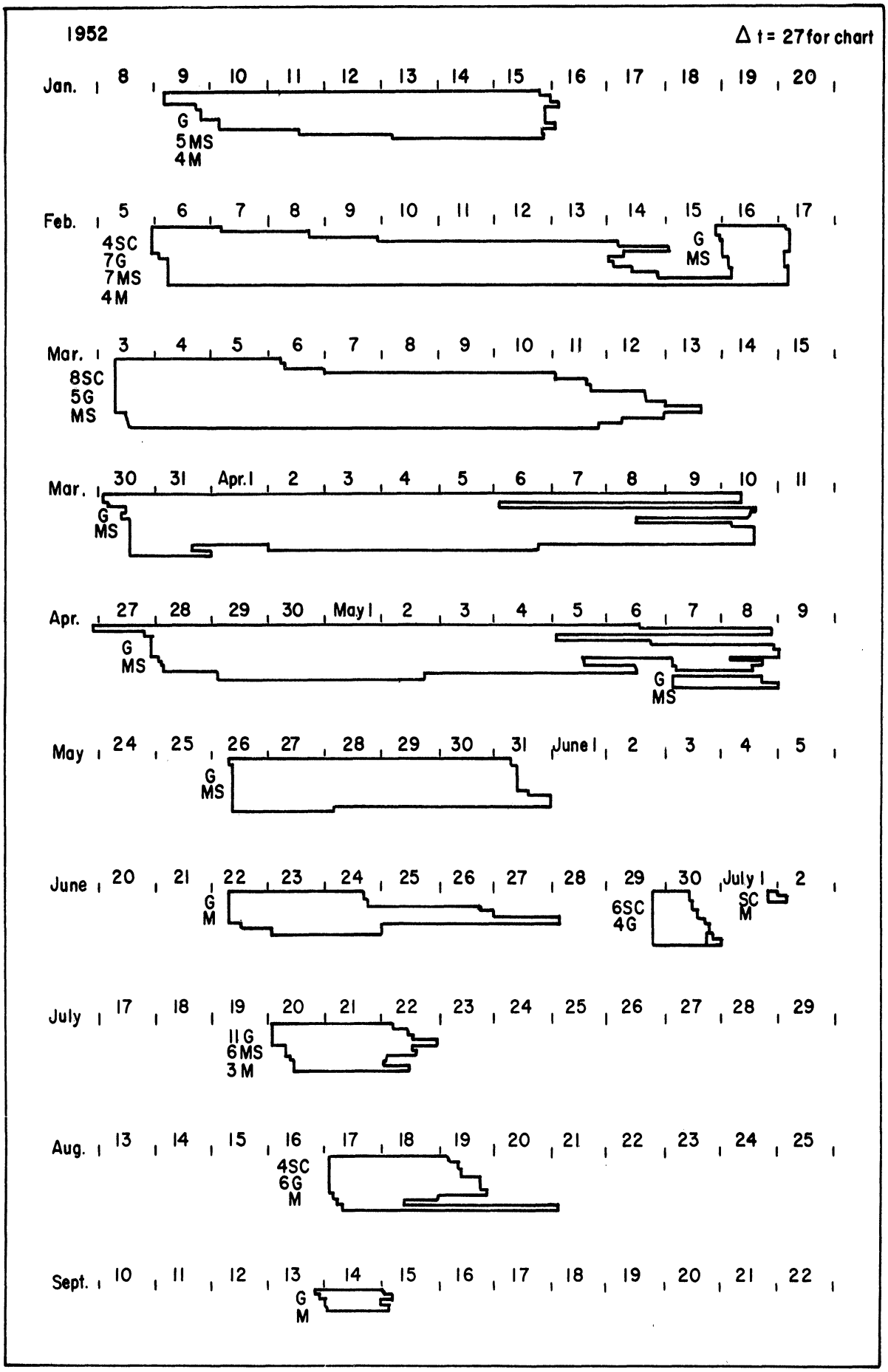

Fig. 1. Plot of "station reports" of geomagnetic storms.

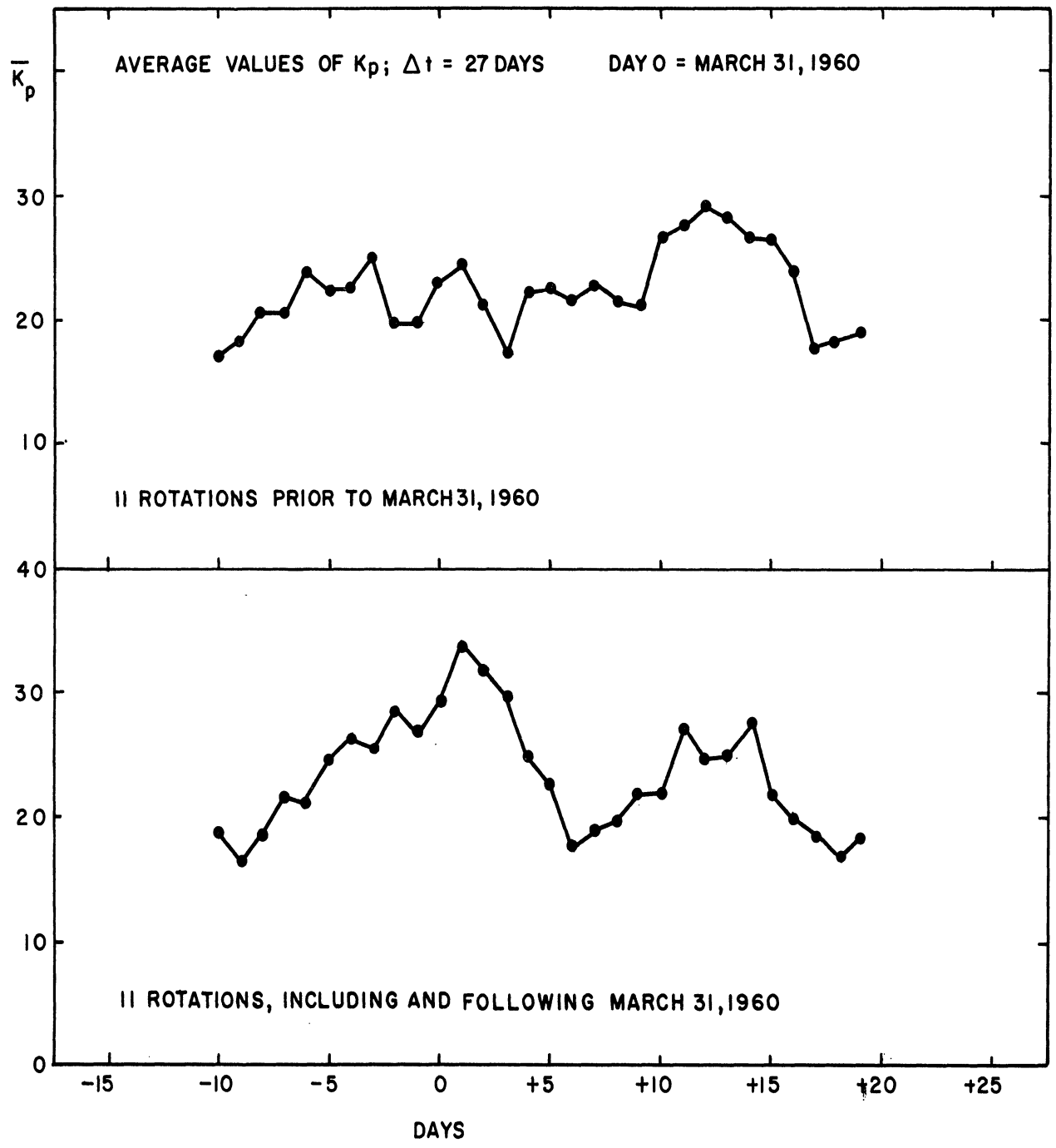
AVERAGE VALUES OF Kp; Δt = 27 DAYS
DAY 0 = MARCH 31, 1960
$\overline{K_p}$
30
20
10
11 ROTATIONS PRIOR TO MARCH 31, 1960
40
30
20
10
0
11 ROTATIONS, INCLUDING AND FOLLOWING MARCH 31, 1960
-15
-10
-5
0
+5
+10
+15
+20
+25
DAYS

Fig. 2

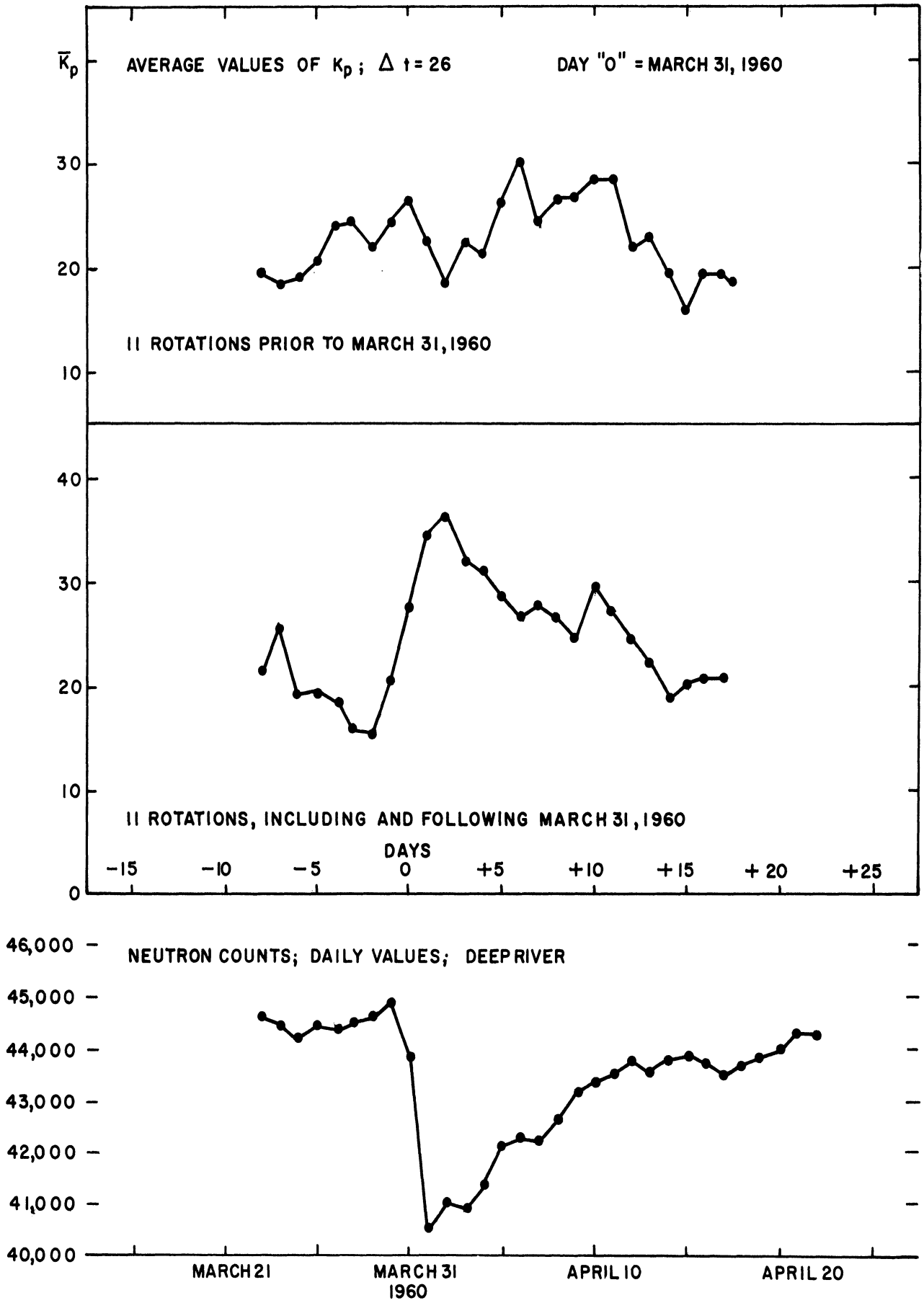
$\bar{K}_p$
AVERAGE VALUES OF K_p ; Δ t = 26
DAY "0" = MARCH 31, 1960
30
20
10
11 ROTATIONS PRIOR TO MARCH 31, 1960
40
30
20
10
0
11 ROTATIONS, INCLUDING AND FOLLOWING MARCH 31, 1960
DAYS
-15
-10
-5
0
+5
+10
+15
+20
+25
46,000
45,000
44,000
43,000
42,000
41,000
40,000
NEUTRON COUNTS; DAILY VALUES; DEEP RIVER
MARCH 21
MARCH 31
1960
APRIL 10
APRIL 20

Fig. 3

ORA PROJECT 03942

JET TASK

JANUARY — MARCH, 1961

It was reported in the last semi-annual summary (July-December, 1960) that preliminary testing in the jet-simulated flare stability program had been conducted, but at the time of that report the data had not been completely analyzed and presentation of quantitative results was impossible. Subsequent thorough examination of those preliminary data revealed previously unanticipated technical difficulties in the data-taking method. Solutions to these technical problems have been obtained during this quarter and the first phase of the testing program has been completed.

The first phase of the testing program (apart from the preliminary exploratory tests) consisted of testing those configurations listed in the last semi-annual summary under conditions that allowed a laminar boundary layer on the model up to the separation point. Subsequent phases of the testing program will include testing of the above indicated configurations under conditions that will insure a turbulent boundary layer at the point of flow separation, and investigation (with laminar and turbulent boundary layers) of models with the circumferential jets at a different location relative to the model base and a different inclination relative to the model surface.

The data obtained during the first phase of the testing program have been sufficiently reduced to conclude that simulation of a body flare by jets exhausting normal to the body surface is possible, and the influence of the jet-simulated flare on stability is favorable.

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OFFICE OF RESEARCH ADMINISTRATION ANN ARBOR

August 1961

ORA PROJECT 03941

STUDIES OF VARIATIONS IN THE EARTH'S MAGNETIC FIELD DUE TO SOLAR ACTIVITY

Quarterly Progress Report

April 1 to June 30, 1961

APRIL 1 TO JUNE 30, 1961

PERSONNEL

Mr. Frederick Stewart is employed on this project.

INSTRUMENTS

The APL-5Mc WWV recorder continues to supply records of interest and value.

STUDIES

A. Dr. Orren Mohler, Miss Ruth Hedeman, and Dr. Helen Dodson attended a meeting in Boulder, Colorado, on June 23, 1961, which had been called by NASA to discuss the prediction of flares associated with Polar Cap Absorption (PCA). The contribution of the McMath-Hulbert Observatory included (1) a brief presentation of the optical and radio frequency characteristics of flares associated with PCA (see Quarterly Report July 1-September 30, 1960, for this contract), and (2) a discussion of the age, the type of sun spots, and the flare history of the regions in which the PCA-causing flares occurred. It was shown that calcium plages in which the PCA flares occurred were in at least their second rotation. It was also shown that PCA flares occurred in the very flare-rich regions, but that not all flare-rich regions produced PCA flares. Information relating to the age and flare history of these regions provided some assistance in distinguishing between the regions associated with PCA and those not so associated.

B. We have continued to study the evidence for recurrent storms in the geomagnetic data for the current phase of the sunspot cycle. Figure 1 shows plots of superposed K_p for the five epochs since the end of December, 1961. Part A shows that the well-developed maximum evident in the preceding 11 cycles on a 26-day recurrence pattern is lost during the first quarter of 1961. Part B shows that the 27-day recurrence pattern still persists. Examination of the individual records suggests that the early member of this pair is now weakening and the second member is strengthening. This effect can also be seen in Part A of Fig. 1. The data continue to suggest the existence of recurrence patterns in the geomagnetic records with time intervals of either 26 or 27 days.

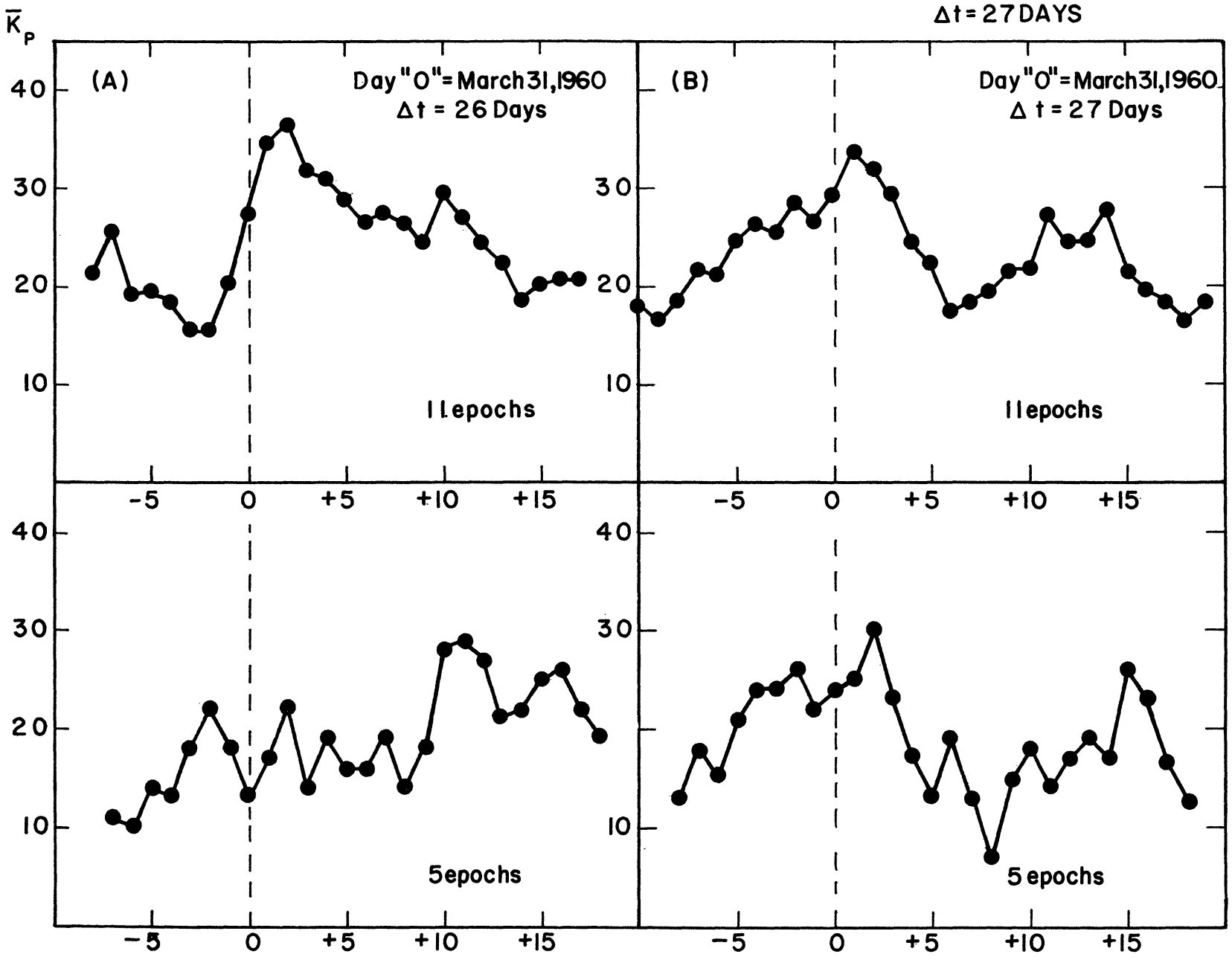

AVERAGE VALUES OF $\overline{K}_p$ FOR 16 EPOCHS MARCH 1960–MAY 1961 FOR Δt = 26 DAYS AND Δt = 27 DAYS
$\overline{K}_p$
(A)
Day "0" = March 31, 1960
Δt = 26 Days
11 epochs
(B)
Day "0" = March 31, 1960
Δ t = 27 Days
11 epochs
5 epochs
5 epochs
40
30
20
10
-5
0
+5
+10
+15

Fig. 1

ORA PROJECT 03942

JET TASK

Semi-Annual Summary

January - June 1961

JANUARY — JUNE 1961

An experimental investigation of the possibility of stabilizing a missile configuration with a jet-simulated flare was conducted during the period covered by this progress report. Most of the data obtained have been reduced and are being prepared for inclusion in a report on the jet-flare stability program. Some of the results obtained to date are included herein and will be briefly discussed.

The basic model used for these tests is an ogive-cylinder of fineness ratio = 6.5. The ogive fineness ratio is 3.0. All tests to date were conducted in an M = 3.97 free stream with a laminar boundary layer on the model. No attempt was made to control, on the model, transition of the separated boundary layer, nor to obtain a fully developed turbulent boundary layer prior to separation. It is expected that some tests will be conducted with a turbulent boundary layer before this exploratory investigation of jet-flare stability is complete, but there are no plans to conduct tests at Mach numbers other than M = 3.97.

The results presented in the enclosed figure were obtained with the model configuration designated 24-J. This model consists of 24 sonic nozzles (d = 0.119") evenly spaced around the circumference of the model at approximately 0.5 calibers from the model base. The data cover an angle of attack range of -0.70° to +2.20°.

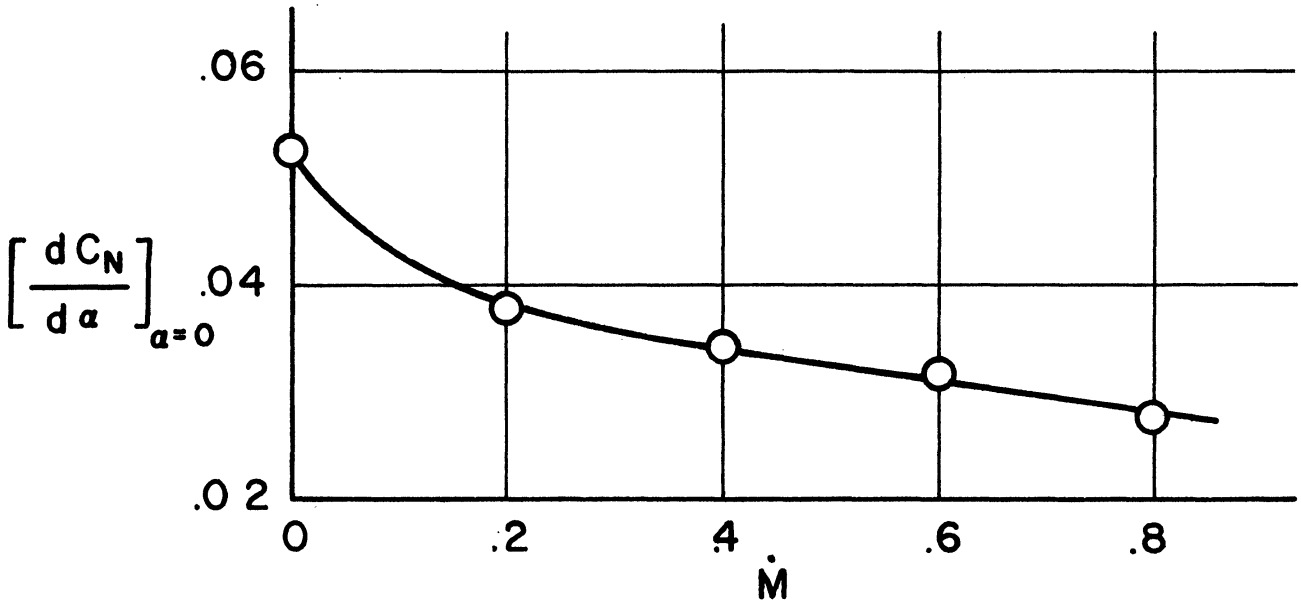
When the nozzles around the circumference of the body are exhausting into the supersonic free stream, the coalesced jet shock causes the laminar boundary layer to separate. Thus for small angles of attack, one could make the assumption that the normal force curve slope and the pitching moment curve slope for an ogive cylinder with a very large jet flare should approach those of a cone if the boundary layer separates at the vertex of the ogive and the bow shock wave remains attached. Under these conditions one would expect an improvement in the stability characteristics of the ogive-cylinders, but the resulting aerodynamic configuration would not necessarily be statically stable.

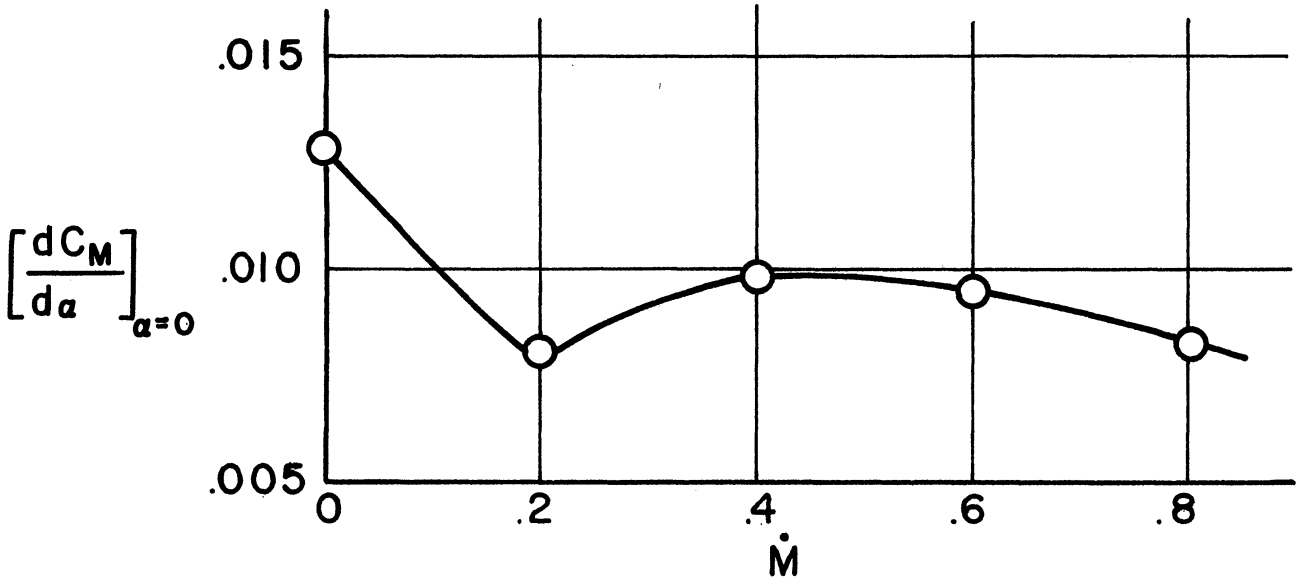
The results enclosed reveal the trends expected on the basis of the simple assumption mentioned above. The stability of the ogive-cylinder is seen to improve about 35% at the highest mass-flow used in the tests over the stability of the plain ogive-cylinder. Static stability was not obtained for this particular model within the range of mass-flows obtained, but the trend of the data shows that static stability should be obtained at some higher mass flow.

Future work planned includes preparation of a report on the jet-flare stability program. Attempts will be made to increase the jet mass-flow to determine what mass-flow is required to obtain static stability. Also an attempt will be made to assess the effects obtained when the boundary layer at the point of separation is changed from laminar to turbulent.

Further investigation of the jet interaction problem is planned immediately after completion of the report on the jet-flare stability program. In this work attempts will be made to reduce the number of parameters of the problem. The point of boundary-layer separation or reattachment will perhaps be controlled by slots on the model or by forcing separation with solid objects.

Some thought is also being given to investigations of a jet-flap. Along this line, the objective of the investigation would be the determination of the conditions under which the high pressures in the zone of separated flow could be completely contained on a body such as a delta wing.





Influnce of a jet-flare on the stability of an ogive cylinder L=13.0, D=2.0, R_{ogive}=18.5, M_∞= 3.97, $Re_L = 1.63 \times 10^6$ Laminar boundary layer.

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OFFICE OF RESEARCH ADMINISTRATION ANN ARBOR

February 1962

ORA PROJECT 03941

STUDIES OF VARIATIONS IN THE EARTH'S MAGNETIC FIELD DUE TO SOLAR ACTIVITY

Quarterly Progress Report

October 1 to December 31, 1961

OCTOBER 1 TO DECEMBER 31, 1961

PERSONNEL

Mr. Frederick Stewart is employed on this project.

INSTRUMENTS

The APL-5Mc WWV recorder continues to supply records of interest and value.

STUDIES

A. During the fourth quarter of 1961, we continued our efforts to distinguish between the geomagnetic disturbances that were primarily a result of 27-day recurrence phenomena and those that were "solar event" associated. The answers are not clear-cut and at this time of the solar cycle the situation is particularly confusing.

B. It has been pointed out in certain of the statistical studies by Dr. Barbara Bell that the correlation between geomagnetic disturbances and centers of activity on the sun is greater for centers with spots classified as γ and $\beta\gamma$ (Mount Wilson classification) than for centers with spots classified as α or β. Since the Mount Wilson program of sunspot classification is being gradually abandoned, we are currently searching for criteria that might help to identify in the future the regions that might have been classified as γ or $\beta\gamma$ by Mount Wilson magnetic measurements. Our first attempt has been a comparison of the Zurich classification of the spots, as done at Zurich, with the Mount Wilson magnetic classification. The results so far are not overly encouraging.

1960 is the last year for which there are reasonably complete Mount Wilson sunspot magnetic data. Out of 542 spots classified by Mount Wilson in that year, only 22 carried the "γ" characteristic (12γ and 10$\beta\gamma$). Spots are classified as γ or $\beta\gamma$ when there is a certain mixing of the polarity such that it is not possible to separate polarities by a simple dividing line across the region. All the other spots were classified as α or β. The Zurich classification of the 22 spots with γ characteristics are given below.

Zurich Classification	Mount Wilson Classification	
	γ	$\beta\gamma$
A	-	-
B	-	-
C	-	2
D	3	2
E	-	3
F	3	3
G	-	-
H	6	-
J	-	-
Total number	12	10

In the Zurich classification F and E are relatively rare types; there are only 9 spots that were predominantly F and 20 predominantly E, out of the approximately 716 spots classified by Zurich in 1960. Two-thirds of the Zurich F spots were Mount Wilson γ or $\beta\gamma$, while only 15% of the E spots carried the γ characteristic. Accordingly, in 1960, for Zurich classification F there was rather high probability of γ or $\beta\gamma$, while E tended to deny this.

The surprising result of our current investigation is the fact that 50% of the spots called γ by Mount Wilson in 1960 were Zurich type H. Zurich class H is not a very frequent grouping in spot classification. In 1960 there were only 26 spots for which the Zurich classification could, in an average sense, be considered as type H, and of these 6 were of type γ. Those that were classified as γ at Mount Wilson were consistently larger than those classified as α or β. There was no systematic difference in the total magnetic field as reported by Mount Wilson for these spots.

Therefore, according to our present study, if one had tried to guess which sunspots in 1960 would carry "γ" characteristics using only the Zurich designation, one could have proceeded as follows and have selected correctly 12 of the 22 γ or $\beta\gamma$ regions, and have included only 3 spots for which the classification was otherwise:

1. Select all spots classified as H by Zurich for which the area was $\geq$ 900 millionths of the solar hemisphere. There are 6 of these and they would all be γ.

2. Select all spots classified by Zurich as F. There are 9: three γ, three $\beta\gamma$, and three β.

It must be emphasized that the relationships here described apply to 1960 data only, and must be extended to other years before any confidence can be placed in their generality.

ORA PROJECT 03942

JET TASK

Semi-Annual Summary

July - December, 1961

JULY - DECEMBER, 1961

During the period of this report, an investigation of a jet flap on a 60° delta wing at a Mach number of 3.9 was begun. The delta wing model has one flat surface, in which is located a spanwise-tapered slot very near the trailing edge. The jet discharges from this slot, perpendicular to the flat surface. The jet width is a maximum at midspan, tapering to zero near each wing tip.

The preliminary tests conducted to date were made with a turbulent boundary layer on the flat surface of the model. Turbulence was induced by roughness grains of approximately .030-in. diameter distributed over a 1/4-in.-wide band along each leading edge. The forces were measured with a four-bridge sting balance, and the mass flows were measured with a standard ASME orifice.

Specific impulse values were computed from these tests, by dividing the force due to the jet (including interaction) by the mass flow of the jet. These data were found to agree with similar data for jets from circular orifices (WADD TR 60-329). The three different maximum slot widths tested gave almost identical results.

In the next report period, the investigation will be extended to include laminar boundary layers, angles of attack, and both larger and smaller mass flows through the jet. Tests may also be made of a device for stabilizing the boundary-layer separation position.

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April 1962

ORA PROJECT 03941

STUDIES OF VARIATIONS IN THE EARTH'S MAGNETIC FIELD DUE TO SOLAR ACTIVITY

Quarterly Progress Report

January 1 to March 31, 1962

JANUARY 1 TO MARCH 31, 1962

PERSONNEL

Mr. Frederick Stewart is employed on this project.

INSTRUMENTS

The APL-5 Mc WWV recorder continues to supply records of interest and value.

STUDIES

We have continued our efforts to find criteria to distinguish between geomagnetic disturbances associated with flares and those primarily resulting from 27-day recurrence, or some other phenomenon. As part of this program we have investigated the relationships between daily K-indices and daily values of neutron counts.

The first results of work in this matter were given in part C of the quarterly report for October 1 to December 31, 1960. In this report we showed that there are at least three kinds of relationships between K_p and neutron counts at times of geomagnetic disturbance:

1. The relatively severe geomagnetic storm with associated Forbush decrease.

2. The geomagnetic storm without an associated diminution in the neutron count, or, in some cases, with a rising neutron count.

3. The relatively rare cases of an apparently large Forbush decrease with a geomagnetic disturbance of only very moderate proportions.

During the quarter for which this report is made, we have brought together the neutron counts from Chalk River and the geomagnetic indices K_p for each day from January 1, 1958, to January 1, 1962. The three aforementioned patterns continue to be present in the data. When the work is completed, it will be possible to separate all the geomagnetic storms or disturbances of this interval into a small number of groups or patterns on the basis of the trends of the associated neutron data. It is hoped that this may prove helpful in recognizing different types of geomagnetic storms. If so, it may make it easier to identify the storms that are associated with flares and to dis-

tinguish them from the storms that may be more related to other phenomena. Data and graphical presentation have already been assembled for 75 storms or disturbances. The available data should provide similar information for approximately 40 more cases.

ORA PROJECT 03942

JET INTERACTION

Quarterly Progress Report

January - March 1962

JANUARY - MARCH 1962

The preliminary jet flap tests reported in the last period have been extended to higher and lower jet pressure ratios and to both laminar and turbulent boundary layers on the flat plate. For a turbulent boundary layer the specific impulse of the jet with interaction has been found to be between 2.4 and 2.8 times the theoretical specific impulse in a vacuum, for a wide range of jet conditions. For a laminar boundary layer the specific impulse is more dependent on the jet conditions, varying from 2.5 times the vacuum specific impulse for the strongest jet tested to 3.6 times for the weakest jet.

During the next quarter a theoretical analysis of the two-dimensional jet flap will be made. A report will be prepared detailing the experimental and theoretical work on the jet flap and comparing the results.

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July 1962

ORA PROJECT 03941

STUDIES OF VARIATIONS IN THE EARTH'S MAGNETIC FIELD DUE TO SOLAR ACTIVITIES

Quarterly Progress Report

April 1 to June 30, 1962

PERSONNEL

Mr. Frederic Stewart is employed on this project.

INSTRUMENTS

The APL-5 Mc WWV recorder continues to supply records of interest and value.

STUDIES

Kp versus Neutron Counts

We have completed the tabulation and plotting of the neutron counts from Chalk River and of Kp, the geomagnetic index, for each day in the interval January 1, 1958 to December 31, 1961. This work is a continuation of the investigations described in Quarterly Reports for October 1 to December 31, 1960, and January 1 to March 31, 1962. The interval now included in the investigation covers approximately 200 cases of events called "storm" by the world-wide geomagnetic stations.

Our independent survey of the plots of Kp versus neutron counts indicates that in the 36 months studied, there were more than 150 intervals for which the relationships of neutron counts and Kp fell into the three general categories described in the preceding Quarterly Report. There were at least 15 cases in which the relationships were not clear. The following table summarizes our first efforts to classify the plots of Kp versus neutron counts. Increased familiarity with the data will probably improve our recognition of the various situations that exist, and future surveys of the same charts may yield changes in the summary included here. Examples of the plots of Kp versus the neutron counts are given in Fig. 1.

Recurrent Geomagnetic Storms

The foregoing study of Kp versus neutron counts is part of our continuing effort to improve the criteria by which flare- or event-associated geomagnetic storms can be distinguished from recurrent and/or non-event-associated storms. It is hoped that efforts directed towards the recognition of flares that cause geomagnetic storms will be assisted by such clarification of the geomagnetic data. That it is necessary to try to distinguish between event-associated and recurrent storms is attested by a recent study done at

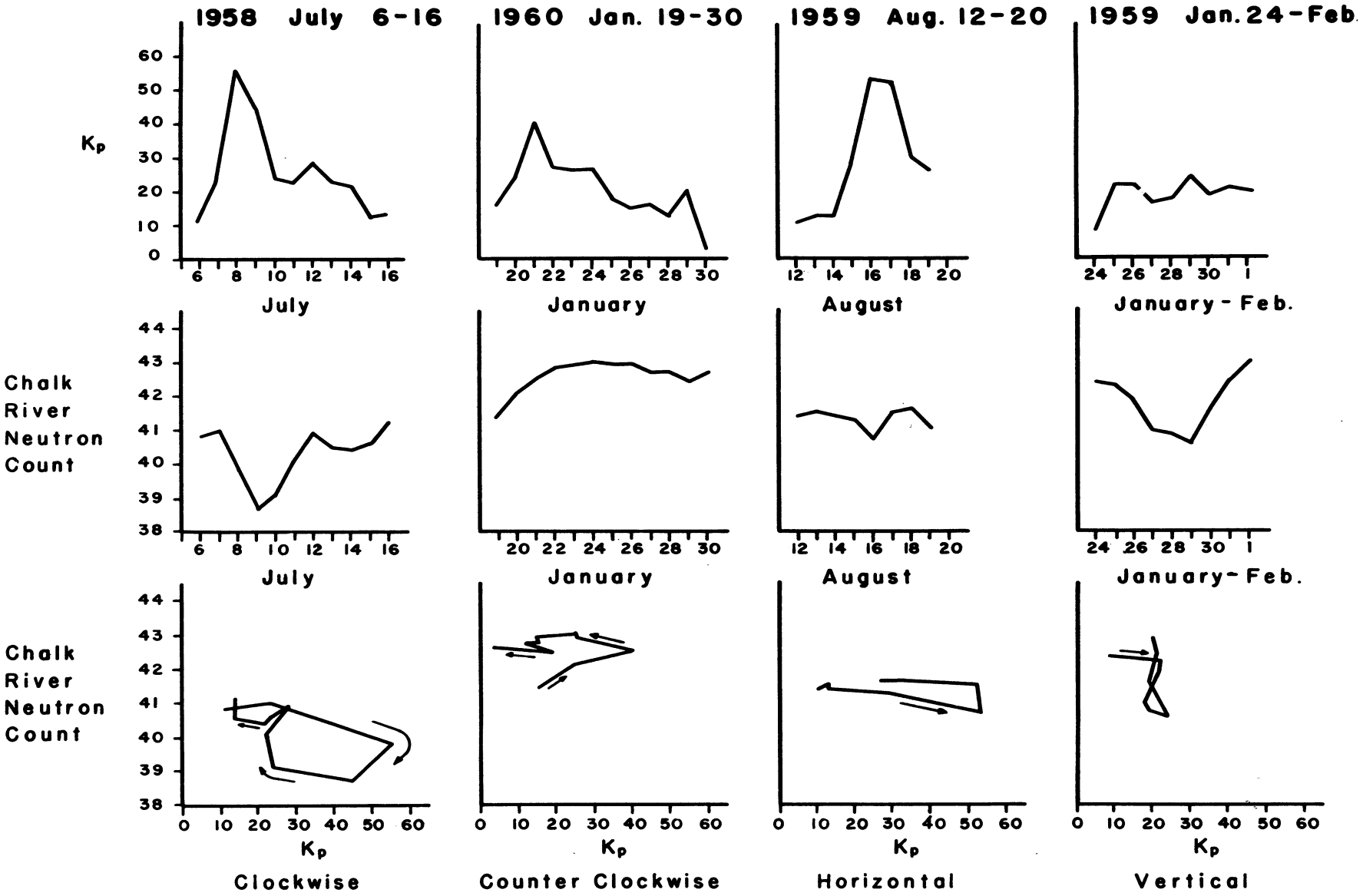
1958 July 6-16
1960 Jan. 19-30
1959 Aug. 12-20
1959 Jan. 24-Feb.
Kp
July
January
August
January - Feb.
Chalk River Neutron Count
Clockwise
Counter Clockwise
Horizontal
Vertical

Fig. 1.

SUMMARY OF FIRST SURVEY OF PLOTS OF Kp, THE DAILY GEOMAGNETIC INDEX, VERSUS DAILY VALUES OF NEUTRON COUNTS FROM CHALK RIVER

JANUARY 1, 1958 to DECEMBER 31, 1961

General Relationship	Description of Chart of Kp versus Neutron Count*	No. of Cases
1. Geomagnetic disturbance with associated diminution in neutron count.	Clockwise	57
2. Geomagnetic disturbance without associated diminution in neutron count.		
a. Increase in neutron count.	Counterclockwise (36)	
b. Primarily "no change" in neutron count.	Horizontal (62)	98
3. Marked diminution of neutron count with relatively small change in Kp.	Vertical	4
Relationship not clear.		15+

*See Quarterly Report for October 1 to December 31, 1960 for additional examples of these charts.

the University of London Observatory. In the report[1] of this study the following statement (page 315) is made: "In Mustel's results, the sporadic storms were not segregated from the recurrent storms, and this may have been the reason why the significance of the minimum was overlooked." That it is not entirely clear just how one should segregate the sporadic from the recurrent storms is implied in another sentence (page 301) in the same study: "By this method it was hoped to segregate the recurrent storms (M) from the sporadic storms (S)."

Our own efforts will now be directed towards ascertaining whether or not the information relating to neutron counts is of assistance in identifying recurrent geomagnetic storms and/or subdividing geomagnetic storms into categories that may assist in studies of solar-terrestrial relationships.

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[1] T. H. Saemundsson, "Statistics of Geomagnetic Storms and Solar Activity;" Monthly Notices, 123, 299, 1962.

ORA PROJECT 03942

JET INTERACTION

Quarterly Progress Report

April 1 to June 30, 1962

A theoretical analysis of the interaction effects produced by a two-dimensional jet flap at supersonic speeds has been made. The calculated results overestimated the interaction force produced by a tapered jet flap on a 60° delta wing, but the trends indicated are similar to those of the experiment. A particularly important result of both theory and experiment is that for a fixed value of jet momentum force, the width of the slot has little effect on interaction force. The interaction is predicted to become increasingly more favorable with increase in Mach number. At hypersonic speeds the lifting efficiency of a wing with jet flap appears to be competitive with that of a conventional wing at angle of attack, if operation at large lift coefficients is required.

A report covering the jet flap work is being prepared and will be issued during the next quarter.

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November 1962

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Quarterly Progress Report

July 1, to September 30, 1962

JULY 1, TO SEPTEMBER 30, 1962

PERSONNEL

Mr. Frederic Stewart is employed on this project.

INSTRUMENTS

The APL-5 Mc WWV recorder continues to supply records of interest and value.

STUDIES

K_p Versus Neutron Counts

Study of the relationships between K_p and neutron counts recorded at Chalk River has been continued. The results of the study were discussed with Dr. Hugh Carmichael of the Physics Division, Atomic Energy of Canada Limited, Chalk River, and with Miss Virginia Lincoln, Chief Radio Warning Services Section, Ionosphere Research and Propagation Division, National Bureau of Standards. Miss Lincoln has requested copies of our reports dealing with this study.

Polar Cap Absorption

Dr. Helen Dodson Prince and Miss E. Ruth Hedeman gave a report of their current investigation of the properties of Flares Associated with Polar Cap Absorption at the meeting of the Midwest Cosmic Ray Physicists at the University of Minnesota, October 12-13, 1962. A copy of this paper is being sent directly to Dr. Zmuda.

ORA PROJECT 03942

JET INTERACTION

Quarterly Progress Report

July 1, to September 30, 1962

JULY 1, TO SEPTEMBER 30, 1962

A report on the jet flap work to date has been prepared ("Interaction Effects of a Jet Flap on a 60° Delta Wing at Mach No. 4, and Comparison with Two-Dimensional Theory," by James L. Amick and Gerard F. Carvalho, WTM 271). The conclusions of this report are as follows:

1. Aerodynamic interaction ahead of a jet flap results in a total normal-force increment due to the jet which is approximately 2 to 4 times as large as the jet force in a vacuum, over a wide range of conditions. This force magnification due to interaction of a jet flap is similar in magnitude to that of a circular jet issuing from a flat plate.

2. The width of the slot producing the jet flap has little influence on the force magnification for a fixed value of the jet force-to-aerodynamic force parameter.

3. A wing with jet flap may be competitive in lifting efficiency with a plain wing at angle of attack, for large lift coefficients at hypersonic speeds.

During the next quarter design work will begin on a two-dimensional jet flap wind tunnel model and on wind tunnel equipment needed to extend the investigation to Mach No. 8.0.

THE UNIVERSITY OF MICHIGAN

COLLEGE OF LITERATURE, SCIENCE, AND THE ARTS
Department of Astronomy

COLLEGE OF ENGINEERING
Department of Aeronautical and Astronautical Engineering

Quarterly Reports

ORA PROJECTS 03941 AND 03942

James L. Amick
Research Engineer

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Professor of Astronomy

under contract with:

DEPARTMENT OF THE NAVY
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February 1963

ORA PROJECT 03941

STUDIES OF VARIATIONS IN THE EARTH'S MAGNETIC FIELD DUE TO SOLAR ACTIVITIES

Quarterly Progress Report

October 1 to December 31, 1962

OCTOBER 1 TO DECEMBER 31, 1962

PERSONNEL

In recent months, Mr. Frederic Stewart has been obliged to assist significantly with the operation of the Hα flare patrol program. Accordingly, starting in December, 1962, he has been assigned half time to the flare patrol program.

Drs. Mohler and Teske and especially Dr. Prince and Miss Hedeman continue to spend large portions of their time working on problems relating to solar-terrestrial relationships and disturbances of the earth's magnetic field.

On October 19, 1962, Miss Virginia Lincoln, Chief, Radio Warning Services Section, Ionosphere Research and Propagation Division, National Bureau of Standards, Boulder, Colorado, and Dr. John C. Noyes, Head, Geo-Astrophysics Laboratory, Boeing Scientific Research Laboratories, Seattle, Washington, visited the McMath-Hulbert Observatory.

INSTRUMENTS

The APL-5 Mc WWV recorder continues to supply records of interest and value.

STUDIES

Recurrent Geomagnetic Storms

As the current solar cycle moves on towards minimum, it becomes all too clear that progress in predicting and understanding the occurrence of geomagnetic storms at this phase of the cycle has not been great. Furthermore, the well defined pattern of 27-day recurrent storms so clearly evident in the geomagnetic data for 1950, 1951, 1952, 1953, and 1954 has not been duplicated in the geomagnetic data for the current cycle through the first half of 1962. Efforts are being continued to identify (1) the reasons for the onset and diminution of the 27-day recurrent storms and (2) the solar events (certain flares) responsible for the sporadic storms. Success in these efforts depends, in part, upon the ability to distinguish between the two kinds of storms. Our studies of the Forbush decreases (neutron counts), reported in preceding quarters, is providing some assistance in these matters.

Problems of Ionospheric Propagation

In December, 1962, Dr. M. Waldmeier, Chairman of Commission Vc of URSI, requested from his commission members comments or data bearing on the question, "How can radio-astronomical observations of the sun be usefully applied for either short or long-term predictions of ionospheric propagation conditions?" On page 1 of his letter he listed the following three questions:

1. What are the desirable characteristics of a solar index which render it most applicable to ionospheric propagation?

2. What solar phenomena, which can be observed in a sufficient objective manner, will provide a more useful index of activity for application to ionospheric propagation than relative sunspot-numbers?

3. What ionospheric characteristics, which can be determined in a sufficient objective manner wherever observed, may be usefully employed as a basic index for ionospheric propagation?

He indicated that two indices had already been proposed:

1. A daily index of the solar radio-emission on 3,000 Mc/s.

2. A triple, 3-hourly index of the intensity of the solar radio-emission on 200 Mc/s. It gives the flux-density, the variability and the burst-energy.

On page 2 of his letter Dr. Waldmeier stated that the "following questions are still open."

1. What solar radio-events may be used for reliable predictions of short-term variations in ionospheric storms?

2. What relationships exist between solar radio-phenomena and ionospheric propagation conditions?

3. What is the relationship between the intensity of solar radiation at radiofrequencies and ionospheric propagation conditions?

4. What is the possibility of establishing an index of solar activity based upon radio observations, which can be usefully employed as a basic index for ionospheric propagation?

5. Which solar radio-events can be used for short-term predictions of ionospheric variations?

6. For which basic solar radio-index is it possible to give long-term predictions, that can be used for long-term predictions for ionospheric propagation?

In response to this inquiry we prepared the accompanying reply and diagrams, which are included herewith because ionospheric problems, though not identical with geomagnetic problems, are closely related to them.

Excerpts from Letter of December 26, 1962,
to M. Waldmeier

With respect to Items 1, 2, and 3 on page 1 of your letter, it is our judgment that only a person actively engaged in ionospheric research can give a meaningful reply. For many years we have plotted the ionospheric "quality figures" reported in Part B of the CRPL F Series of the U.S. National Bureau of Standards, in juxtaposition to solar data. We have not given serious study to this material because we have been unsure of the meaning and validity of the "quality figures." Several days ago I spoke to Miss Virginia Lincoln at CRPL and asked if she knew of any other ionospheric index that we could use. Her reply was, "No, unless we became deeply enmeshed in ionospheric matters." Until a satisfactory ionospheric index or measurement is developed, efforts to find solar indices useful for prediction will be severely hampered.

We note on page 2 the two indices already proposed. For many years we have kept track of solar radio emissions in the neighborhood of 3,000 Mc/s. In our judgment this quantity varies in a manner so similar to relative sunspot numbers that if one is satisfactory for prediction, the other also should be satisfactory; if one fails, the other should fail. If it is considered desirable to have a directly measured quantity rather than a derived index, such as the relative sunspot number, then the 3,000 Mc data probably could be substituted for sunspot number without either harm or improvement. The second index relating to 200 Mc/s gives significantly different information from the 3,000 Mc data and relative sunspot number. It may or may not assist in the ionospheric problems. Until we are more sure of an ionospheric index and the problems of ionospheric propagation for which an index is sought, we cannot comment on the suitability of the 200 Mc data.

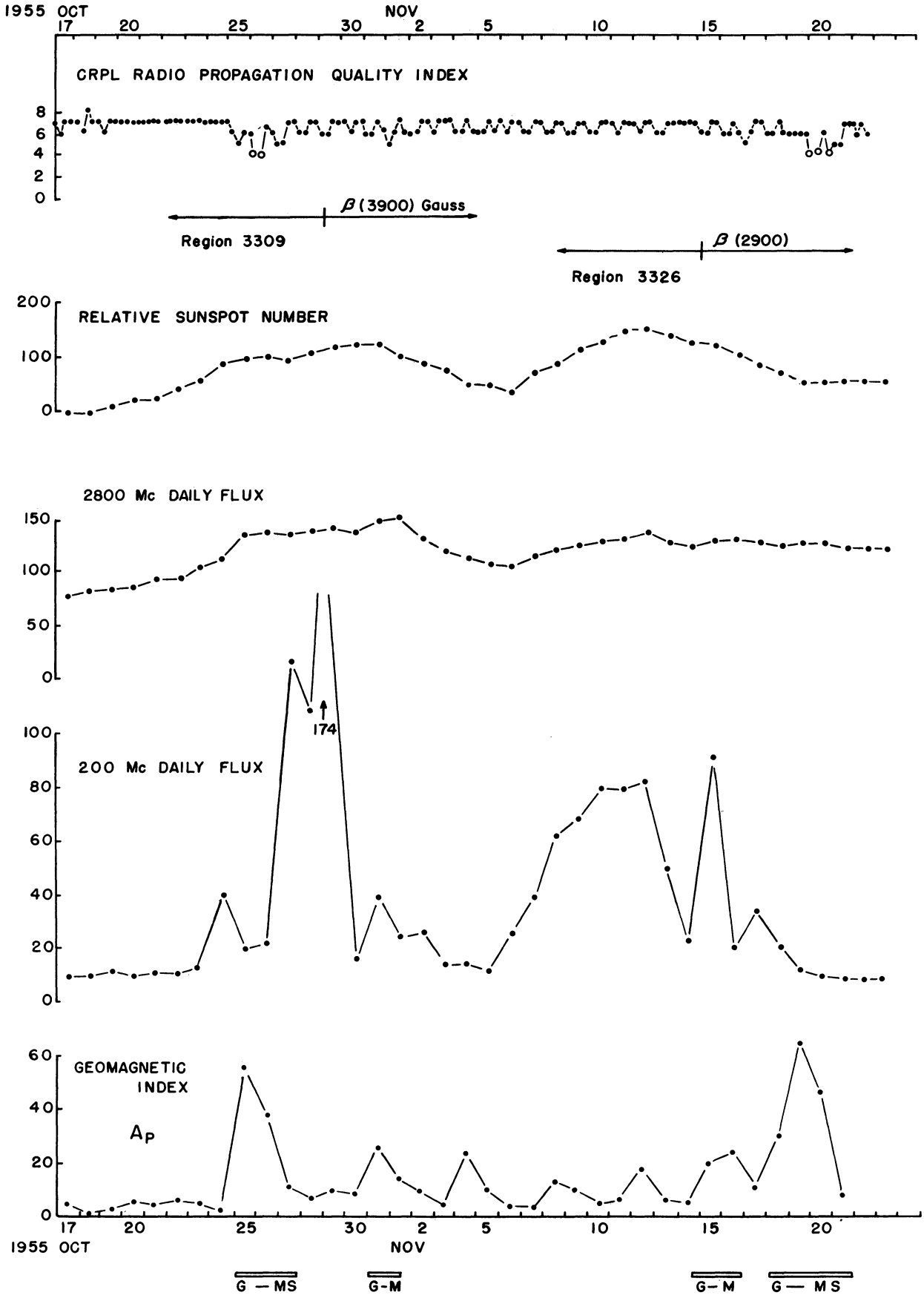
The six questions on page 2 raise many problems. Again, one of our principal difficulties is in trying to distinguish between problems stated in terms of ionospheric phenomena and the somewhat related problems in terms of geomagnetic disturbances. The two are not identical.

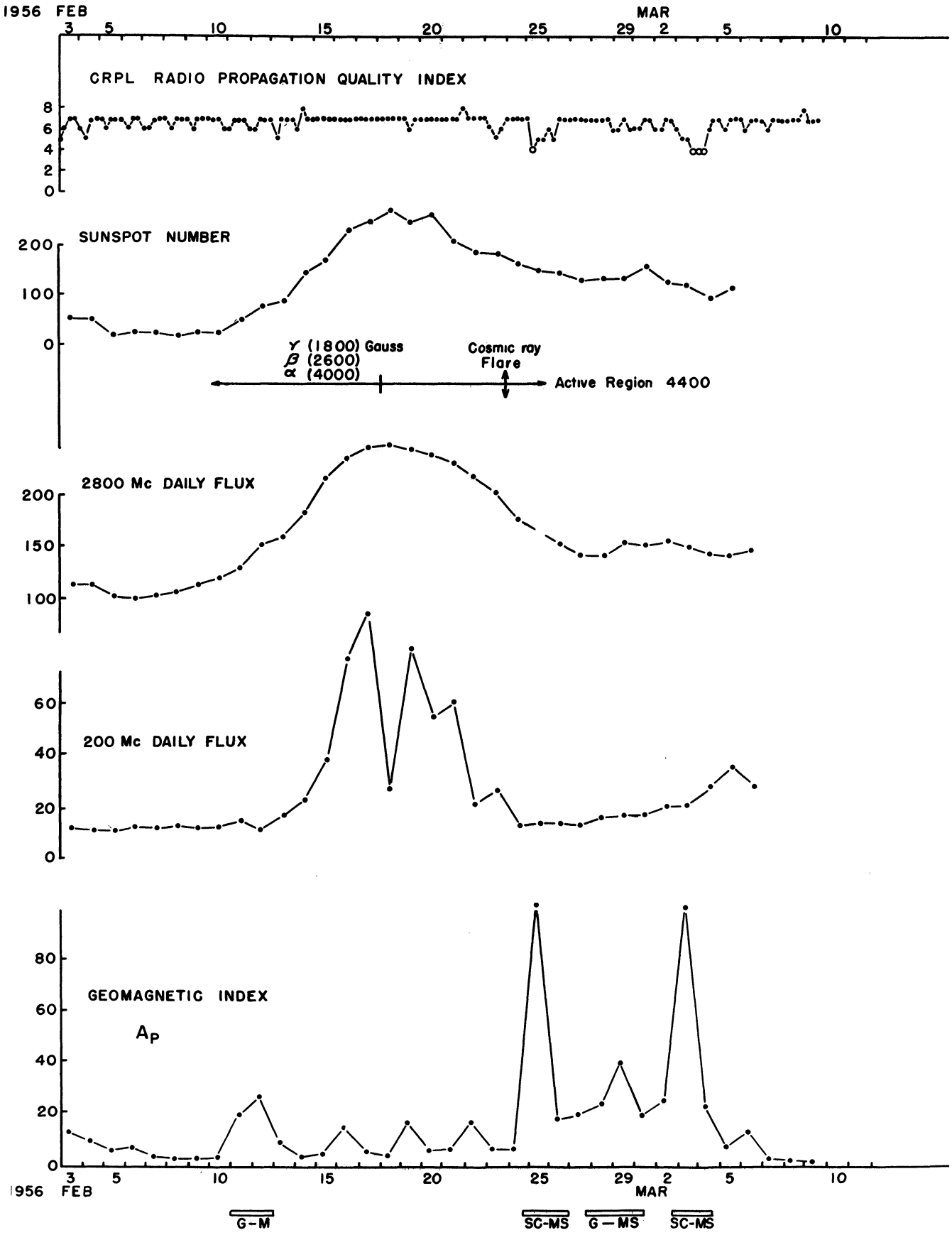
In an effort to provide specific assistance with respect to question 5 and problems relating to short-term predictions of ionospheric variations, we have prepared charts of solar and ionospheric data for six intervals. Two refer to the premaximum phase of the present solar cycle, two to times near maximum, and two to the post-maximum phase. The charts show the CRPL ionospheric quality figure at the top. The low points (open circles) are the times of very poor

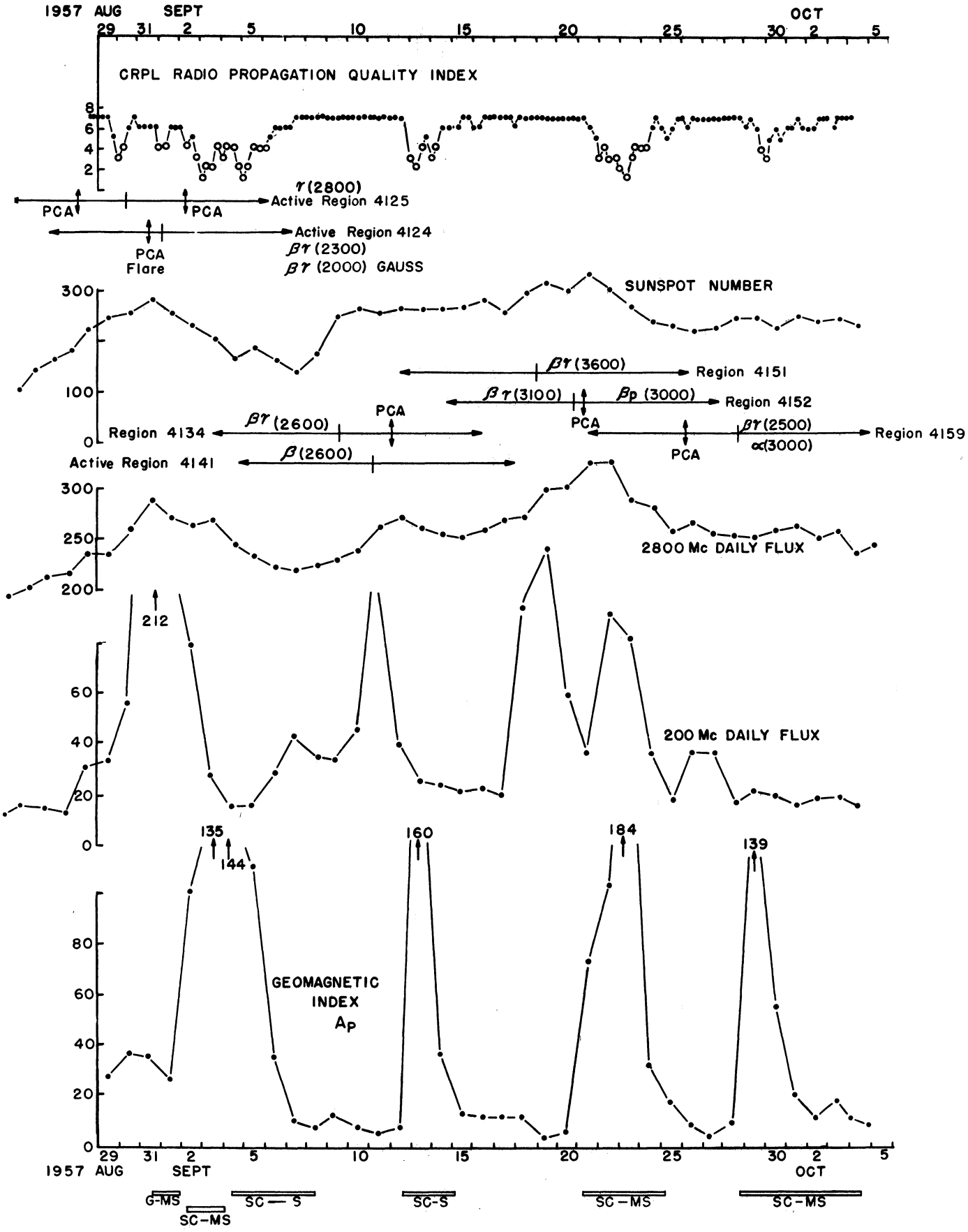
quality and are the times, presumably, that one desires to predict. Beneath the ionospheric index is given the relative sunspot number, 2800 Mc daily flux, 200 Mc daily flux, and the geomagnetic index Ap. Near the top of the page there is information about the time of transit of the principal plages and their associated spots. Near the bottom of the page the times, type, and severity of geomagnetic storms are indicated.

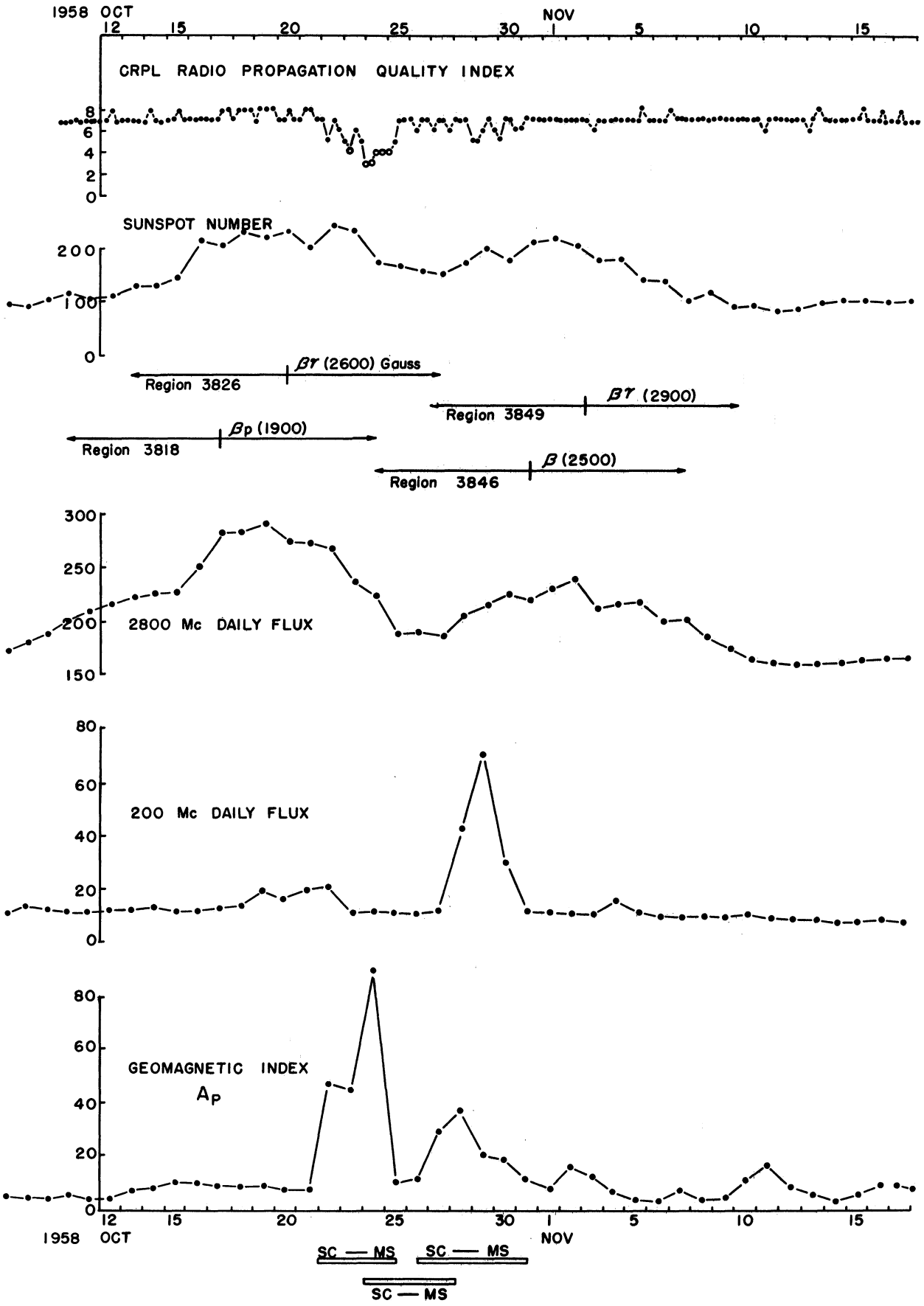
The charts illustrate primarily the complexity of the problem. They have been selected to show that there are (a) cases when strong centimeter and/or meter radiation accompanies or precedes disturbed ionospheric conditions (successes) and (b) cases when there is almost an anti-correlation (failures). The similarity between changes in the relative sunspot number and 2800 Mc flux is clearly shown. In some of the apparently "successful" cases (especially September, 1957), individual flares associated with polar cap absorption and its attendant phenomena may be the responsible agents rather than circumstances related to the day-to-day radiofrequency emission.

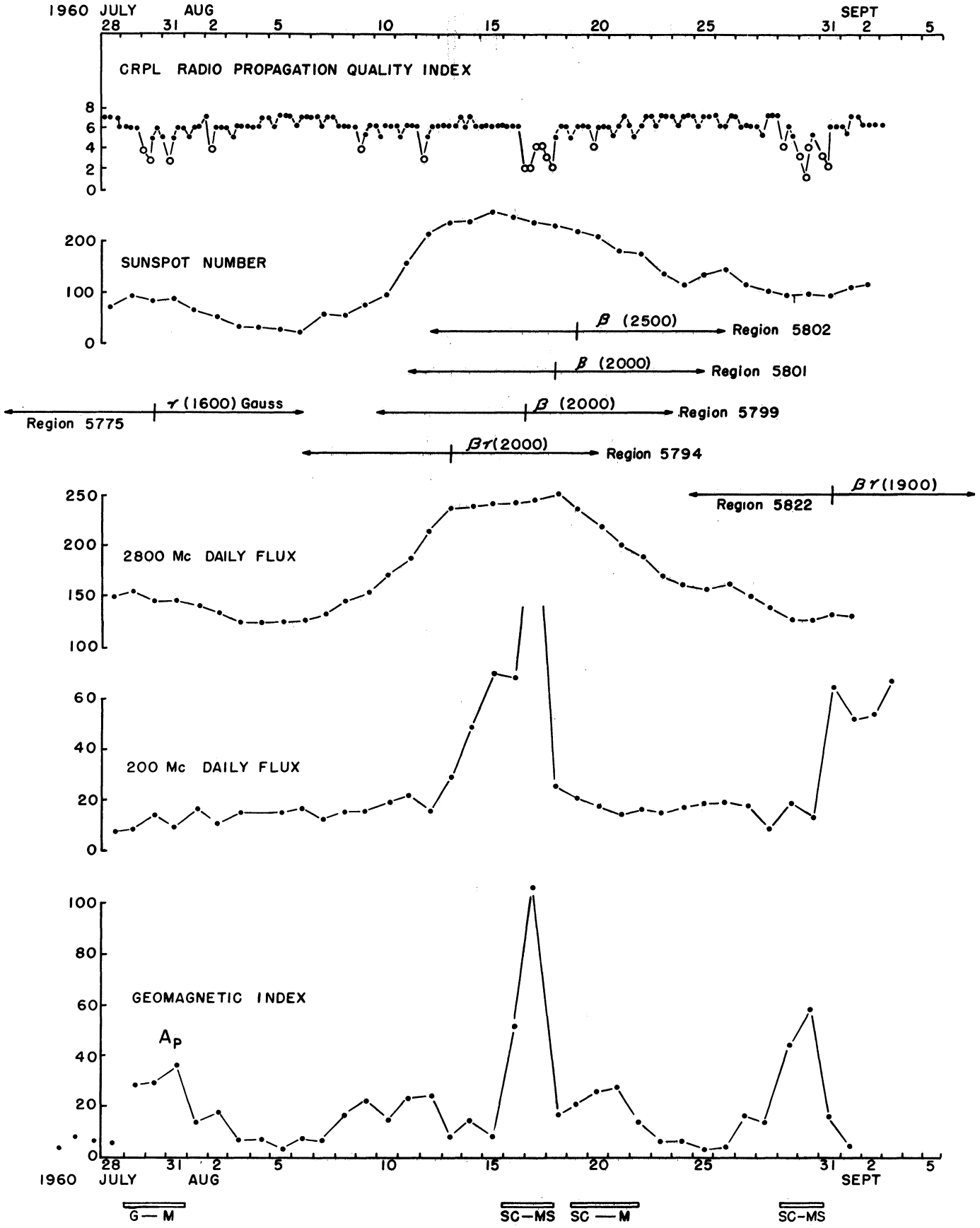
In our judgment much more basic research is needed before recommendations regarding solar indices useful for short-term ionospheric predictions can have real value.

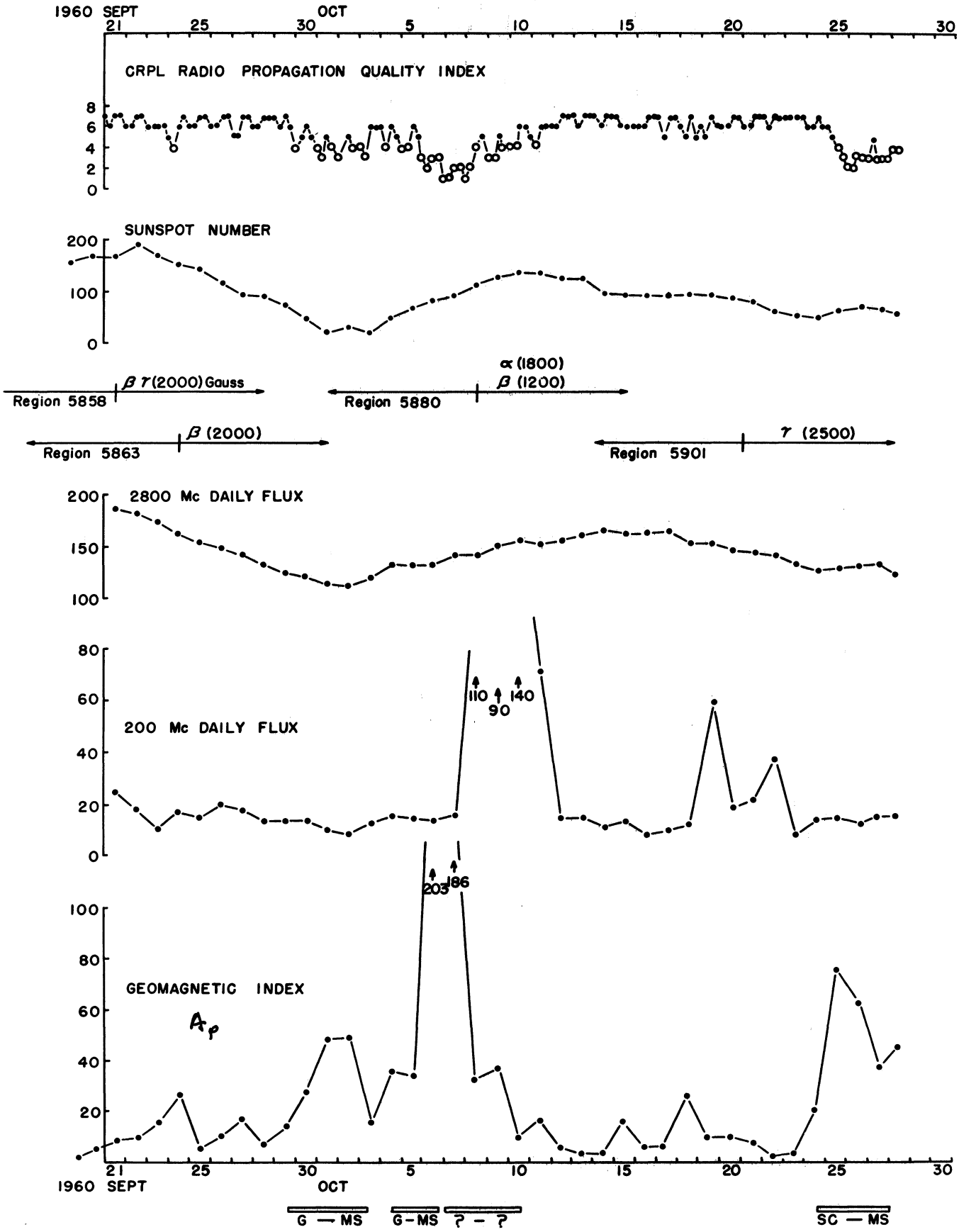

1955 OCT
17
20
25
30
NOV
2
5
10
15
20
CRPL RADIO PROPAGATION QUALITY INDEX
8
6
4
2
0
β (3900) Gauss
Region 3309
β (2900)
Region 3326
200
RELATIVE SUNSPOT NUMBER
100
0
2800 Mc DAILY FLUX
150
100
50
0
174
100
200 Mc DAILY FLUX
80
60
40
20
0
60
GEOMAGNETIC INDEX
A_P
40
20
0
17
20
25
30
2
5
10
15
20
1955 OCT
NOV
G — MS
G-M
G-M
G — MS


1956 FEB
MAR
3 5 10 15 20 25 29 2 5 10
CRPL RADIO PROPAGATION QUALITY INDEX
8
6
4
2
0
SUNSPOT NUMBER
200
100
0
γ (1800) Gauss
β (2600)
α (4000)
Cosmic ray Flare
Active Region 4400
2800 Mc DAILY FLUX
200
150
100
200 Mc DAILY FLUX
60
40
20
0
GEOMAGNETIC INDEX
Ap
80
60
40
20
0
3 5 10 15 20 25 29 2 5 10
1956 FEB
MAR
G-M
SC-MS
G—MS
SC-MS


1957 AUG
SEPT
OCT
29 31 2 5 10 15 20 25 30 2 5
CRPL RADIO PROPAGATION QUALITY INDEX
8
6
4
2
γ(2800)
Active Region 4125
PCA
PCA
Active Region 4124
βγ (2300)
βγ (2000) GAUSS
PCA
Flare
SUNSPOT NUMBER
300
100
0
βγ (3600)
Region 4151
βγ (3100)
βp (3000)
Region 4152
PCA
PCA
Region 4134
βγ (2600)
PCA
βγ (2500)
Region 4159
α(3000)
Active Region 4141
β (2600)
300
250
200
2800 Mc DAILY FLUX
212
60
40
20
0
200 Mc DAILY FLUX
135
144
160
184
139
80
60
40
20
0
GEOMAGNETIC
INDEX
Ap
29 31 2 5 10 15 20 25 30 2 5
1957 AUG
SEPT
OCT
G-MS
SC-MS
SC — S
SC-S
SC-MS
SC-MS


1958 OCT
12
15
20
25
30
NOV
1
5
10
15
CRPL RADIO PROPAGATION QUALITY INDEX
8
6
4
2
0
SUNSPOT NUMBER
200
100
0
βγ (2600) Gauss
Region 3826
βγ (2900)
Region 3849
βp (1900)
Region 3818
β (2500)
Region 3846
300
250
200
150
2800 Mc DAILY FLUX
80
60
40
20
0
200 Mc DAILY FLUX
80
60
40
20
0
GEOMAGNETIC INDEX
Ap
12
15
20
25
30
1
5
10
15
1958 OCT
NOV
SC — MS
SC — MS
SC — MS


1960 JULY
AUG
SEPT
28
31
2
5
10
15
20
25
31
2
5
CRPL RADIO PROPAGATION QUALITY INDEX
8
6
4
2
0
200
100
0
SUNSPOT NUMBER
β (2500)
Region 5802
β (2000)
Region 5801
γ (1600) Gauss
Region 5775
β (2000)
Region 5799
βγ(2000)
Region 5794
βγ(1900)
Region 5822
250
200
150
100
2800 Mc DAILY FLUX
60
40
20
0
200 Mc DAILY FLUX
100
80
60
40
20
0
GEOMAGNETIC INDEX
Ap
28
31
2
5
10
15
20
25
31
2
5
1960 JULY
AUG
SEPT
G — M
SC—MS
SC — M
SC-MS


1960 SEPT
21
25
30
OCT
5
10
15
20
25
30
CRPL RADIO PROPAGATION QUALITY INDEX
8
6
4
2
0
SUNSPOT NUMBER
200
100
0
α (1800)
β (1200)
β γ (2000) Gauss
Region 5858
Region 5880
β (2000)
Region 5863
γ (2500)
Region 5901
200
150
100
2800 Mc DAILY FLUX
80
60
40
20
0
200 Mc DAILY FLUX
110
90
140
203
186
100
80
60
40
20
GEOMAGNETIC INDEX
Ap
1960 SEPT
OCT
G — MS
G-MS
? - ?
SC — MS

ORA PROJECT 03942

JET INTERACTION

Quarterly Progress Report

October 1 to December 31, 1962

Design work on the additional nozzle for the high speed tunnel system was begun. This axisymmetric nozzle is intended to provide uniform parallel flow at a Mach number of 8.0. The centerline Mach number distribution has been chosen as that given by the equation

$$h_o = 1 + 12.788 \left(\frac{X}{L}\right)^2 \left[6 - 8\frac{X}{L} + 3\left(\frac{X}{L}\right)^2\right]$$

where h_o is the area ratio parameter

$$h_o = \sqrt{\frac{(M_o^2 + 5)^3}{216\, M_o}}$$

and L is the distance from the throat to the beginning of the cone of uniform flow. The axial distributions of Mach number and area ratio parameter are plotted in Fig. 1. Figure 2 shows streamlines of the potential flow having this centerline Mach number distribution, as calculated by the Friedrich's method. One of these streamlines, or a streamline intermediate between the two, will be used as the perfect fluid contour.

Streamlines in the supersonic portion of the nozzle will be calculated by the method of characteristics. The choice of which streamline to use for the perfect fluid core will be based on minimum nozzle length and freedom from regions of compression.

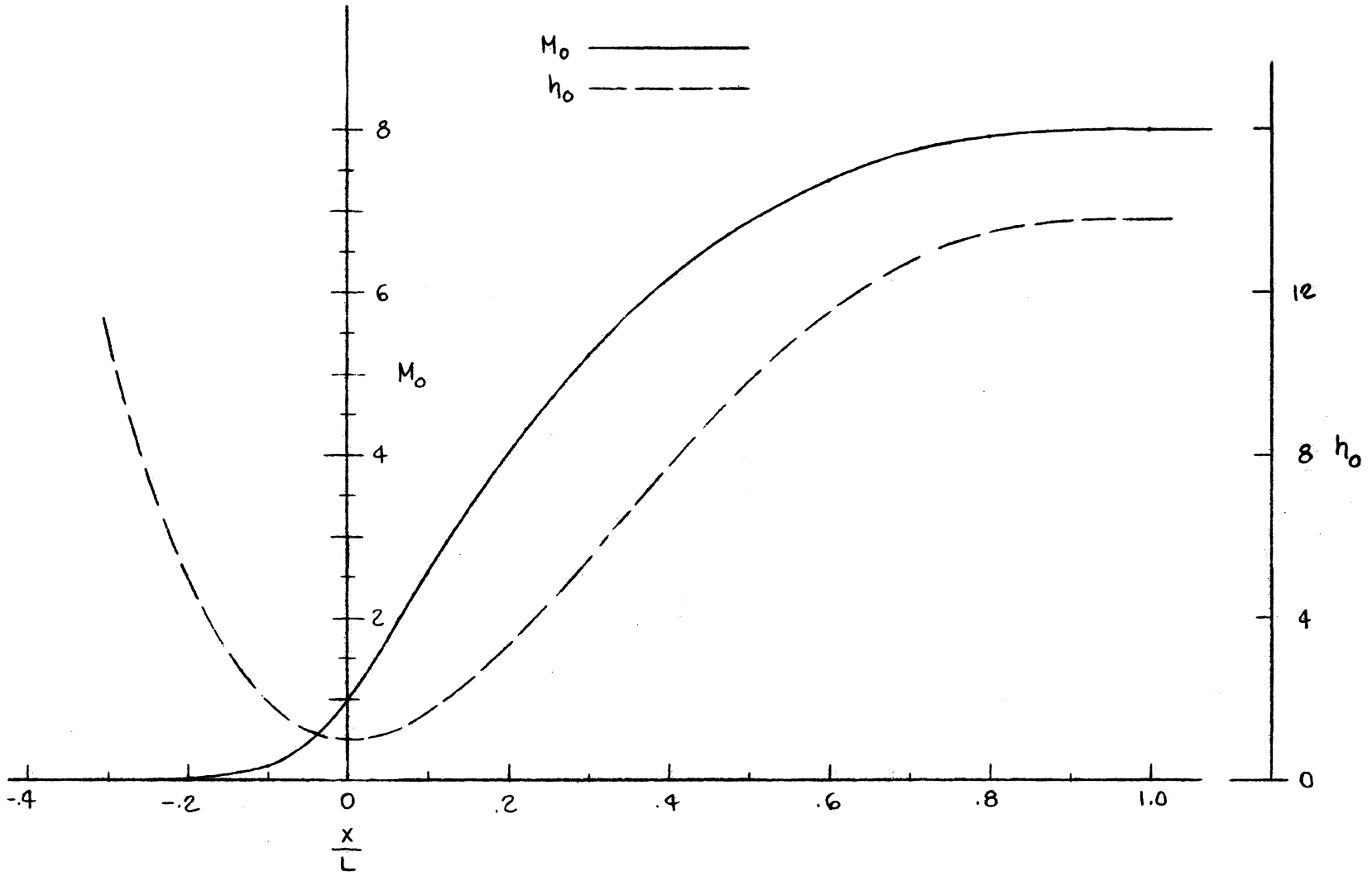


Fig. 1. Axial distribution of Mach number and area ratio parameter along nozzle centerline.

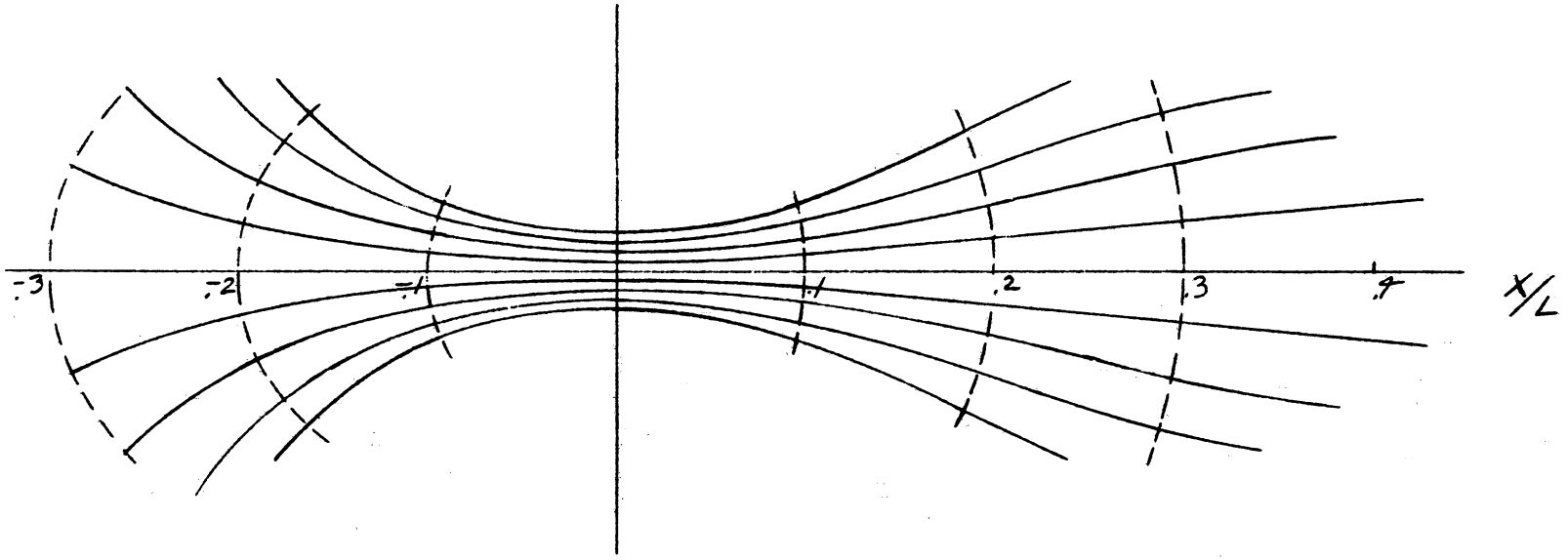


Fig. 2. Streamlines and potential lines for prescribed axial Mach number distribution.

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Quarterly Reports

ORA PROJECTS 03941 AND 03942

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June 1963

ORA PROJECT 03941

STUDIES OF VARIATIONS IN THE EARTH'S MAGNETIC FIELD DUE TO SOLAR ACTIVITIES

Quarterly Progress Report

January 1, to March 31, 1963

JANUARY 1, TO MARCH 31, 1963

PERSONNEL

Mr. Frederick Stewart continues to be employed half-time on this project. Miss Hedeman and Dr. Prince have also been giving extended consideration to the review of the problems of solar terrestrial relationships for the present and immediately preceding solar cycles. Dr. Prince is expecting to spend the months of March through May, 1963, at solar observatories in western Europe where she will discuss with European colleagues mutual problems relating to solar terrestrial matters. She will also attend the Second Assembly of IQSY in Rome, March 18-22.

Dr. C. W. Allen, Chairman of Inter-Union on Solar Terrestrial Relationships, came to the McMath-Hulbert Observatory in January under the sponsorship of this contract.

INSTRUMENTS

The APL-5 Mc WWV recorder continues to supply records of interest and value.

STUDIES

Recurrent Geomagnetic Storms

Dr. Allen reviewed the extensive data at the McMath-Hulbert Observatory which brings together observed optical events and geomagnetic storms. His long experience in trying to relate that which is seen or observed on the sun with that which happens in the earth was of great value to the staff at the Observatory, as well as was his encouragement with respect to the studies now in progress. The relationships are far from clear-cut and the chance of real progress is still small, but Dr. Allen felt that progress is being made. Dr. Prince and Miss Hedeman have been invited by Dr. Allen to prepare a manuscript for the review report of his committee on the Problem of Differentiation of Flares with respect to Terrestrial Effects.

Solar Minimum

In order to be able to participate meaningfully at the forthcoming assembly of IQSY in Rome, we have reviewed in detail solar and geomagnetic phenomena of the three years centered on 1954, minimum, in the preceding cycle. It is clear from the records that the years of minimum provide great opportunities for perhaps clearing up of some of the ambiguities that exist in solar terrestrial relationships but that the months when the sun is truly simple are few in number; perhaps only three, and certainly not more than six.

ORA PROJECT 03942

JET INTERACTION

Quarterly Progress Report

January 1, to March 31, 1963

JANUARY 1, TO MARCH 31, 1963

Work continued on the design of the Mach number 8.0 nozzle for the high speed tunnel system. The nozzle is being designed for minimum length (consistent with the requirement for uniform flow at the exit), in order to promote a laminar nozzle boundary layer, which in turn will insure a low turbulence level in the test section.

With a short nozzle length, great accuracy is required in the contour calculations. It was therefore decided to use the Friedrichs method for the transonic part of the flow, in place of the unrealistic assumptions usually employed. Expressions were derived for the coefficients of the Friedrichs series out to the third terms. The centerline area ratio distribution which was found to give satisfactory streamline shapes in both subsonic and supersonic parts of the nozzle (see the preceeding progress report) was modified slightly, in order to give constant velocity along a potential line at the nozzle inlet. (A porous metal filter of constant thickness will be placed at this potential line.) The calculations by the Friedrichs method have been programmed for the IBM 7090 computer, using the Fortran modification known as MAD (Michigan Algorithmic Decoder).

A new programming of the method of characteristics for axisymmetric flow has been made for the IBM 7090 computer, since no existing program could be found that would accept the centerline area ratio distribution used in the calculation of the transonic flow by the Friedrichs method. The new program uses the characteristic equations in the convenient form presented by Squires, Roberts, and Fisher in Navord 3995. In order to increase the computational accuracy, second order approximations to the values of the flow variables between net points are used, instead of the usual linear approximations. The program is being checked by applying it to source flow and comparing the results with the analytical solution.

Most of the design work for the test section and the connections to the existing system was completed. The supporting structure for the nozzle-test section assembly was built, and some of the inlet piping was assembled.

The hollow sting balance used in measuring jet interaction forces was modified to give more accurate results and to permit the use of internal cooling in hypersonic tests, if desired. The modification consisted principally of two concentric tubes which were installed inside the sting. The innermost tube supplies air to the jet. The second tube divides the remaining annular passage into two passages for the cooling air or water, one for the inlet and the other for the outlet.

A new solenoid valve of minimum size was connected close to the downstream

end of the sting, for starting or stopping the flow of jet air. New hoses for the jet air and for the coolant, made of high temperature resistant materials, were installed. A new set of sixteen strain gages was mounted on the sting.

The checkout and calibration of the new balance system is continuing. Already it has been found that the modifications eliminate the lag and drift problems that were the principal sources of error in the old system. (The old system had a lag of up to four seconds, from the time the jet air solenoid valve was closed until the jet stagnation pressure was reduced to ambient. This lag was due to the much larger volume between the jet orifice and the solenoid valve in the old system. During this lag period the strain gages were changing temperature because of the change in cooling conditions on the inside of the thin-walled sting, which resulted in a drift of some of the strain gage outputs. Consequently, there was some uncertainty in the change of force due to turning-off the jet.)

The jet flap report was published as CM-1031.