N65-21300
(ACCESSION NUMBER) (THRU)
65 1
(PAGES) (CODE)
CR-57992 29
(NASA CR OR TMX OR AD NUMBER) (CATEGORY)
FACILITY FORM 602

# PROJECT PREP
# STUDY OF THE APPLICATION OF PERCEPTRONS FOR PREDICTION OF SOLAR FLARES
# SOLAR FLARE FORECASTING WITH A RECOGNIZING AUTOMATON

Prepared For:
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

FINAL REPORT FOR PHASE II

By: C.M. Theiss, A.E. Murray

Contract NAS 5-3825
CAL Report No. VS-1945-X-1
February 1965

CORNELL AERONAUTICAL LABORATORY, INC.
OF CORNELL UNIVERSITY, BUFFALO, N. Y. 14221

CORNELL AERONAUTICAL LABORATORY, INC.
BUFFALO, NEW YORK 14221

# FINAL REPORT FOR PHASE II
# PROJECT PREP
# STUDY OF THE APPLICATION OF PERCEPTRONS FOR PREDICTION OF SOLAR FLARES
# SOLAR FLARE FORECASTING WITH A RECOGNIZING AUTOMATON

CAL REPORT NO. VS-1945-X-1

CONTRACT NAS 5-3825

FEBRUARY 1965

PREPARED BY:
*C.M. Theiss*
*A.E. Murray*

C. M. Theiss
*C.M. Theiss*
*Project Engineer*

APPROVED BY: T. R. Babcock
*T.R. Babcock, Head*
*Experimental Techniques Section*

*W.S. Holmes, Head*
*Computer Research Department*

Prepared for:
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

TABLE OF CONTENTS

## LIST OF TABLES



## LIST OF FIGURES

## ABSTRACT

A multiple factor classification technique, of a sort resembling "learning machines" which have been studied as pattern recognition automata, has been experimentally applied to forecasting solar flares likely to have produced proton showers in the interplanetary space. Type IV radio emission was used as a criterion for this likelihood since (a) the two phenomena are highly correlated, and (b) the radio emission is likely to be detected although the high energy protons may not reach the earth. In Phase I, a forecast accuracy of 77 percent was achieved in predicting the occurrence of spectral type IV flare in the next four days within a given region of the sun. In Phase II, reported here, effort has been concentrated on refining both the data and the experimental method whose preliminary tests in Phase I warranted further study. While an improvement in forecasting quality and range has been sought, a secondary goal has been toward a meaningful physical description of the development of an active center by discovering the identity and the interaction of observable phenomena preceding radar flares. In Phase II, progress has been made toward eliminating a considerable amount of useless bias and variation in solar data from which predictions must be made, and this effort has incidentally resulted in a small improvement in prediction quality. More important, small systematic improvements in prediction quality resulting from a succession of refinements in technique indicate that the over-all research plan seems to be pointed in the right direction. Experience gained in this phase (from failure as well as success) has helped to define a future course seeking better predictions and an improved descriptive understanding of the related pre-flare events.

## 1.0 INTRODUCTION AND BACKGROUND

This is the final report of the second phase of the project entitled, Proton Event Prediction (hereafter referred to as PREP II), Contract No. NAS 5-3825, conducted by Cornell Aeronautical Laboratory, Inc. for National Aeronautics and Space Administration. This work is a continuation of a study initiated by project PREP I under Contract NAS 5-3262 by CAL for NASA which was documented in a final report[1] dated January 1964.

The objective of Project PREP is to apply perceptron classification techniques to the problem of predicting solar flares as discussed and outlined in the final report for Phase I. In order to conduct specific prediction experiments and gather the prerequisite data prior to the experiments, the problem was restricted to answering the following question:

"Given a four-day history of data on each active solar region submitted, will that region produce a type IV radio emission flare, meeting the assigned intensity-duration criterion within the next four days?"

The active solar regions considered are those identified by the High Altitude Observatory, Boulder, Colorado, and for which sufficient data has been published by the various observatories throughout the world.

### 1.1 PREP I Procedure and Results

A major portion of the efforts of Phase I was devoted to a thorough search of available data, both published and unpublished, and a study of each of those measurements pertinent to solar activity which have been recorded for a sufficient number of solar regions over a sufficient period of time to determine which show qualities as predictors of type IV radio-emission flares.

The specific items of data selected are described and listed in Section 2.0. These consisted of general data which were applicable to the overall region and did not change over a single passage across the solar disk and daily data which changed with time. Several samples from each region passage were available for experimental purpose. Each sample consisted of a single day of a given region passage for which a set of data for the previous four days is known and for which it is known whether a type IV radio emission flare occurred within the following four days or not, to be referred to hereafter as FLARE or QUIET samples, respectively.

These data were punched onto IBM cards for processing on CAL's IBM 704 digital computer. Each datum value was issued as a property value and/or used as parameter in calculating more sophisticated property values. A total of 212 properties was used for evaluation in a perceptron programmed on the 704 computer.

In Phase I, the samples were divided into two groups, one for training and one for prediction testing, and used for a prediction experiment in the perceptron classification program. The training set consisted of 31 FLARE and 13 QUIET samples while the test set consisted of 30 FLARE and 14 QUIET samples. In the experiment, 25 of the 30 FLARE and 9 of the 14 QUIET samples were properly classified. Although this was considered to be a modest prediction (77 percent overall accuracy), it showed sufficient promise to continue the work.

## 1.2 PREP II Procedure

The efforts of Phase II consisted of (a) increasing and refining the available data measurements in order to increase the knowledge of solar activity immediately preceding the production of a type IV radio-emission flare, and (b) to apply this knowledge to the task of establishing four-day prediction forecasts of this type of flare.

Since there are many more active region passages which produce no type IV radio-emission flares than do, and the Phase I data set does not contain many all QUIET region passages, the literature was searched for more all-QUIET, solar region passages. Section 2.0 is a discussion of the new set of data including the data gathered in both Phase I and Phase II.

The several means of refinement, some of which were included in later prediction experiments, are discussed in Section 3.0.

It was not possible to obtain all measurements for all region passages. Therefore, a method was developed and reported in Section 3.1 to fill in the missing data by comparing the same data in similar situations in other region passages.

The data measurements are obtained by observations of the sun which appears as a flat disk when in actuality it is a sphere. Thus, the measurements tend to fall off in value (are foreshortened) near the limbs of the solar disk. An empirical method is developed in Section 3.2 which corrects this effect. The advantages of this empirical method over an analytic approach is that the analytic function may be unknown and the method includes all systematic anomalies which may occur in the data as a function of displacement from the Central Meridian Point (CMP). Thus, the resulting corrections are often referred to in this report as the "foreshortening, etc." corrections.

Section 3.3 describes one procedure whereby a property (i.e., an observed measurement or a parameter calculated from one or more observed measurements) may be evaluated for its FLARE predicting qualities, and at times, even when the prediction point is imbedded in a "noisy signal."

Section 3.4 is a discussion of possible methods of correcting solar reports to include unreported flares. The latter are suspected to exist due to periods when the sun is not under observation due to weather conditions, and other reasons for not making observations.

The procedure of processing the raw data (that data taken from the literature which are measured by the various observatories) into the indicator properties, which is very similar to that used in Phase I, is briefly discussed in Section 4.0. Sections 5 and 6 are descriptions of the prediction experiments conducted in Phase II and a discussion of the experimental results, respectively. Section 7 is a discussion of the accomplishments of Phase II efforts, and Section 8 recommends future efforts that might be applied to obtain a greater knowledge of pre-FLARE solar activity and to more effectively forecast type IV radio-emission flares. The experiments designed in Phase II were conducted on an IBM 7044 digital computer at CAL using a single computer program. In order to avoid the necessity of redesigning the computer program for each new experiment (the specification of which, in most cases, was not known at the time of program design), considerable flexibility was built into the program through the use of control and data cards. A detailed description of the usage of the prediction program is given in Appendix A.

## 2.0 FURTHER DATA GATHERING

The data set used in PREP I consisted of the data of 28 HAO region passages from which 61 FLARE and 27 QUIET samples were available.

Since most active region passages produce no FLARES, and the variability of QUIET passages (passages in which no FLARE is produced) may very likely be greater than FLARE passages, the available literature was searched further to add more QUIET passages to the data set. The test set now consists of 54 region passages from which 61 FLARE and 297 QUIET samples are available. Table I lists the HAO region passages together with the number of samples from each and indicates the usage for each experiment.

Tables IIa and IIb list the various measurements desired for each region, and the format in which they are listed on the IBM cards for insertion into the computer program. Table IIa is the general data, i.e., data for the region passages which do not change during one passage across the sun's disk. Table IIb is the daily data, i.e., data which change with time and for which measurements are available on a daily basis.

Where certain datum points could not be entered due to lack of information, the entry columns on the input cards were left blank.* The computer would later recognize these "holes" in the data and fill them in a statistical fashion. (See Section 3.1.)

---

*In a number of cases where isolated data were desired and not available, but sufficient data was available from adjacent days, these data were given values by interpolation prior to punching on cards. These datum points, therefore, are not considered as "holes" at the time of computation.

## 3.0 DATA REFINEMENT

The chief deterrent to an attempt at understanding flare mechanisms, active region development, or to systematically and reliably predicting localized events of solar activity, rests in the poverty of the generally available data. It is reasonable to question whether and to what degree the data which is available from routine solar observations is pertinent to the problems of flare prediction. If, as is suspected, at least some of these data are pertinent, they suffer severely from perturbations, errors, and uncertainties which contribute a great deal of noise. Some general remarks by Solomon Golomb in a recent article (Ferreting Signals Out of Noise, Int'l. Sci. and Technol., Oct. '63) appear to apply very well to the problem of finding meaningful relationships between flares and other sunspot phenomena. The relationships appear to be "weak phenomena hidden in a formidable background," and the investigator's problem is "the extraction of a needle of signal from a haystack of noise." Therefore, it seems obvious and crucial that every reasonable effort should be made to "smooth" and refine the solar data, correcting for known errors (due to foreshortening, etc.) and adjusting as far as possible for variations caused by incidental and irrelevant influences (such as observing conditions).

A number of data refinements are investigated. These are:

a. A better method for filling in missing data which is unavailable for various reasons.

b. Adjustment of reported daily measures to correct for foreshortening and other systematic perturbations which are functions of distance from CMP (defined as "foreshortening, etc." corrections).

c. A study of the plots of daily measurements before the occurrence of the first FLARE in a passage (defined as FLARE profiles).

d. A study of the effects of "no-seeing" time, i.e., periods of time when the sun is not being observed.

Each of these items is discussed in one of the following sections.

### 3.1 Filling of Missing Data

As stated in Section 2.0, some of the input data is missing. In fact, no region passage in the test data is complete in all respects.

In Phase I, each property was standardized over all samples by first subtracting its mean and dividing by its standard deviation. Then, when a particular datum was missing, it was filled in with the standardized mean, zero.

A more operational procedure was used in most of the experiments of Phase II. Here, the overall mean and standard deviation are first calculated for each property using all samples of the training subset only. In addition the mean for each class, i.e. QUIET, FLARE 1 day hence, ...., FLARE 4 days hence, is also calculated. Then during normalization of the data (subtraction of the overall mean and division by the standard deviation), a missing datum is filled with the normalized mean of the given class during training and by zero (the effective overall mean) during prediction. In this manner, the best value is used to replace holes in the data in each case without assuming advance knowledge.

Non-quantitative objective data should not be normalized in the standard sense as above. For example, each region is given one of nine possible Zurich classifications, A thru J. (I is not used). Since this subjective property cannot be given a graduated quantitative scale, each classification is treated as a separate binary property. However, missing data can still be treated in an appropriate manner. During data preprocessing, a score is maintained for the various Zurich classes for each flare classification (QUIET, FLARE 1-day hence, etc.). Then, when the Zurich classification is missing, the Zurich class with the highest score for the sample's class is assigned. For the prediction phase (testing), the Zurich class with the highest overall score found during training is assigned when the sample class and Zurich class are unknown.

3.2 Foreshortening Effects

It is a common observation that all quantitative daily measures of sunspot groups tend to be relatively small at the East limb, climb to a maximum around CMP,* and decrease as the region approaches the West limb. While the effect stems from errors imposed by the projection on a spherical surface onto a plane, other factors such as the unknown but finite altitude or thickness of visible chromospheric features (e.g., sunspots or flares) prevent the accurate use of a simple $\frac{\sin \theta}{\theta}$ rule. Because of the impracticality of attempting an analytical correction,** historical data is used to obtain an empirical correction.

The succession of daily measured values of any regional property, plotted as a function of time or angle, $\theta$, from CMP, is what we have called a passage profile. (As an example, see Figure 1.)

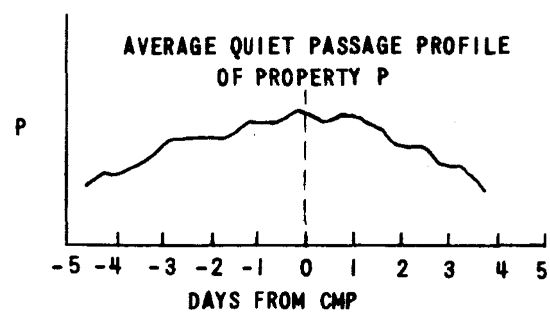


Figure 1 AVERAGE QUIET PASSAGE PROFILE OF PROPERTY P

The passage profile for any one property and any one region, even if QUIET, is usually a bumpy curve, having day to day fluctuations, due to regional activity, superimposed on a (probably) smooth rise and fall due to "foreshortening, etc.".*** In order to find the true shape of the "foreshortening

*CMP is the abbreviated form for Central Meridian Point.

**Since authorities differ considerably on flare size corrections, an immediate "true" solution is not likely. Also mixed data may have different corrections already applied.

***"Foreshortening, etc." is used as a collective term to include other factors which may have biased the results as well as foreshortening which are functions of meridian displacement from CMP.

etc." error, which is due merely to viewing angle, so that the error may be removed from the observed passage profiles, means must be employed to combine a number of QUIET region profiles so as to smooth out the internal activity fluctuations and allow extraction of the aspect angle error component.

Averaging a group of QUIET region profiles is a suitable procedure, but is only fully acceptable if these profiles are each first normalized. For any one property, P, one finds considerable variation from region passage to region passage in the absolute size of the profiles. Hence, it is intended to characterize the "size" of each individual region passage profile by an average of its values observed at and near CMP, where little or no aspect angle correction is needed. Then each of the profiles will be adjusted to a standard size, by applying to the measured property values a multiplying factor $P_s/P_m$, where $P_m$ is the average P-max, observed at CMP, and $P_s$ is the standard P-max to which all profiles will be adjusted at their midpoints. After such normalizing, the averaging of a group of 25 or so passage profiles for one property should produce a relatively smooth curve.

Residual bumps in this curve may be smoothed by eye or by any simple alternative, but more objective, technique. The resulting smoothed, normalized error curve (see Figure 2) is the source of correction factors to be applied to all individual passage profiles, whether QUIET or not.

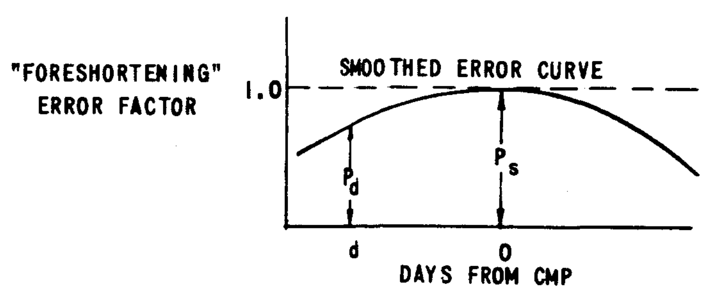


Figure 2 "FORESHORTENING, etc." CORRECTION CURVE

Because of "foreshortening, etc.," $P_d$, a value of P measured d days from CMP, is smaller than it should be. If the smoothed error curve can be assumed to be free of fluctuations due to region activity, which we have tried to smooth out, the factor for correcting any observed value of P, measured d days from CMP on any passing region, is $P_s/P_d$ and, being multiplicative, can be directly applied to any observed profile to obtain the "true" profile, free of "foreshortening, etc." error.

Briefly restating the above, a passage profile of a regional property is first normalized with respect to its own CMP value for each of a number of QUIET regions. These normalized profiles are then averaged over all the QUIET regions to produce an average passage profile. Following the hypothesis that solar spot and flare activity is independent of solar longitude, the average passage profile should be a straight line with any deviation being due to the "foreshortening, etc." effect, which is mainly due to viewing the solar sphere as a flat disk. Hypothesizing further, it is reasonable to expect the profile to be symmetrical about a maximum at the CMP with a gradual sloping off toward the limbs. This average QUIET profile can then be used to correct the profile of each sample to produce a more accurate input for prediction purposes.

Computer experiments were conducted using the 29 QUIET regions whose histories for a complete passage are known to determine the average passage profiles of sunspot number and area, plage area and brightness, duration and number of subflares, flares of importance 1, 2 and 3, and numbers of north and south poles respectively which give a total of 14 properties.

As expected, the resulting curves were quite "bumpy" and rough, but only a few indicated a tendency toward the expected curve. Most show a definite bias toward the east limb; this is most noticeable in spot number and area as illustrated in Figures 3 and 4. Plage area and brightness profiles are practically straight lines, indicating little foreshortening. The curves for the number of north and south poles (Figures 5 and 6) are closer to the expected result but still indicate some bias toward the east limb.

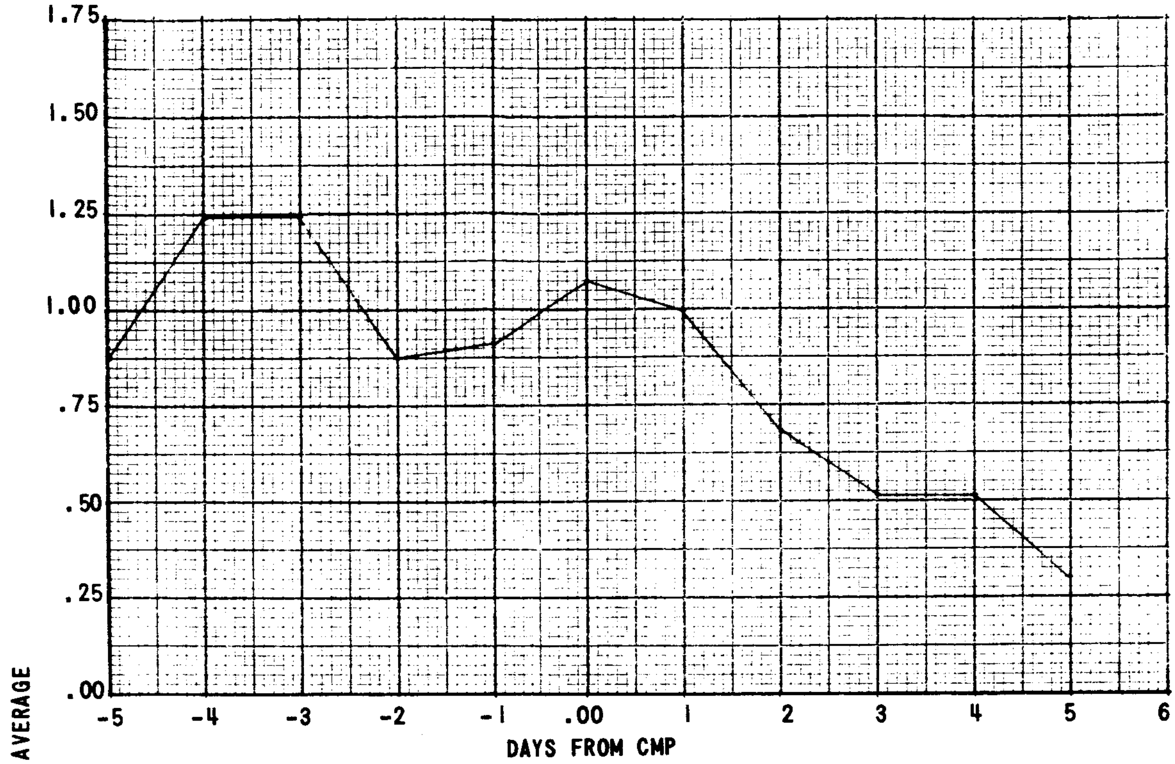


Figure 3 CORRECTION CURVE, SUNSPOT NUMBER - FIRST EXPERIMENT

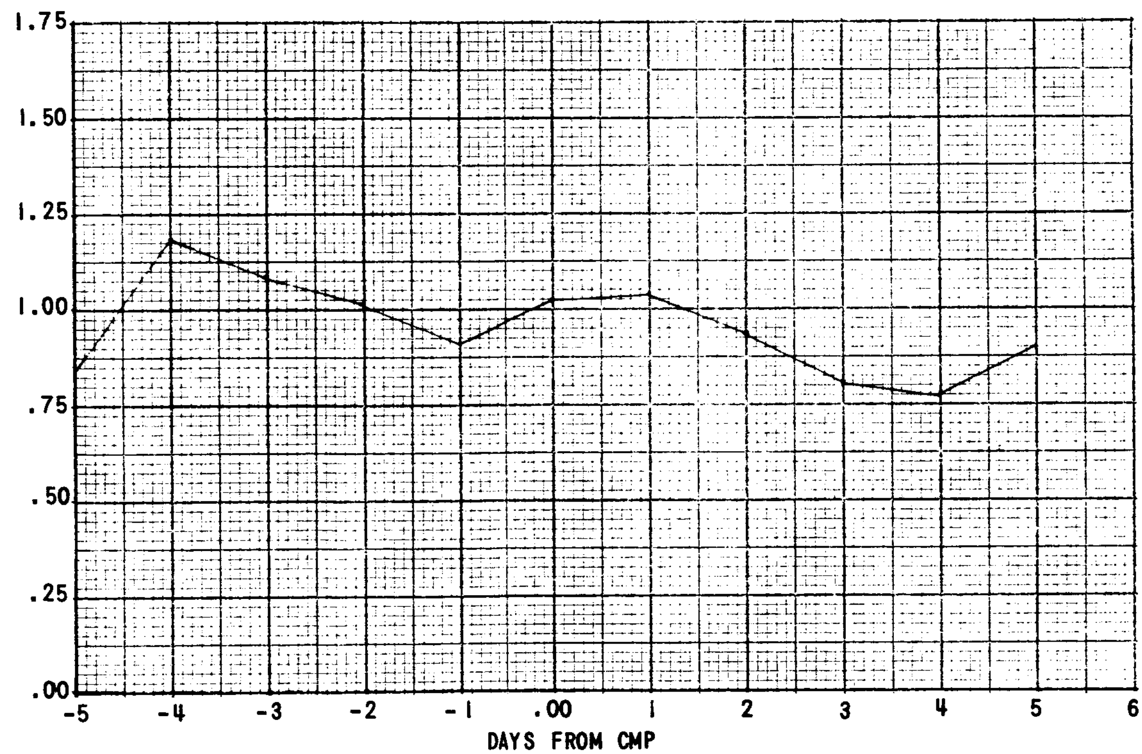


Figure 4 CORRECTION CURVE, SUNSPOT AREA - FIRST EXPERIMENT

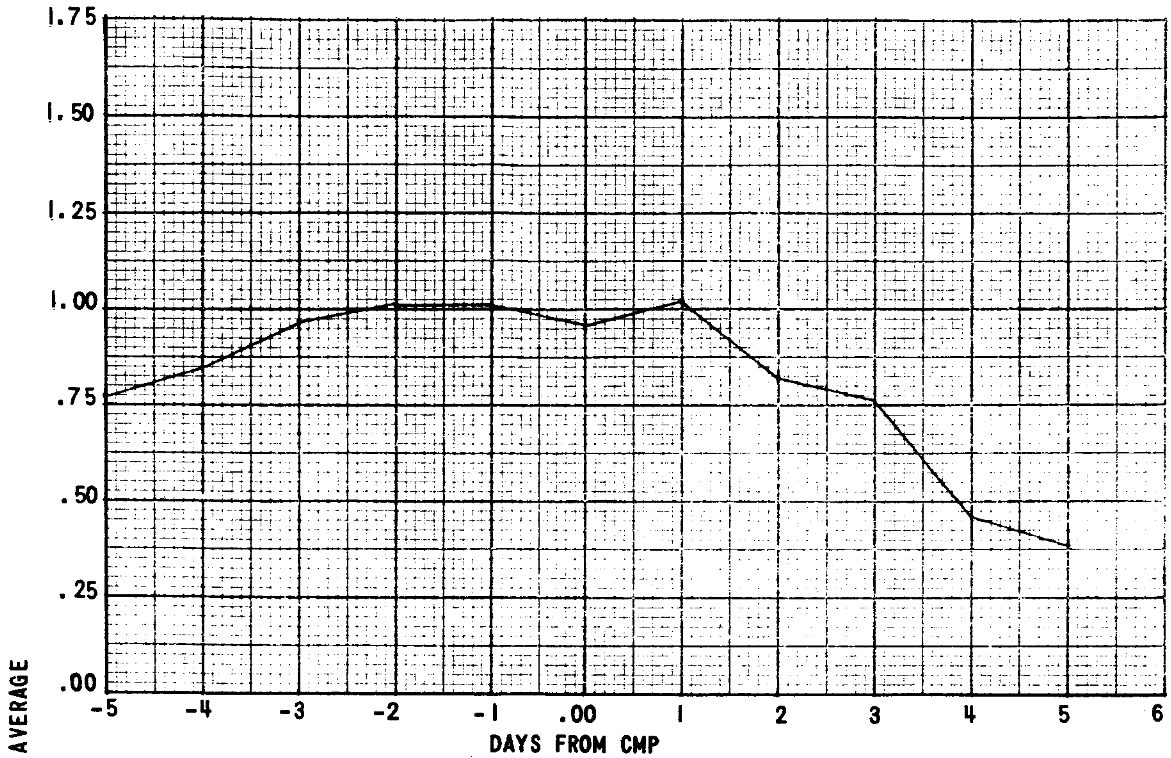


Figure 5 CORRECTION CURVE, NUMBER OF NORTH POLES - FIRST EXPERIMENT

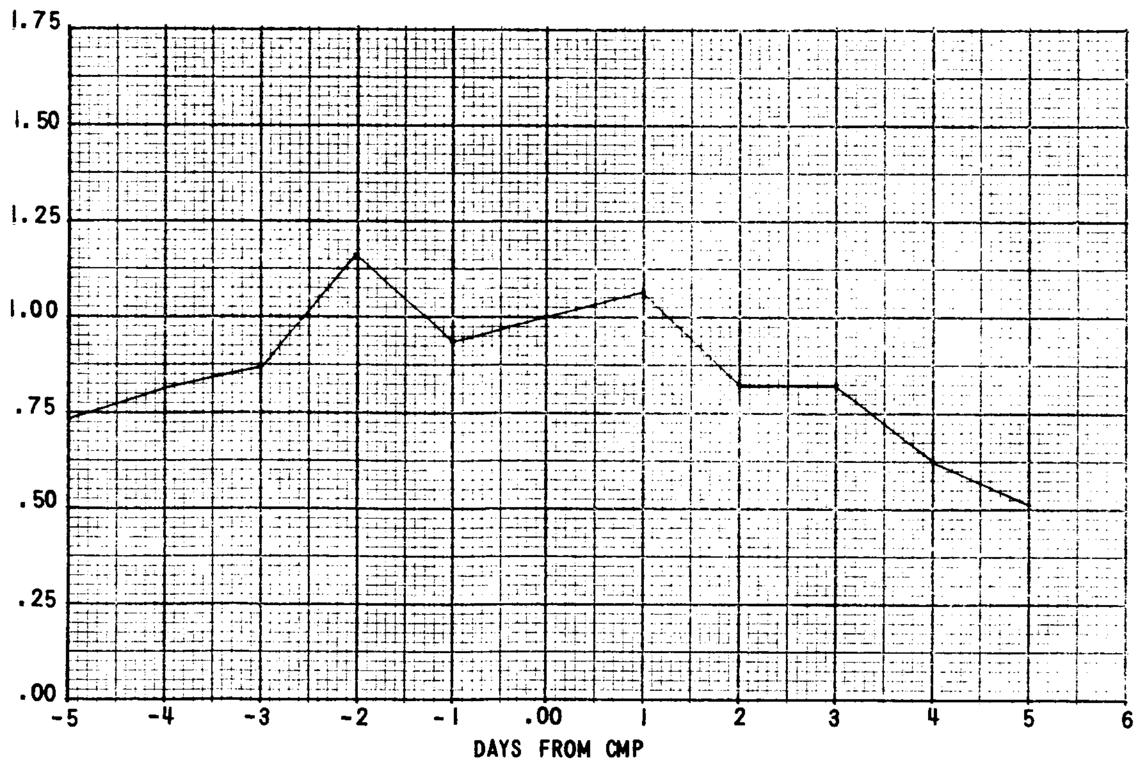


Figure 6 CORRECTION CURVE, NUMBER OF SOUTH POLES - FIRST EXPERIMENT

In reviewing the input data, it was seen that the QUIET regions were selected from four closely packed time periods; July and August, 1957; May and June, 1958; August and September, 1958; and October and November, 1959, with a few picked from other times. To determine whether the bias is being caused by a possible periodic phenomenon, the experiment was repeated using samples evenly distributed over a 6 month period, from June to December. Due to the scarcity of data, samples for a particular month had to be drawn from more than one given year (1957, 1958 and 1959). These inputs produced profiles which were more symmetrical than found previously. However, some eastward bias was still apparent from the results plotted on Figures 7 through 10.

The possibility that the east bias is caused by the increase of activity toward the east limb by an excess of decaying activity regions in the test data was considered. Therefore, the experiment was repeated with the last pass of multi-pass regions removed from the input samples. The resulting curves were very similar to the previous curves, contrary to this hypothesis.

The unexpected east bias in the correction profiles could be the result of either (or both) of two causes: (1) the regions chosen for inputs were not sufficiently scattered over a long period of time, and possibly introducing long-term biases, or (2) the hypothesis that solar activity is uniformly distributed across all solar longitudes is incorrect.

For an investigation of the first possibility, the QUIET regions were divided into four groups according to their time of passage. Since the number of samples in each group is quite small and the measurements appear to be highly cross correlated, a single composite curve of all measurements was plotted for each group. The results of this experiment are shown in Figure 11.

It can be seen that the bias toward the east exists in all four plots. However, the bias decreases with time. Therefore, it is suggested that this solar activity might be affected by some periodic phenomenon (perhaps the solar cycle of 11 years) and these four plots are only a few samples from a fraction of the cycle. Similar plots for other time periods would be necessary to confirm this hypothesis. Due to the need of more raw data which is

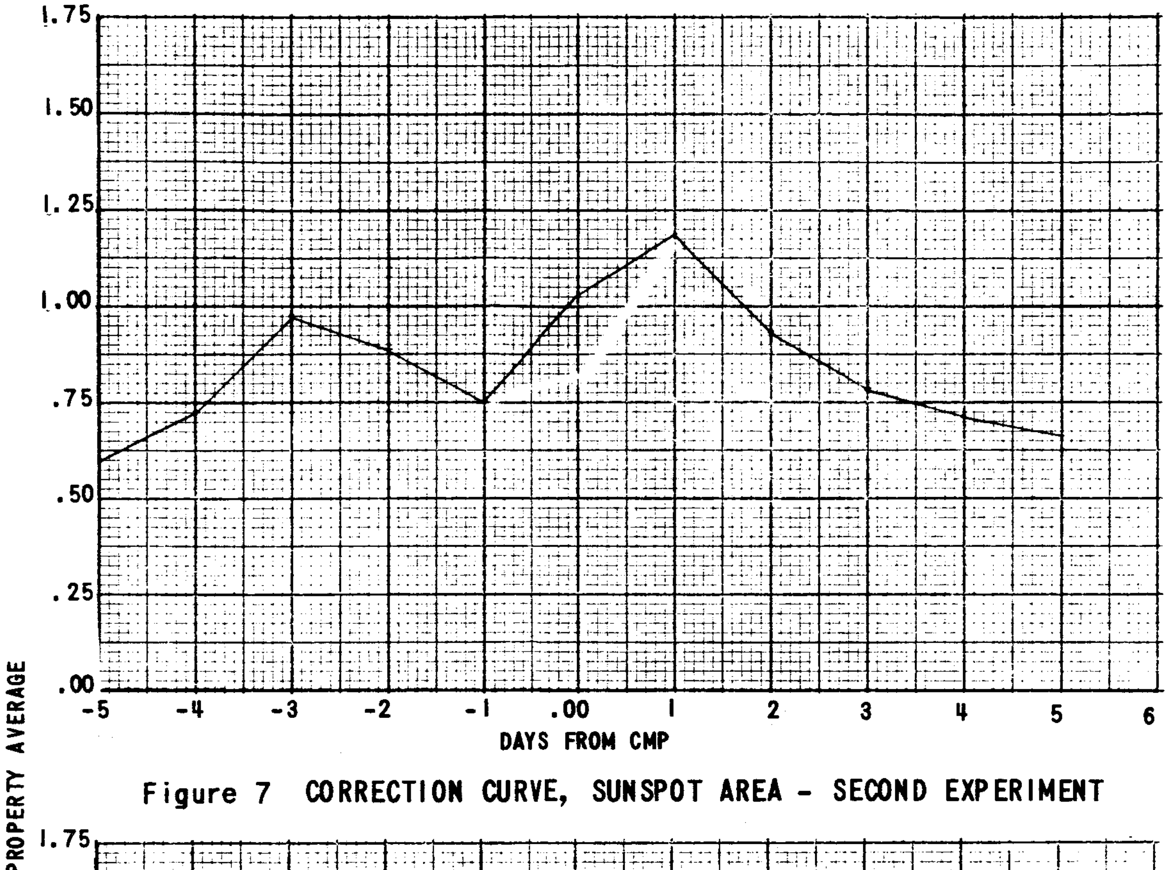


Figure 7 CORRECTION CURVE, SUNSPOT AREA - SECOND EXPERIMENT

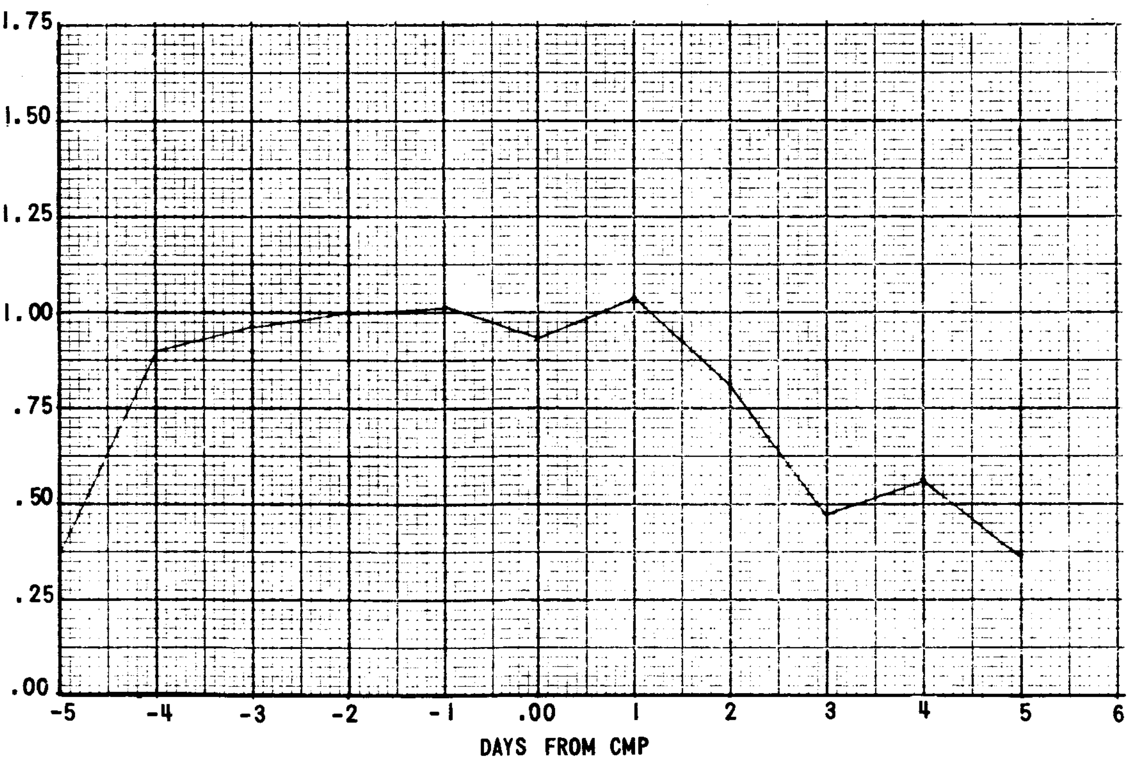


Figure 8 CORRECTION CURVE, SUNSPOT NUMBER - SECOND EXPERIMENT

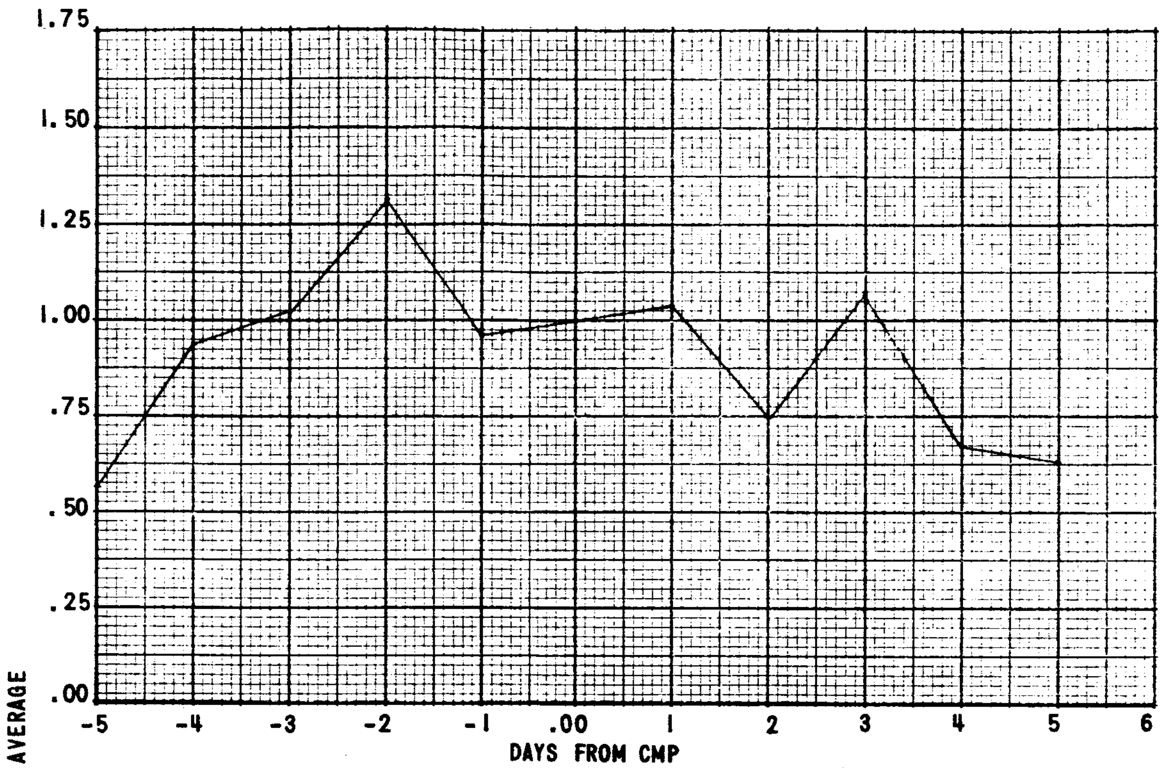


Figure 9 CORRECTION CURVE, NUMBER OF SOUTH POLES - SECOND EXPERIMENT

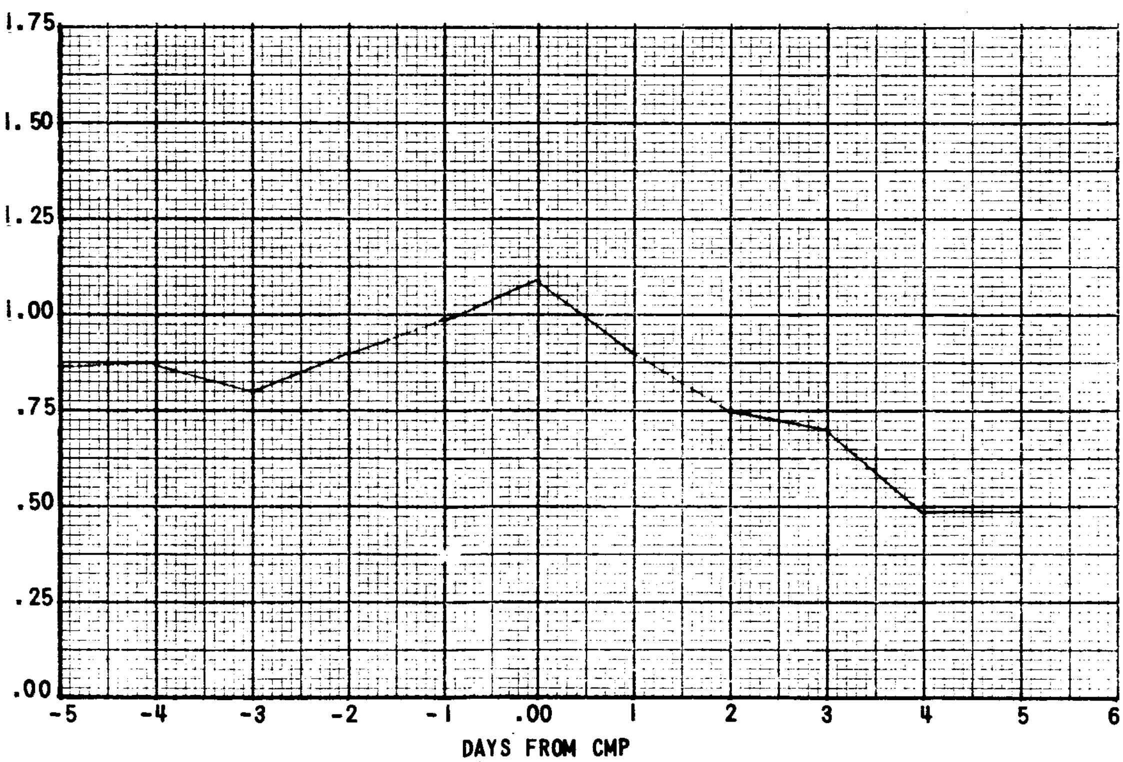


Figure 10 CORRECTION CURVE, NUMBER OF NORTH POLES - SECOND EXPERIMENT

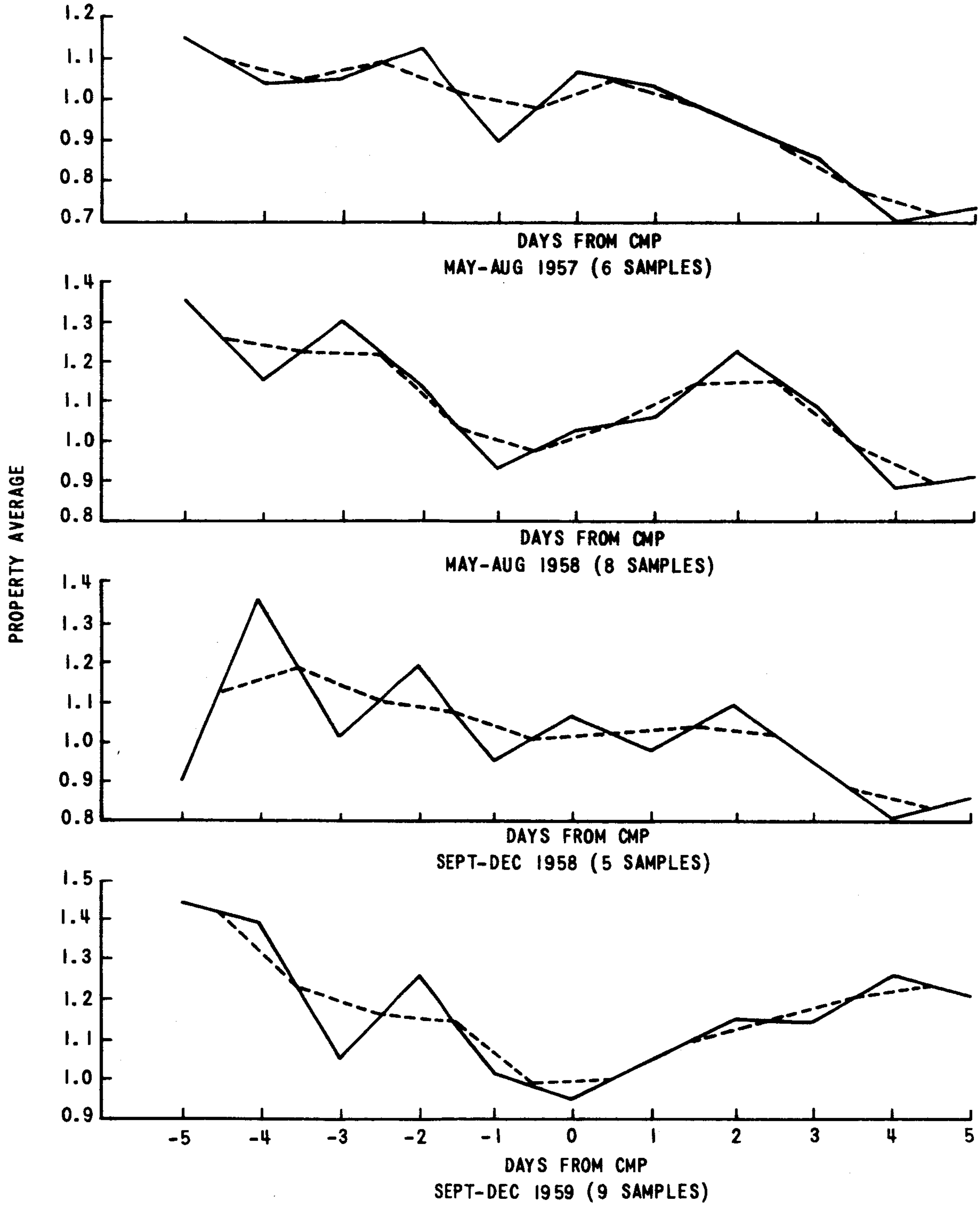


Figure 11 COMPOSITE PASSAGE PROFILES OF QUIET REGIONS FOR DIFFERENT PERIODS IN TIME (DASHED LINE AFTER 1ST ORDER SMOOTHING)

very scarce and the limited time schedule, no further efforts were expended in this direction.

The second possibility listed above has considerable backing in that the eastward bias in observation was first reported by Mrs. Maunder in 1907, who attributed the phenomenon to a westward tilt of the sunspots which was, in turn, measured by others in more recent years (see Kuiper,[2] p. 328 and Smith and Smith,[3] p. 51). Thus, the "foreshortening, etc." corrections are asymmetrical with respect to the CMP.

The foreshortening corrections used are listed in Table III. The passage profile for each individual property is corrected by dividing by the values listed for the respective distance from CMP.

The average passage profile for several properties having to do with number and duration of flares were very irregular, partly due to insufficient data to produce smoothing. Since these properties are closely related, an average of all properties was used to obtain a better indication of the smooth statistical trend. This is the reason some of correction values for different properties are identical.

## 3.3 Flare Based Profiles

From the daily data of the region passages, data is available for a collection of passage profiles for each measurement -- some will be large scale, some small -- some will be from QUIET passages, some from FLARE passages. An obvious use for these is to compare those from FLARE passes with those from QUIET passes. In particular, one would look for a significant inflection in the profile occurring prior to a FLARE to serve as a predictor. It is conceivable that in individual profiles a significant change may be masked by variations due to other causes. Hence, it is expected that trends may be more strongly displayed when abstracted from average profiles of a large number of FLARE regions.

One reasonable assumption is that the signalling inflection occurs a fixed time before the FLARE. If so, the inflection may be sought by averaging a number of profiles which are suitably translated right or left to superimpose all the 1st-FLARE days as illustrated in Figure 12.

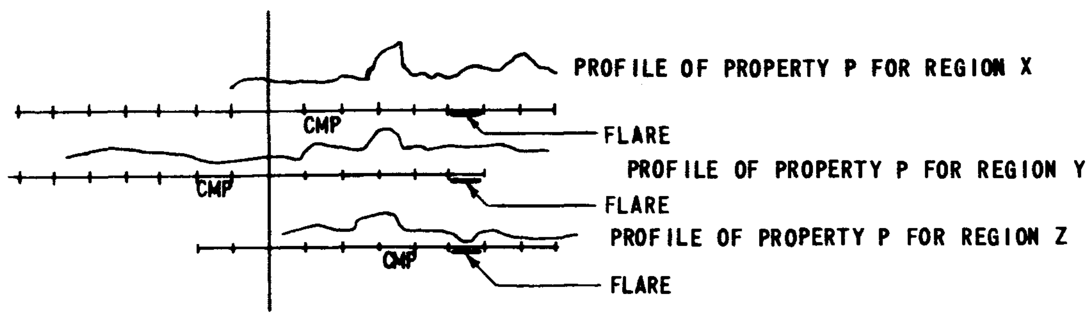


Figure 12 TRANSLATION OF PASSAGE PROFILES TO DAY OF FIRST FLARE

The data for a number of FLARE regions were normalized, averaged and plotted as a function of time to FLARE. The most promising are shown in Figures 13 through 16. These profiles do not include "foreshortening" corrections. Although the expected inflections before the time of a FLARE are not very obvious, the buildup in each profile is a promising indicator.

Further study of these profiles, especially when foreshortening corrections are included, should point out those properties with the best FLARE indicating characteristics.

## 3.4 Reduced Observation Effect

Another refinement that will probably be beneficial, but not investigated sufficiently in Phase II due to limited time schedule, is an adjustment of the reported daily flare and subflare counts to correct for probable losses due to intervals of reduced or no flare patrol.

The correction to flare counts for reduced seeing is somewhat complicated by the fact that the probability of missing a flare is a function of the duration of the flare, the duration of the interval of reduced observation,

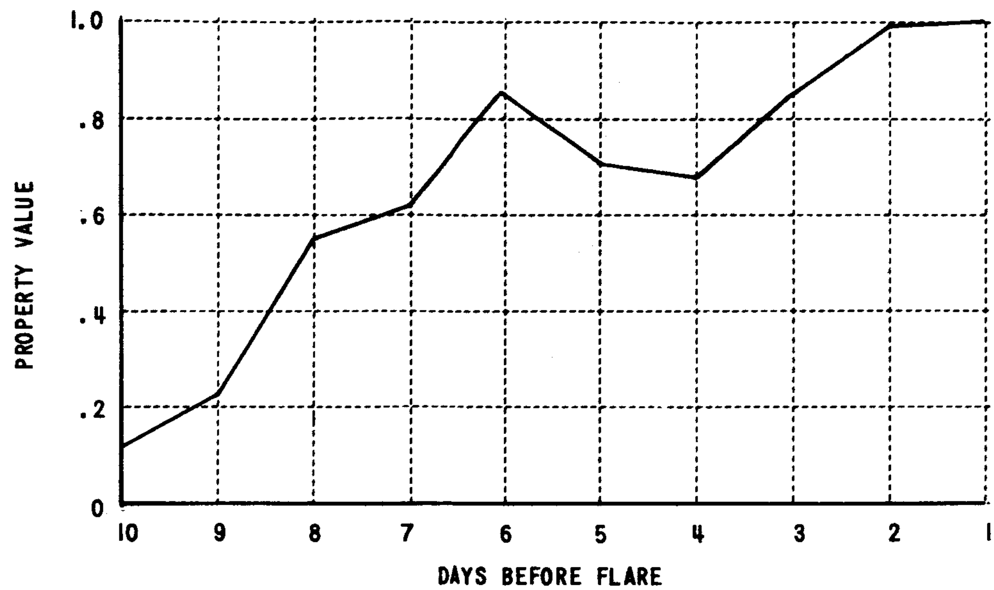


Figure 13 SUN SPOT AREA vs. DAYS BEFORE FLARE

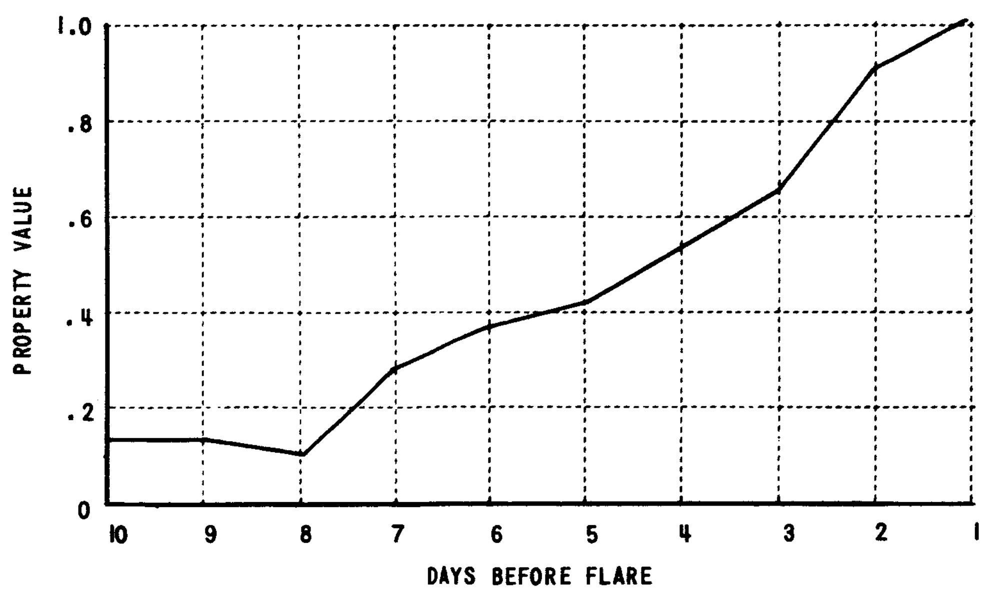


Figure 14 NUMBER OF SUN SPOTS vs. DAYS BEFORE FLARE

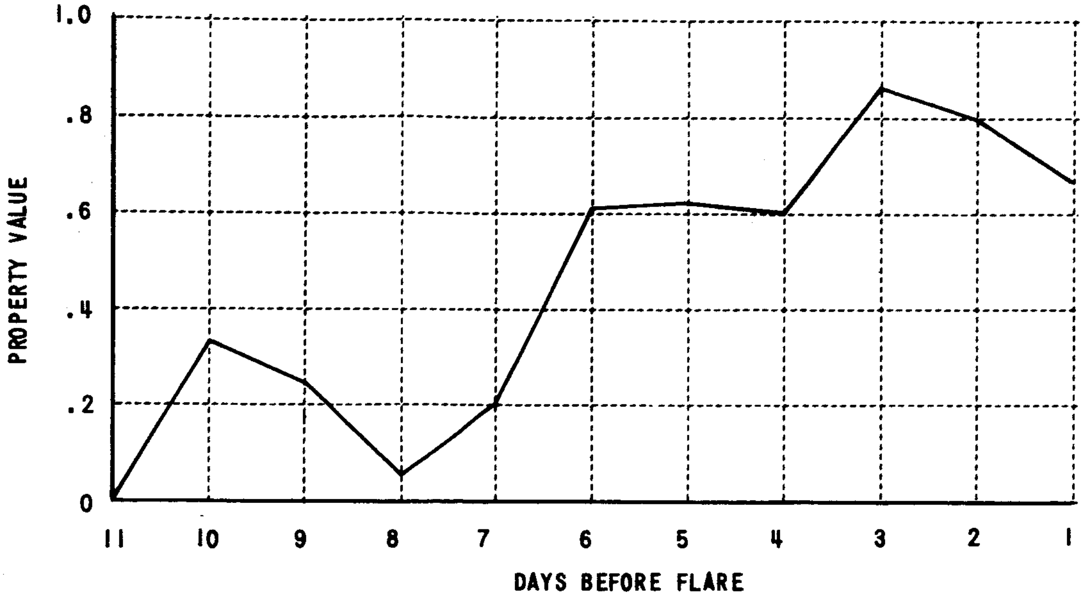


Figure 15 NUMBER OF NORTH POLES vs. DAYS BEFORE FLARE

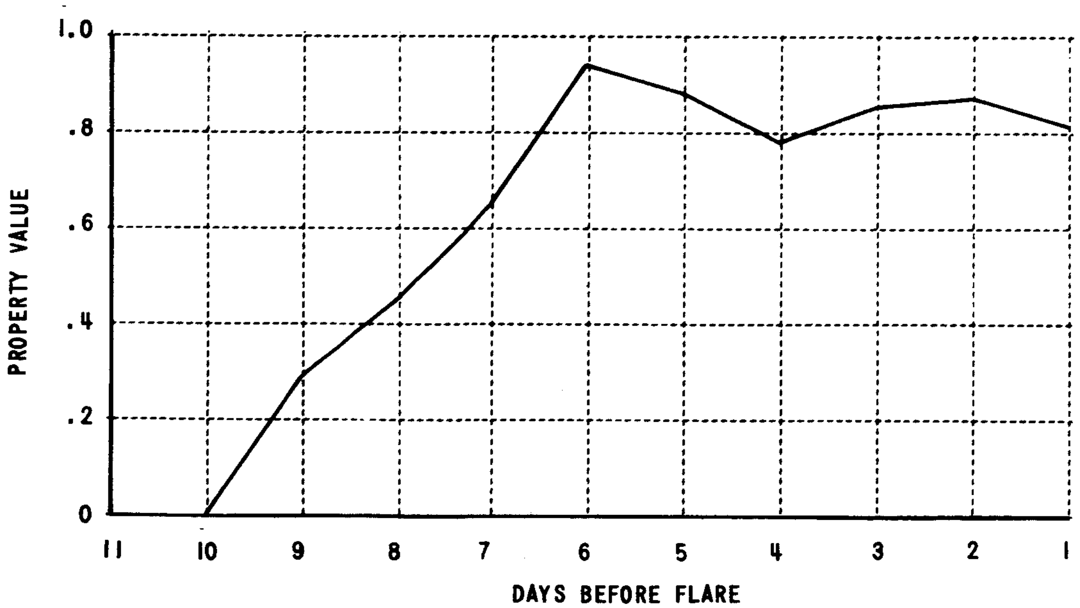


Figure 16 NUMBER OF SOUTH POLES vs. DAYS BEFORE FLARE

and the number of observatories on duty during the interval as compared to the number normally on duty. The I. A. U. quarterlies give daily charts on flare patrol coverage, in which, for each day, the intervals of no patrol, one observatory, and two or more observatories, are shown. From these, one may obtain the total hours of each kind of coverage:

Let $X_o$ = total hours of no patrol in one particular day

$X_1$ = total hours of one observatory only

Then $24 - (X_o + X_1)$ = hours of "full" coverage -- two or more observatories on duty.

As reported in the I. A. U. bulletins, the intervals making up $X_o$ and $X_1$ are given in relatively fine units of time, on the order of 6 - 10 minutes. For our purposes, we do not intend to recognize intervals shorter than 15 minutes in estimates of $X_o$ and $X_1$.

If events of an average length $L \ll 15$ minutes occur at random throughout the day, in which there are various successive intervals of "full-seeing" and "no-seeing", then the reported number of events $Z_o$ may be corrected to the probably true number of events by $Z_t = Z_o + \frac{Z_o}{24 - X_o}(X_o)$ where $\frac{Z_o}{24 - X_o}$ is the hourly rate at which events were being reported during "full-seeing", and $X_o$ is the number of no-seeing hours. This expression reduces to $Z_t = \frac{24 Z_o}{24 - X_o}$.
If $L$ is not $\ll 15$ minutes and if there are intervals of "partial seeing" (totaling $X_1$) and the relative effect of "partial seeing" is not known, then the full correction will be

$$Z_t = A \times \frac{24 Z_o}{24 X_o} + B \times \frac{24 Z_o}{24 - X_1}$$

in which A and B are constants whose values are less than 1.0 but which must be determined.

## 4.0 DATA PROCESSING

The raw data for each region passage as described in Section 2 are used in several ways in the classification procedure. Some are used directly, others as parameters in calculated properties, and some in both. Table IV is a list of the prepared properties used and the method in which each is derived. It is to be noted that the overall list is essentially the same as used in the PREP I experiment.

# 5.0 PREDICTION EXPERIMENTS

The design of a prediction experiment of the general type being conducted requires many specific decisions with respect to data treatment and decision strategy. Because there is at least some chance that more than one of these choices may be critical to the success of the experiment, the computer programs of Phase I were revised to provide more of the versatility that could be foreseen to be important. Increased flexibility was obtained from the use of input control cards, thus removing the necessity to rewrite portions of the program for each experiment. A detailed description of the use of the prediction program for CAL's new IBM 7044 digital computer is given in Appendix A.

A number of experiments were conducted to test the prediction techniques using several variations of data and sample combinations.

For comparison of the various experiments, the inputs are placed together in the following tables and figures.

a. Table I lists the input samples used for training and prediction for each experiment.

b. Tables IIa and IIb list the measurements and observations of raw data from available literature, both published and unpublished.

c. Table III lists the "foreshortening, etc." correction factors used.

d. Table V lists the properties, both derived and measured, of the test samples used for each experiment.

## 5.1 Experiment OA

This is the 4-day experiment conducted on project PREP I and is included here for purposes of comparisons.

## 5.2 Experiment OB

This experiment is identical to experiment OA above except a number of samples were interchanged between the training and prediction subsets. (Experiments OA and OB are hereafter referred to as the Phase I experiments.)

## 5.3 Experiment 1B

This is the first experiment using any of the improvements discussed in the previous sections. The basic characteristics of the experiment are as follows:

a. Property List

There are 204 prepared properties used. Except for a few minor changes as can be seen in Table IV, this is essentially the same list as used for experiments OA and OB. They consist of 12 properties for the region in general (5 continuous, 7 binary), and 48 for each of the 4 days preceding the sample data (32 continuous, 16 binary). Before data preparation, the raw data were corrected for foreshortening as discussed in Section 3.2.

b. Sample List

A total of 297 samples were used, 238 being classified as QUIET and 59 as FLARE taken from 53 HAO region passages, 29 of which produced no FLAREs.

c. Sample Selection

The samples were divided into two groups, one for training purposes, the other for prediction tests. They were arranged in chronological order and then divided on a paired region basis, i.e., the first two regions were placed in the training set, the next two in the test set, and next two in the training set and so forth. This resulted in 34 FLARE and 124 QUIET samples for training, and 25 FLARE and 114 QUIET samples for prediction tests.

d. Normalization and "Hole Filling"

All prepared data are normalized and those items which are blank due to lack of input data are filled in the manner detailed in Section 3.1.

## 5.4 Experiment 2A

a. Property List

Same as for Experiment 1B.

b. Sample List

Same as for Experiment 1B.

c. Sample Selection

The samples were divided into two groups, each having approximately the same number of samples, according to their occurrence in time, i.e., those occurring before August 27, 1958 were used for training and those after this date for prediction tests. There were 43 FLARE and 104 QUIET samples for training, and 16 FLARE and 134 QUIET samples for prediction tests.

d. Normalization and "Hole Filling"

Same as for Experiment 1B.

## 5.5 Experiment 4B

a. Property List

Same as for Experiment 1B.

b. Sample List

The all QUIET region passages used in the previous two experiments included QUIET samples quite close to the west limb, making it difficult to confirm whether these qualify as truly QUIET samples. The danger of a false QUIET sample was removed by eliminating all QUIET samples which occurred more than two days beyond the CMP. With the elimination of these, a total of 59 FLARE and 143 QUIET samples remained.

c. Sample Selection

Same as for Experiment 1B. However, in light of the reduced sample list, there are now 34 FLARE and 80 QUIET samples for training, and 25 FLARE and 71 QUIET samples for prediction tests.

d. Normalization and "Hole Filling"

Same as for Experiment 1B.

5.6 Experiment 4A

a. Property List

Same as for Experiment 1B.

b. Sample List

Same as for Experiment 4B.

c. Sample Selection

Same as for Experiment 4B except 3 FLARE samples were taken from the prediction subset and included in the training subset.

d. Normalization and "Hole Filling"

Same as for Experiment 1B.

5.7 Experiment 5A

a. Property List

In the process of "hole-filling" during training, the mean and standard deviation are determined for each continuous property. In addition, the normalized deviation of the mean of each class is also computed for each continuous property. Inspection of these after the above experiments indicated that the separation of these mean deviations were good for some properties and poor for others. Therefore, those with poor separations from the training set in Experiment 4A were selectively culled from the property list resulting in a total of 136 properties (67 continuous and 69 binary).

b. Sample List

Same as for Experiment 4B.

c. Sample Selection

Same as for Experiment 4B.

d. Normalization and "Hole Filling"

Same as for Experiment 1B.

5.8 Experiment 6A

a. Property List

Same as for Experiment 5A except that binary properties are also selectively culled, resulting in a total of 84 properties (67 continuous and 17 binary properties).

b. Sample List

Same as for Experiment 4B.

c. Sample Selection

Same as for Experiment 4B.

d. Normalization and "Hole Filling"

Same as for Experiment 1B.

5.9 Experiment 7

a. Property List

Same as for Experiment 1B.

b. Sample List

Same as for Experiment 4B.

c. Sample Selection

Same as for Experiment 4B.

d. Normalization and "Hole Filling"

Same as used for Phase I experiments (OA and OB), where normalization is used over all samples, both training and prediction subsets and blank data are set to zero.

## 6.0 DISCUSSION OF EXPERIMENTAL RESULTS

The nine experiments outlined above produced different results from a variety of input conditions as shown in Figure 17 and Table VI.

Experiments OA and OB were conducted under conditions formulated under Phase I of Project PREP and differed only in the manner in which the test samples were divided between the training subset and the prediction subset. However, the results of OA and OB (see Table VI and Figure 17) differ somewhat, the overall prediction being 76.7 and 63.6 percent, respectively. The objectives of the Phase II efforts were to study the data and to improve them by a number of refinements as discussed in earlier sections in order to increase the knowledge of solar activity leading to a FLARE (in particular how this activity is unique from all other activities, i.e., non-FLARE producing activities) and then to apply the results of this knowledge to forecasting future FLAREs. Therefore, the remainder of the prediction experiments described here (those conducted with Phase II refinements discussed in previous sections) differ from the first two (the Phase I experiments) in that (except where noted otherwise), the following improvements were included:

a. An increased number of QUIET samples were used (see Section 2.0).

b. The raw data were corrected for "foreshortening, etc." effects as described in Section 3.2.

c. An improved method of normalization and "hole filling" of prepared data were used as described in Section 3.1.

Experiments 1B and 2A included all these improvements and, as before, differed only in the manner in which the test samples were divided between the training and prediction subsets. The overall predictions of 80.6 percent and 85.3 percent respectively not only showed a decreased variation between them (a difference of 4.7 percent instead of 13.1 percent), but an encouraging increase in overall average accuracy of approximately 13 percent.

As shown in Table VI, there is a decrease in the number of False Alarms (a FLARE predicted when no FLARE appears) in the Phase II experiments over the Phase I experiments at the expense of an increased number of Misses (a QUIET period is predicted when in fact a FLARE is produced). One contributing factor for this shift in bias could be due to the use of QUIET samples taken too close to the west limb of the solar disk, where it is much more difficult to verify whether a type IV radio-emission flare is produced within the next four days or not. Therefore, Experiment 4B was made to repeat the conditions of Experiment 1B except that all QUIET samples appearing more than two days west of the CMP were eliminated from both the training and prediction subsets. The results showed a modest shift of the bias toward a lower number of Misses. However, the experiment was repeated in Experiment 4A by shifting one region passage containing three FLARE samples and no QUIET samples from the prediction subset to the training subset as well as the elimination of the western QUIET samples. The result here was very encouraging in that there is a remarkable decrease in the number of Misses at no cost in increased False Alarms.

Since the FLARE profile plots, discussed in Section 3.3, were not sufficiently analyzed at the time the prediction experiments were being run on the computer, a different, but statistically logical, approach was used to cull the property list of properties which do not contribute to correct forecasts. In the training portion of the computer program, the means of each class (QUIET, FLARE 1-day hence, ... FLARE 4 days hence) are printed for each continuous property in units of standard deviations from the training subset mean. Those continuous properties whose QUIET mean fell between the means of two of the FLARE classes in Experiment 4B were culled from the list. The objective properties were not culled at this point. With this reduced property list (see Table V for the culled list), and all other conditions being identical to those of Experiment 4B, Experiment 5A resulted in no change in the number of Misses but a decrease in the number of False Alarms.

The objective properties were studied next for culling possibilities to continue improvement. Since the statistics of these were in the form of the number of times each occurred in training, no systematic means of culling was recognized. However, they were culled by using selective personal judgment of the printed data to reduce the property list of Experiment 5A still further as indicated in Table V for Experiment 6A. The results, as shown in Table VI, showed a decrease in the number of Misses at a relatively small cost of increased False Alarms.

The results of these two experiments, 5A and 5B, indicate that performance can be improved even with the relatively crude procedure used here. It can be expected that with the results of FLARE profiles of both continuous and objective properties those forecasts can be further improved.

As a test of the hole-filling procedure used in all of the above Phase II experiments, Experiment 7 was conducted by using all the conditions of Experiment 4B except that the normalization and hole-filling procedure of Phase I were used (see Section 3.1). Although a decrease in the number of False Alarms is offset by an increase in the number of Misses with the overall accuracy remaining constant, the Phase II method should be considered superior in that FLARE data of the prediction subset is no longer used at no cost to prediction capability.

All the experiments of Phase II show a much greater bias toward QUIET predictions as compared to the Phase I experiments. This can be attributed to two factors working in concert, a situation which can be uncorrelated if desired. There are many more QUIET samples in the training lists than FLARE samples. Thus, when a "hole" in the data is filled in the prediction samples before making a forecast, the value filled in is strongly biased toward the QUIET. This bias can be eliminated, or even reversed, if desired, by using the average of means of QUIET and FLARE samples, respectively, or even weighting the means according to some prescribed ratio, if desired.

## 7.0 CONCLUSIONS

In the first phase of project PREP,[1] a multiple factor classification technique, of a sort resembling "learning machines" which have been studied as pattern recognition automata, was experimentally applied to forecasting solar flares likely to have produced proton showers in the interplanetary space. Type IV radio emission was used as a criterion for this likelihood since (a) the two phenomena are highly correlated and (b) the radio emission is likely to be detected although the high energy protons may not reach the earth. The results were sufficiently encouraging to proceed into a Phase II program which is reported here.

Two goals were established; the first is toward obtaining a meaningful physical description of the development of a solar activity center by discovering the identity and the interaction of the observable phenomena preceding proton emitting flares. The second is to apply this knowledge to the improvement of forecasting quality and range. Progress toward the first goal was made in productive investigation of the refinement of the input data, i.e., measurements of solar activities obtained from the literature of the various observatories.

A relatively simple technique for correcting these data for foreshortening errors (errors resulting from observing a spherical sun as a flat disk) by empirical calculations was developed. A particular advantage of this procedure is that any systematic perturbation of the data, which is a function of meridian displacement across the solar disk, is included in the corrections. A prime example of this appeared unexpectedly in the form of a definite east bias in the passage profiles. This bias can be attributed to the westward tilt of sunspots (first reported by Mrs. Maunder[2, 3] in 1907) which causes the data to be degraded toward the western half of the solar disk. The resulting correction factors were easily applied to all data in further experimentation.

Concurrently with the above investigation, a different study was being conducted in the form of a search for identifying inflections in the passage profiles by averaging individual measurements over several passage profiles that were first time adjusted to a common FLARE point. Although no outstanding inflections or peaks appeared,* the gradual and steady increase in activity of several of the profiles showed considerable promise. Comparing the range of values in the curves (see Figures 13 through 16) with the profiles of region passages which produced no FLAREs (see Figures 7 through 10), it is seen that activity is considerably greater in the days just prior to the production of a FLARE. Further study of these profiles, especially after "foreshortening, etc." corrections can be applied, by comparison of a number of individual profiles of both FLARE producing and QUIET (non-FLARE producing) region profiles should reveal some strong FLARE indicators.

A preliminary study was initiated to determine a means of correction of FLARE counts for reduced seeing (periods of time which the sun was not under observation). There is considerable evidence as reported in I.A.U. quarterlies,[4] which contain daily charts of flare patrol coverage, that there probably are a number of unreported flares produced. The correction factor would be a probabilistic function of duration of flares of interest, time of observation of individual observers as well as lengths of no patrol periods, and the number of active regions present at the time. Investigation along these lines should be continued to obtain corrections to the observed data.

Other improvements, i.e. better normalization and hole-filling procedure and property culling, were also applied and tested in the prediction experiments. The best overall achieved prediction was 85 percent, compared to 77 percent for Phase I.

*The expected inflections could, in all likelihood, have been hidden by the coarseness of the data. Greater resolution of the data, i.e. hourly instead of daily, measurements might be helpful.

## 8.0 RECOMMENDATIONS

The results of the refinement studies discussed above and the experiments discussed in Section 5 indicated that progress toward the goals of increased knowledge of pre-FLARE solar activities and the application of this knowledge to improved forecasting was made. Furthermore, they pointed the way to future possibilities for more enlightenment and improved forecasting. Therefore, the following recommendations for future efforts are suggested.

a. Continue the study for obtaining corrections to the data for errors resulting from reduced observation time.

b. Correct the FLARE based profiles for foreshortening and reduced observation time, and investigate these profiles further for FLARE indicator characteristics within a few days prior to the FLARE.

c. Cull the property list of superfluous properties by quantitative analysis of the property statistics (only a qualitative analysis was applied in the Phase II experiments) including cross-correlations of paired properties.

d. Change the normalization and hole filling portion of the program to eliminate the bias toward QUIET prediction. It would be even better to make this value adjustable to permit an additional control on trade-off between Misses and False Alarms.

e. Investigate the addition of other properties such as heliocentric longitude as suggested by Guss,[5] and the superposition of parallel rows of sunspots and filament patterns as suggested by Avignon, et. al.[6]

f. Increase the resolution of the data in time and surface area of the sun. The day and HAO region, respectively, used here are relatively coarse. It is anticipated that a new publication, "Geophysics and Space Data Bulletin," recently announced by

NASA will be beneficial in supplying the additional data necessary.

g. Investigate the use of other means of region identification, such as squares of the solar surface identified by heliocentric longitude and latitude.

h. Consider and develop other training techniques which may prove more satisfactory for forecasting solar activity.

i. Investigate the feasibility of predicting all great flares (importance 3 and greater) rather than just those producing type IV radio emissions.

## Table I REGION - PASSAGES AND USAGE

NOTE: T = USED IN TRAINING, P = USED IN PREDICTION TESTING
SUBSCRIPT = NO. OF SAMPLES IN PASSAGE USED. NO SUBSCRIPT INDICATES ALL SAMPLES IN PASSAGE USED.

| REGION PASSAGES | | | | | USAGE IN EXPERIMENTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HAD IDENT. | PASSAGE NO. | CMP DAY | FLARE DAY | NO. OF SAMPLES | 0A | 0B | 1B | 2A | 4B, 5A, 6A, 7 | 4A |
| 57JA | 2 | 176 | - | 8 | $P_5$ | $T_5$ | T | T | $T_5$ | $T_5$ |
| NONE | 1 | 195 | 197 | 2 | P | T | T | T | T | T |
| 57JE | 1 | 202 | 201 | 2 | T | P | P | T | P | P |
| 57JA | 3 | 202 | 205 | 5 | P | P | P | T | P | P |
| 57QD | 1 | 207 | - | 8 | | | T | T | $T_5$ | $T_5$ |
| 57JC | 2 | 213 | 214 | 2 | T | T | | | | |
| 57JH | 1 | 226 | - | 8 | | | T | T | $T_5$ | $T_5$ |
| 57JK | 1 | 226 | - | 8 | | | P | T | $P_5$ | $P_5$ |
| 57JA | 4 | 230 | - | 8 | | | P | T | $P_5$ | $P_5$ |
| 57QD | 2 | 234 | - | 8 | | | T | T | $T_5$ | $T_5$ |
| 57JG | 2 | 243 | 243 | 2 | P | P | T | T | T | T |
| 57JH | 2 | 252 | 255 | 4 | T | P | P | T | P | P |
| 57QD | 3 | 262 | 261 | 1 | P | T | P | T | P | P |
| 57JG | 3 | 270 | 269 | 1 | T | T | T | T | T | T |
| 57JU | 1 | 290 | 291 | 3 | $P_2$ | P | T | T | T | T |
| 57QG | 1 | 352 | - | 8 | T | P | P | T | $P_5$ | $P_5$ |
| 57JZ | 1 | 359 | 360 | 2 | T | P | P | T | P | P |
| 58B | 2 | 38 | 40 | 4 | T | T | T | T | T | T |
| 58B | 4 | 94 | 96 | 4 | P | T | T | T | T | T |
| 58N | 1 | 135 | - | 8 | | | P | T | $P_5$ | $P_5$ |
| 58Q | 2 | 144 | - | 8 | | | P | T | $P_5$ | $P_5$ |
| 58M | 2 | 150 | - | 8 | | | T | T | $T_5$ | $T_5$ |
| 58K | 1 | 150 | 155 | 7 | T | P | T | T | T | T |
| 58P | 1 | 161 | - | 8 | | | P | T | $P_5$ | $P_5$ |
| 58P | 2 | 188 | 188 | 2 | P | P | P | T | P | P |
| 58S | 2 | 207 | 211 | 6 | T | T | T | T | T | T |
| 58BC | 2 | 224 | 228 | 6 | P | T | T | T | T | T |
| 58S | 3 | 233 | - | 8 | | | P | T | $P_5$ | $P_5$ |
| 58CA | 1 | 236 | - | 8 | | | P | P | $P_5$ | $P_5$ |
| 58BA | 2 | 238 | - | 8 | | | T | P | $T_5$ | $T_5$ |

Table I (CONT.)

| REGION PASSAGES | | | | | USAGE IN EXPERIMENTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HAD IDENT. | PASSAGE NO. | CMP DAY | FLARE DAY | NO. OF SAMPLES | 0A | 0B | 1B | 2A | 4B, 5A, 6A, 7 | 4A |
| 58BB | 2 | 243 | - | 8 | | | T | P | $T_5$ | $T_5$ |
| 58M | 6 | 257 | - | 8 | | | P | P | $P_5$ | $P_5$ |
| 58Z | 1 | 259 | - | 8 | | | P | P | $P_5$ | $P_5$ |
| 58BB | 3 | 270 | - | 8 | | | T | P | $T_5$ | $T_5$ |
| 58BC | 4 | 278 | - | 8 | | | T | P | $T_5$ | $T_5$ |
| 58BI | 1 | 294 | 294 | 2 | P | T | P | P | P | P |
| 58BL | 1 | 328 | 328 | 1 | T | P | P | P | P | P |
| 58DF | 1 | 337 | - | 6 | P | T | T | P | $T_4$ | $T_4$ |
| 58BQ | 1 | 345 | 345 | 2 | T | T | T | P | T | T |
| 59C | 4 | 103 | 104 | 3 | T | P | P | P | P | P |
| 59X | 1 | 244 | 243 | 1 | T | T | P | P | P | P |
| 59DD | 1 | 279 | - | 8 | | | T | P | $T_5$ | $T_5$ |
| 59R | 2 | 281 | - | 8 | | | T | P | $T_5$ | $T_5$ |
| 59DE | 1 | 284 | - | 9 | | | P | P | $P_5$ | $P_5$ |
| 59AA | 1 | 294 | - | 8 | | | P | P | $P_5$ | $P_5$ |
| 59DC | 1 | 300 | - | 8 | | | T | P | $T_5$ | $T_5$ |
| 59DF | 1 | 301 | - | 8 | | | T | P | $T_5$ | $T_5$ |
| 59DG | 1 | 302 | - | 8 | | | P | P | $P_5$ | $P_5$ |
| 59AB | 1 | 316 | - | 8 | | | P | P | $P_5$ | $P_5$ |
| 59DF | 2 | 329 | - | 7 | | | T | P | $T_4$ | $T_4$ |
| 60L | 2 | 128 | 127 | 1 | T | P | T | P | T | T |
| 60S | 1 | 177 | 177 | 2 | P | T | P | P | P | T |
| 60X | 2 | 226 | 225 | 1 | P | P | P | P | P | T |
| 60HH | 2 | 316 | 317 | 3 | P | P | T | P | T | T |

Table II a

RAW DATA FORMAT

GENERAL DATA

| CARD COLUMNS | SYMBOL | PROPERTY |
|---|---|---|
| 1-3 | | CAL SERIAL NUMBER |
| 4 | | NO. OF PASSAGE |
| 5 | | HEMISPHERE |
| 6-7 | $\phi$ | LATITUDE (ABSOLUTE VALUE) |
| 8-9 | $Y$ | YEAR |
| 10-12 | | CMP DAY OF YEAR |
| 13-14 | $\phi_E$ | EXPECTED LATITUDE |
| 15 | | SOLAR CYCLE PHASE |
| 16-18 | | FLARE INDEX LAST PASSAGE |
| 19-21 | | AVE. NO. OF SUNSPOTS LAST PASSAGE |
| 22 | $M$ | NO. OF MT. WILSON GROUPS |
| 53-54 | $\phi_1$ | LATITUDE OF MT. WILSON GROUP 1 |
| 55 | | IS GROUP 1 PRIME |
| 56 | | IS GROUP 1 SHARED |
| 57 | | NEITHER OF ABOVE |
| 58-59 | $\phi_2$ | SAME AS 53-57 BUT FOR GROUP 2 |
| 60 | | |
| 61 | | |
| 62 | | |
| 63-64 | $\phi_3$ | SAME AS 53-57 BUT FOR GROUP 3 |
| 65 | | |
| 66 | | |
| 67 | | |
| 68-69 | $\phi_4$ | SAME AS 53-57 BUT FOR GROUP 4 |
| 70 | | |
| 71 | | |
| 72 | | |
| 73-77 | | HAO REGION IDENTIFICATION |

## Table II b
## RAW DATA FORMAT

DAILY DATA

NOTE; ONE CARD FOR EACH DAY OF DATA

| CARD COLUMNS | SYMBOL | PROPERTY |
|---|---|---|
| 1-6 | | CLASS |
| 7-9 | $N_S$ | NO. OF SUNSPOTS |
| 10-13 | $A_S$ | TOTAL AREA OF SUNSPOTS |
| 14-18 | $A_P$ | AREA OF PLAGE |
| 19 | Z | ZURICH CLASSIFICATION |
| 20-21 | B | PLAGE BRIGHTNESS |
| 22-23 | $T_{F0}$ | DURATION OF SUNFLARES |
| 24-25 | $T_{F1}$ | DURATION OF IMPORTANCE 1 FLARES |
| 26-27 | $T_{F2}$ | DURATION OF IMPORTANCE 2 FLARES |
| 28-29 | $T_{F3}$ | DURATION OF IMPORTANCE 3 FLARES |
| 30-31 | $N_{F0}$ | NO. OF SUBFLARES |
| 32-35 | $N_{F1}$ | NO. OF IMPORTANCE 1 FLARES |
| 34 | $N_{F2}$ | NO. OF IMPORTANCE 2 FLARES |
| 35 | $N_{F3}$ | NO. OF IMPORTANCE 3 FLARES |
| 36 | $W_0$ | MT. WILSON MAGNETIC CLASSIFICATION |
| 37 | P | IS THIS A GOOD TEST SAMPLE |
| 38-40 | D | DAY OF YEAR |
| 53 | $W_1$ | MT. WILSON MAGNETIC CLASSIFICATION OF MT. WILSON GROUP 1 |
| 54-55 | $N_{N1}$ | NO. OF NORTH POLES IN GROUP 1 |
| 56-57 | $N_{S1}$ | NO. OF SOUTH POLES IN GROUP 1 |
| 58 | $W_2$ | |
| 59-60 | $N_{N2}$ | SAME AS 53-62, EXCEPT FOR GROUP 2 |
| 61-62 | $N_{S2}$ | |
| 63 | $W_3$ | |
| 64-65 | $N_{N3}$ | SAME AS 53-62, EXCEPT FOR GROUP 3 |
| 66-67 | $N_{S3}$ | |
| 68 | $W_4$ | |
| 69-70 | $N_{N4}$ | SAME AS 53-62, EXCEPT FOR GROUP 4 |
| 71-72 | $N_{S4}$ | |
| 73-77 | | HAO REGION IDENTIFICATION |

Table III

FORESHORTENING CORRECTION FACTORS

| PROPERTY | DAYS BEFORE CMP | | | | | CMP | DAYS AFTER CMP | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5 | 4 | 3 | 2 | 1 | | 1 | 2 | 3 | 4 | 5 |
| SPOT NUMBER | 1.0000 | 1.1500 | 1.1300 | 0.9600 | 0.9500 | 1.0200 | 0.9500 | 0.7200 | 0.5500 | 0.4600 | 0.3500 |
| SPOT AREA | 1.0000 | 1.0800 | 1.1000 | 1.0100 | 0.9700 | 1.0000 | 1.0100 | 0.9300 | 0.8400 | 0.8200 | 0.8500 |
| PLAGE AREA | 1.0000 | 1.1600 | 1.1300 | 1.1100 | 1.0500 | 1.0000 | 0.9800 | 1.0300 | 1.1200 | 1.2000 | 1.2000 |
| PLAGE BRIGHTNESS | 1.000 | 1.000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9500 | 0.9000 |
| DURATION OF SUBFLARES | 1.3000 | 1.2500 | 1.2200 | 1.1200 | 1.0300 | 1.0400 | 1.1000 | 1.1300 | 1.0800 | 0.9400 | 0.9000 |
| DURATION OF IMP.1 FLARES | 1.3000 | 1.2500 | 1.2200 | 1.1200 | 1.0300 | 1.0400 | 1.1000 | 1.1300 | 1.0800 | 0.9400 | 0.9000 |
| DURATION OF IMP.2 FLARES | 1.3000 | 1.2500 | 1.2200 | 1.1200 | 1.0300 | 1.0400 | 1.1000 | 1.1300 | 1.0800 | 0.9400 | 0.9000 |
| DURATION OF IMP.3 FLARES | 1.3000 | 1.2500 | 1.2200 | 1.1200 | 1.0300 | 1.0400 | 1.1000 | 1.1300 | 1.0800 | 0.9400 | 0.9000 |
| NO. OF SUBFLARES | 1.3000 | 1.1500 | 1.0500 | 1.1100 | 1.0800 | 1.0000 | 1.0800 | 1.0800 | 0.8700 | 0.8700 | 1.0000 |
| NO. OF IMP. 1 FLARES | 1.2000 | 1.0900 | 1.0500 | 1.2100 | 1.0500 | 0.9600 | 1.0800 | 1.2000 | 1.1000 | 0.9600 | 0.8000 |
| NO. OF IMP. 2 FLARES | 1.3000 | 1.2500 | 1.2200 | 1.1200 | 1.0300 | 1.0400 | 1.1000 | 1.1300 | 1.0800 | 0.9400 | 0.9000 |
| NO. OF IMP. 3 FLARES | 1.3000 | 1.2500 | 1.2200 | 1.1200 | 1.0300 | 1.0400 | 1.1000 | 1.1300 | 1.0800 | 0.9400 | 0.9000 |
| NO. OF NORTH POLES | 0.7700 | 0.8600 | 0.9500 | 1.0000 | 1.0000 | 0.9800 | 0.9500 | 0.8500 | 0.7000 | 0.5300 | 0.3800 |
| NO. OF SOUTH POLES | 0.7400 | 0.8000 | 0.9300 | 1.0200 | 1.0000 | 1.0000 | 0.9900 | 0.8900 | 0.7800 | 0.6500 | 0.5000 |

Table IV
DEFINITIONS OF PROPERTIES

| TYPE | PROPERTY | METHOD OBTAINED | SYMBOL |
|---|---|---|---|
| | GENERAL DATA | | |
| DISCRETE | PASSAGE NUMBER | MEASURED | PN |
| | HEMISPHERE | " | H |
| CONTINUOUS | LATITUDE (ABSOLUTE) | " | $\phi$ |
| " | LATITUDE DEVIATION | COMPUTED = $\phi = \phi_E$ | $\Delta\phi$ |
| " | NO. OF MT. WILSON GROUP IN REGION | MEASURED | M |
| " | AVE. LATITUDE DEVIATION OF MT. W. GROUP | COMPUTED $\frac{1}{M}\sum_{m=1}^{M} \Delta\phi_m$ | $\Delta\phi_{GA}$ |
| " | MAX. LATITUDE DEVIATION OF MT. W. GROUP | COMPUTED | $\Delta\phi_{GM}$ |
| | DAILY DATA | 2nd SUBSCRIPT WHEN USED INDICATES NO. OF DAYS PRIOR TO SAMPLE DAY VALUE WAS MEASURED (OR COMPUTED) | |
| CONTINUOUS | NUMBER OF SUNSPOTS | MEASURED | $N_S$ |
| " | TOTAL AREA OF SUNSPOTS | " | $A_S$ |
| " | PLAGE AREA | " | $A_P$ |
| " | PLAGE BRIGHTNESS | " | B |
| DISCRETE | ZURICH CLASSIFICATION | " AND DEFINED | Z |
| CONTINUOUS | TOTAL DURATION OF SUBFLARES | MEASURED | $T_{F0}$ |
| " | TOTAL DURATION OF FLARES OF IMPORTANCE I | " | $T_{FI}$ |
| " | TOTAL DURATION OF FLARES OF " 2 | " | $T_{F2}$ |
| " | TOTAL DURATION OF FLARES OF " 3 | " | $T_{F3}$ |
| " | TOTAL DURATION OF ALL FLARES | CALCULATED $\sum_{n=0}^{3} T_{Sn}$ | $T_F$ |
| " | NUMBER OF SUBFLARES | MEASURED | $N_{F0}$ |
| " | NUMBER OF FLARES OF IMPORTANCE I | " | $N_{FI}$ |
| " | NUMBER OF FLARES OF " 2 | " | $N_{F2}$ |
| " | NUMBER OF FLARES OF " 3 | " | $N_{F3}$ |
| " | TOTAL NUMBER OF ALL FLARES | CALCULATED $\sum_{n=0}^{3} N_{Fn}$ | $N_F$ |
| " | AVERAGE DURATION OF FLARES | " $T_F / N_F$ | $T_{FA}$ |
| " | NUMBER OF SUNSPOTS/UNIT OF PLAGE AREA | " $N_S / A_P$ | |
| " | AVERAGE NO. OF FLARES PER SUNSPOT OVER LAST FOUR DAYS | " $\left(\sum_{n=1}^{4} N_{F,n}\right) / \left(\sum_{n=1}^{4} N_{S,n}\right)$ | |
| " | CHANGE IN AVE. DURATION OF FLARES | " $T_{FA,1} - T_{FA,2}$ | $\Delta T_{FA}$ |
| " | RELATIVE CHANGE IN AVE. FLARE DURATION | " $\Delta T_{FA} / T_{FA}$ | $RT_{FA}$ |
| " | CHANGE IN SUNSPOT NUMBER | " $N_{S,1} - N_{S,2}$ | $\Delta N_S$ |
| " | RELATIVE CHANGE IN SUNSPOT NUMBER | " $\Delta N_S / N_{S,1}$ | $RN_S$ |
| " | CHANGE IN SUNSPOT AREA | " $(A_{S,1} - A_{S,2})$ | $\Delta A_S$ |
| " | RELATIVE CHANGE IN SPOT AREA | " $\Delta A_S / A_{S,1}$ | $RA_S$ |
| " | CHANGE IN PLAGE AREA | " $(A_{P,1} - A_{P,2})$ | $\Delta A_P$ |
| " | RELATIVE CHANGE IN PLAGE AREA | " $\Delta A_P / A_{P,1}$ | $RA_P$ |

Table IV (Cont.)
DEFINITIONS OF PROPERTIES

| TYPE | PROPERTY | METHOD OBTAINED | SYMBOL |
|---|---|---|---|
| DISCRETE | MT. WILSON MAGNETIC CLASSIFICATION<br>1) DETERMINED BY CLASS OF ENTIRE REGION IF IT IS CLASSIFIED<br>2) OTHERWISE SAME AS MT. WILSON GROUP WITH MAX NO. OF POLES | MEASURED AND DEFINED | W |
| CONTINUOUS | MAX. NO. OF POLES IN ANY MT. WILSON GROUP | CALCULATED | $N_{p\ max}$ |
| " | (POLE DIFFERENCE/POLE SUM) OF MAX. GROUP | $\|N_{Dm}\|/N_{Pm}$ m = GROUP WITH MAX POLES | $U_{PG}$ |
| " | ( " " " " ) TOTAL | $N_{Dm}/N_P$ | $U_{PT}$ |
| " | (POLE DIFFERENCE, GROUP AVERAGE) | $N_D\ /M$ | $\Delta N_{PA}$ |
| " | AVE. NO. OF POLES PER GROUP | $N_P\ /M$ | $N_{PA}$ |
| " | POLE CHANGE | $N_{P,1} - N_{P,2}$ | $\Delta N_P$ |
| " | RELATIVE CHANGE | $\Delta N_P/N_{P,1}$ | $RN_P$ |
| " | AVE. DAILY POLE DIFFERENCE | $\|N_{AD}\|/M$ | |
| " | TOTAL NUMBER OF POLES | N1 | $N_P$ |

NOTE: $M_{Pm} = N_{Nm} + N_{Sm}$

$$N_{Dm} = N_{Nm} - N_{Sm}$$

$$N_P = \sum_{m=1}^{M} N_{Pm}$$

$$N_D = \left| \sum_{m=1}^{M} N_{Dm} \right|$$

$$N_{ADm} = |N_{Nm} - N_{Sm}|$$

$$N_{AD} = \sum_{m=1}^{M} N_{ADm}$$

Table V PROPERTY USAGE IN EXPERIMENTS

| SYMBOL | ABBREVIATED TITLE | PROPERTY IN EXPERIMENTS | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | EXP. 0A & 0B | | | | | EXP. 1B,2A,4A, 4B, 7 | | | | | EXP. 5A | | | | | EXP 6A. | | | | |
| | | DAYS BEFORE SAMPLE MEASURED (n) | | | | GENERAL | DAYS BEFORE SAMPLE MEASURED (n) | | | | GENERAL | DAYS BEFORE SAMPLE MEASURED (n) | | | | GENERAL | DAYS BEFORE SAMPLE MEASURED (n) | | | | GENERAL |
| | | 1 | 2 | 3 | 4 | | 1 | 2 | 3 | 4 | | 1 | 2 | 3 | 4 | | 1 | 2 | 3 | 4 | |
| PN | 1ST PASSAGE | | | | | X | | | | | X | | | | | X | | | | | X |
| DISCRETE VALUES | 2ND " | | | | | X | | | | | X | | | | | X | | | | | X |
| | 3RD " | | | | | X | | | | | X | | | | | X | | | | | X |
| | 4TH " | | | | | X | | | | | X | | | | | | | | | | |
| | 5TH " | | | | | X | | | | | X | | | | | | | | | | |
| | 6TH " | | | | | X | | | | | X | | | | | | | | | | |
| PN | 4,5,6 PASS | | | | | | | | | | | | | | | X | | | | | X |
| $\phi$ | LATITUDE | | | | | X | | | | | X | | | | | X | | | | | X |
| $\Delta\phi$ | LAT. DEV | | | | | X | | | | | X | | | | | X | | | | | X |
| M | NO. MT.W. GP | | | | | X | | | | | X | | | | | X | | | | | X |
| $\Delta\phi_{GA}$ | MWG L.D. AVE | | | | | X | | | | | X | | | | | X | | | | | X |
| $\Delta\phi_{GM}$ | MWG L.D. MAX | | | | | X | | | | | X | | | | | X | | | | | X |
| H | HEMISPHERE | | | | | X | | | | | X | | | | | X | | | | | X |
| $N_S$ | Dn SPOT NO. | X | X | X | X | | X | X | X | X | | X | X | X | X | | X | X | X | X | |
| $A_S$ | Dn SPOT AREA | X | X | X | X | | X | X | X | X | | X | X | X | X | | X | X | X | X | |
| $A_P$ | Dn PLAGE A | X | X | X | X | | X | X | X | X | | | | | X | | | | X | | |
| B | Dn PLAGE BR | X | X | X | X | | X | X | X | X | | X | X | X | X | | X | X | X | X | |
| Z | Dn ZURICH A | X | X | X | X | | X | X | X | X | | X | X | X | X | | | | | | |
| ↑ | " " B | X | X | X | X | | X | X | X | X | | X | X | X | X | | | | | | |
| | " " C | X | X | X | X | | X | X | X | X | | X | X | X | X | | | | | | |
| | " " D | X | X | X | X | | X | X | X | X | | X | X | X | X | | | | | | |
| | " " E | X | X | X | X | | X | X | X | X | | X | X | X | X | | | | | | |
| | " " F | X | X | X | X | | X | X | X | X | | X | X | X | X | | | | | | |
| | " " G | X | X | X | X | | X | X | X | X | | X | X | X | X | | | | | | |
| | " " H | X | X | X | X | | X | X | X | X | | X | X | X | X | | | | | | |
| DISCRETE VALUES | " " J | X | X | X | X | | X | X | X | X | | X | X | X | X | | | | | | |
| | " " BF | | | | | | | | | | | | | | | | X | X | X | X | |
| | " " EH | | | | | | | | | | | | | | | | X | X | X | X | |
| | " " AB | X | X | X | X | | | | | | | | | | | | | | | | |
| | " " CDE | X | X | X | X | | | | | | | | | | | | | | | | |
| ↓ | " " FG | X | X | X | X | | | | | | | | | | | | | | | | |
| Z | " " HJ | X | X | X | X | | | | | | | | | | | | | | | | |

Table V (CONT.)

| SYMBOL | ABBREVIATED TITLE | PROPERTY IN EXPERIMENTS | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | EXP. 0A & 0B | | | | EXP. 1B, 2A, 4A, 4B, 7 | | | | EXP. 5A | | | | EXP 6A | | | |
| | | DAYS BEFORE SAMPLE MEASURED (n) | | | | DAYS BEFORE SAMPLE MEASURED (n) | | | | DAYS BEFORE SAMPLE MEASURED (n) | | | | DAYS BEFORE SAMPLE MEASURED (n) | | | |
| | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| $T_{F0}$ | Dn DUR SUBFL | X | X | X | X | X | X | X | X | | | | | | | | |
| $T_{F1}$ | " " IMP 1 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| $T_{F2}$ | " " " 2 | X | X | X | X | X | X | X | X | X | X | | | X | X | | |
| $T_{F3}$ | " " " 3 | X | X | X | X | X | X | X | X | | | X | X | | | X | X |
| $T_F$ | " " FLARE | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| $N_{F0}$ | Dn NO. SUBFL | X | X | X | X | X | X | X | X | | | | | | | | |
| $N_{F1}$ | " " IMP 1 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| $N_{F2}$ | " " " 2 | X | X | X | X | X | X | X | X | X | X | | X | X | X | | X |
| $N_{F3}$ | " " " 3 | X | X | X | X | X | X | X | X | | | X | X | | | X | X |
| $N_F$ | " " FLARE | X | X | X | X | X | X | X | X | X | X | X | | X | X | X | |
| $T_{FA}$ | Dn DUR FL AV | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| $N_S/A_P$ | Dn SN/PA | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| $(N_F/N_S)4D$ | Dn FN/SN 4D | X | X | X | X | X | X | X | X | X | X | X | | X | X | X | |
| $\Delta T_{FA}$ | Dn FL DUR CH | X | X | X | | X | X | X | X | | | | | | | | |
| $\mathcal{R}T_{FA}$ | Dn FL DUR RC | X | X | X | | X | X | X | X | | X | | X | | X | | X |
| $\Delta N_S$ | Dn SPOT N CH | X | X | X | | X | X | X | X | X | | | | X | | | |
| $RN_S$ | Dn SPOT N RC | X | X | X | | X | X | X | X | X | | | | X | | | |
| $\Delta A_S$ | Dn SPOT A CH | X | X | X | | X | X | X | X | | | | | | | | |
| $RA_S$ | Dn SPOT A RC | X | X | X | | X | X | X | X | | | | | | | | |
| $\Delta A_P$ | Dn PLAGE A C | X | X | X | | X | X | X | X | | | | | | | | |
| $RA_P$ | Dn PLAG A RC | X | X | X | | X | X | X | X | X | | | | X | | | |
| W | Dn MW MAG AP | X | X | X | X | X | X | X | X | X | X | X | X | | | | |
| ← DISCRETE VALUES → | " " " AF | X | X | X | X | X | X | X | X | X | X | X | X | | | | |
| | " " " BP | X | X | X | X | X | X | X | X | X | X | X | X | | | | |
| | " " " BF | X | X | X | X | X | X | X | X | X | X | X | X | | | | |
| | " " " B | X | X | X | X | X | X | X | X | X | X | X | X | | | | |
| | " " " G | X | X | X | X | X | X | X | X | X | X | X | X | | | | |
| | " " " BG | X | X | X | X | X | X | X | X | X | X | X | X | | | | |
| W | " MT. W MAG | | | | | | | | | | | | | X | X | X | X |

Table V (CONT.)

| SYMBOL | ABBREVIATED TITLE | PROPERTY IN EXPERIMENTS | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | EXP. 0A & 0B | | | | EXP. 1B,2A,4A, 4B, 7 | | | | EXP. 5A | | | | EXP 6A | | | |
| | | DAYS BEFORE SAMPLE MEASURED | | | | DAYS BEFORE SAMPLE MEASURED (n) | | | | DAYS BEFORE SAMPLE MEASURED (n) | | | | DAYS BEFORE SAMPLE MEASURED (n) | | | |
| | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| $N_P MAX$ | Dn N+S GX | X | X | X | X | X | X | X | X | X | X | X | | X | X | X | |
| $U_{PG} MAX$ | Dn PD/PS GX | X | X | X | X | X | X | X | X | | | | | | | | |
| $U_{PT}$ | Dn PD/PS GT | X | X | X | X | X | X | X | X | | | | X | | | | X |
| $\Delta N_{PA}$ | Dn N-S GA | | | | | X | X | X | X | | X | | | | X | | |
| $\Delta N_P$ | Dn P SUM CH | X | X | X | | X | X | X | X | | X | | | | X | | |
| $RN_P$ | Dn P SUM RC | X | X | X | | X | X | X | X | | X | | | | X | | |
| $N_P$ | Dn N+S GA | | | | | X | X | X | X | X | X | | | X | X | | |
| $N_{PA}$ | Dn P SUM GT | X | X | X | X | | | | | | | | | | | | |
| $\|N_{AD}\|/M$ | | X | X | X | X | | | | | | | | | | | | |

Table VI
RESULTS OF PREDICTION EXPERIMENTS

| EXP. NO. | NO. OF SAMPLES IN TRAINING | | PREDICTION RESULTS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | NO. OF FLARE SAMPLES | | | NO. OF QUIET SAMPLES | | | OVERALL |
| | FLARE | QUIET | ACTUAL | CORRECTLY PREDICTED | FRACTION CORRECTLY PREDICTED | ACTUAL | CORRECTLY PREDICTED | FRACTION CORRECTLY PREDICTED | FRACTION CORRECTLY PREDICTED |
| 0A | 32 | 12 | 29 | 24 | .828 | 14 | 9 | .643 | .767 |
| 0B | 30 | 14 | 32 | 20 | .625 | 12 | 8 | .667 | .636 |
| 1B | 34 | 124 | 25 | 4 | .16 | 114 | 108 | .947 | .806 |
| 2A | 43 | 104 | 16 | 4 | .25 | 134 | 124 | .925 | .853 |
| 4A | 37 | 80 | 22 | 10 | .454 | 71 | 55 | .775 | .699 |
| 4B | 34 | 80 | 25 | 6 | .24 | 71 | 61 | .859 | .698 |
| 5A | 34 | 80 | 25 | 6 | .24 | 71 | 63 | .887 | .719 |
| 6A | 34 | 80 | 25 | 10 | .40 | 71 | 58 | .817 | .708 |
| 7 | 34 | 80 | 25 | 3 | .12 | 71 | 66 | .930 | .719 |

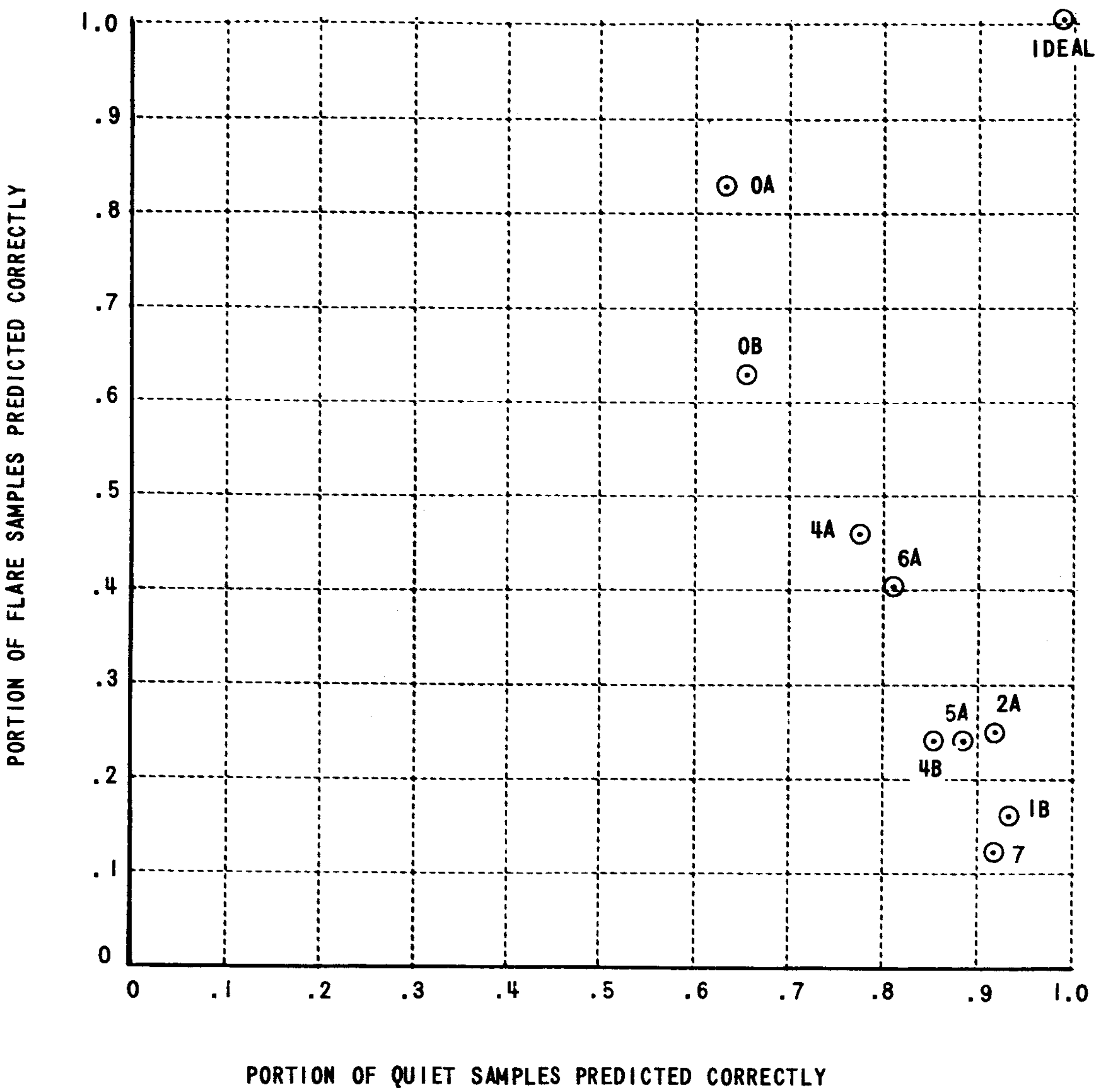


Figure 17 PREDICTION CHARACTERISTICS

(NO. BESIDE EACH POINT IDENTIFIES EXPERIMENT)

# REFERENCES


1. Murray, A. E. and Vossler, C.M., "Final Report for Phase I, Project PREP, Study of the Application of Perceptrons for the Prediction of Solar Flare, Solar Flare Forecasting with a Recognizing Automaton". CAL Report No. VS-1799-X-1, January 1964 under NASA contract No. NAS 5-3262.

2. Kuiper, C. P., "The Sun", The University of Chicago Press, Chicago, Illinois, 1953.

3. Smith, H. J. and Smith, E. P. "Solar Flares", The Macmillan Company, New York, N. Y., 1963.

4. Quarterly Bulletin on Solar Activity, International Astronomical Union, Published by Eidgen. Sternwarte, Zurich.

5. Guss, Donald E., "Distribution in Heliographic Longitude of Flares which Produce Energetic Solar Particles", Physical Review Letters, Vol. 13, No. 12, 21 Sept. 1964.

6. Avignon, Y., Caroubalos, C., Martres, J. J., Tripe, and Pick, M., "Optical Characteristics of Chromospheric Flares Associated With Type IV Radio Bursts or Noise Storms", pp. 25-26.

# APPENDIX A

## DESCRIPTION OF COMPUTER PREDICTION PROGRAM

The following computer programs were designed for prediction experiments on project PREP II for use on an IBM 7044 digital computer. Programming languages FORTRAN IV or MAP were used throughout. It is not necessary, however, for the reader to have a complete knowledge of these computer languages to understand the following description. All programs are punched on IBM cards for feeding to the IBM 7044 through an IBM 1401 peripheral computer.

The Prediction Program is actually four subprograms (subroutines) under the control of an executive program (main routine). At the time the program is placed on a computer any combination of the four subprograms may be used in any order and any number of times as specified by executive control cards.

A brief description of each follows.

1. The Preparation Subprogram (entry code, PREPAR) has two alternatives, only one of which may be used in any one computer run. The choice is determined through interchanging that portion of the program deck.

   a. Alternate 1:

      Raw data is read from the raw data cards and used in calculation of the prepared property values which are written on the property tape (tape unit 3).

   b. Alternate 2:

      A previously prepared property tape (on tape unit 2) is read, its contents edited (i.e. samples and properties culled) and the results used to write a new property tape (on tape unit 3). (The original property tape is not erased in the process).

2. The Property Report Subprogram (entry code, PROPOT) reads the property tape and prints the data in written report easily read by man.

3. The Training Subprogram (entry code, TRAIN) reads selected samples from the property tape and trains according to a standard linear discrimination technique.

4. The Prediction Subprogram (entry code, PREDIC) reads selected samples from the property tape and classifies them according to the separating hyperplane formulated by the Training Program. It checks its own results against the true classification and determines its own prediction performance factors.

Tables A-I through A-VI list the order and format of the control and data cards required for running the prediction programs.

## TABLE A-I
## EXECUTIVE CONTROL CARD FORMAT AND USAGE

| INTERNAL SYMBOL | COLUMNS | TYPE** | PURPOSE |
|---|---|---|---|
| NZ | 1 - 4 | I | $\neq 0$, DUMP* CORE MEMORY (FOR DIAGNOSTIC USE ONLY)<br>$= 0$, PROCEED |
| N5 | 5 - 8 | I | $\neq 0$, COMPUTER PAUSES FOR TAPE LOADING<br>$= 0$, PROCEED WITHOUT PAUSING |
| N1 | 9 - 12 | I | $< 0$, CALL PREPARATION SUBPROGRAM FOLLOWED BY CORE DUMP<br>$> 0$, CALL PREPARATION SUBPROGRAM WITH NO CORE DUMP<br>$= 0$, PROCEED |
| N2 | 13 - 16 | I | $< 0$, CALL PROPERTY REPORT SUBPROGRAM FOLLOWED BY DUMP<br>$> 0$, CALL PROPERTY REPORT SUBPROGRAM WITH NO DUMP<br>$= 0$, PROCEED |
| N3 | 17 - 20 | I | $< 0$, CALL TRAINING SUBPROGRAM FOLLOWED BY DUMP<br>$> 0$, CALL TRAINING SUBPROGRAM WITH NO DUMP<br>$= 0$, PROCEED |
| N6 | 21 - 24 | I | $\neq 0$, IF TRAINING TOOK PLACE, PROPERTY TAPE IS REWOUND<br>$= 0$, PROCEED |
| N4 | 25 - 28 | I | $< 0$, CALL PREDICTION SUBPROGRAM FOLLOWED BY DUMP<br>$> 0$, CALL PREDICTION SUBPROGRAM WITH NO DUMP<br>$= 0$, PROCEED |
| N8 | 29 - 32 | I | $= 0$, PROGRAM IS TERMINATED<br>$\neq 0$, ANOTHER EXECUTIVE CONTROL CARD IS READ AND FURTHER DIRECTIONS TAKEN FROM IT |

NOTE: ACTION TAKES PLACE IN ORDER LISTED.

*DUMP MEANS THE PROGRAM AND DATA, IF ANY, ARE PRINTED ON PAPER. THIS ACTION IS AVAILABLE FOR DIAGNOSTIC PURPOSES ONLY.

**TYPE OF FORMAT ENTRY ON IBM CARDS

I = INTEGER NUMBER
F = REAL NUMBER
A = ALPHA NUMERIC CHARACTERS

## TABLE A-II PREPARATION DATA CARDS (ALTERNATE I ONLY)

NOTE: 1. USED ONLY IF PREPARATION SUBPROGRAM IS CALLED BY EXECUTIVE PROGRAM.
2. PROPERTY TAPE ON TAPE UNIT 3.

| INTERNAL SYMBOL | COLUMNS | TYPE | PURPOSE |
|---|---|---|---|
| | PREPARATION CONTROL CARD | | |
| NEW | 1-4 | I | = 0, A NEW PROPERTY TAPE IS TO BE PREPARED<br>≠ 0, MORE SAMPLES TO BE ADDED TO EXISTING PROPERTY TAPE |
| ITAPE | 5-8 | I | ≠ 0, INTERMEDIATE DATA IS PRINTED (FOR DIAGNOSTIC PURPOSES ONLY)<br>= 0, NO ACTION |
| NGEN | 9-12 | I | NUMBER OF GENERAL PROPERTIES } NOT USED WHEN PREPARING NEW TAPE |
| NDAY | 13-16 | I | NUMBER OF DAILY PROPERTIES (TOTAL) } NOT USED WHEN PREPARING NEW TAPE |
| | FORESHORTENING FACTOR CARDS (1 FOR EACH PROPERTY FORESHORTENED) | | |
| A | 1-6 | A | NAME OF RAW DATUM (MEASUREMENT) TO BE FORESHORTENED |
| B(J) | 15J-8 THRU 15J th | F | FORESHORTENING FACTOR FOR DAY CMP + J-8, $J_{max}$ = 15 |
| | END OF FORESHORTENING CARD | | |
| A | 1-3 | A | LETTERS END, } INDICATES END OF FORESHORTENING DATA |
| | 4-6 | A | MUST BE BLANK } INDICATES END OF FORESHORTENING DATA |
| | RAW DATA CARDS, 1 SET PER REGION PASSAGE | | |
| | START CARD (FIRST CARD OF RAW DATA SET) | | |
| | 1-5 | A | LETTERS START |
| | 6 | A | MUST BE BLANK |
| NQ | 13 | I | ≠ 0, IF COLUMNS 73-77 DO NOT AGREE IN ALL CARDS OF SET, PROGRAM IS TERMINATED (NQ OF FIRST REGION ONLY USED)<br>= 0, IF COLUMNS 73-77 DO NOT AGREE IN ALL CARDS OF SET, DIAGNOSTIC IS PRINTED BUT PROGRAM CONTINUES |
| | GENERAL DATA CARD (SECOND CARD OF RAW DATA SET) | | |
| HAO | 1-3 | F | CAL SERIAL NO OF REGION PASSAGE |
| PASSNO | 4 | F | NO. OF PASSAGE |
| HEM | 5 | F | HEMISPHERE 2 = NORTH 1 = SOUTH |
| FLAT | 6-7 | F | LATITUDE (ABSOLUTE) |
| YEAR | 8-9 | F | YEAR |
| CMP | 10-12 | F | CMP DAY OF YEAR |
| ELAT | 13-14 | F | EXPECTED LATITUDE |
| CYCLE | 15 | F | SOLAR CYCLE PHASE |
| FIXLP | 16-18 | F | FLARE INDEX LAST PASS |
| SSNLP | 19-21 | F | AVERAGE NO. OF SUNSPOTS LAST PASS |
| FNMWG | 22 | F | NO. OF MT. WILSON MAGNETIC GROUPS IN REGION |
| GRLAT(J) | 53-54 | F | LATITUDE OF FIRST MT. WILSON GROUP |
| GRPRI(J) | 55 | F | IS FIRST GROUP PRIME, = 0 NO, = 1 YES } J = 1 |
| GRSHFL(J) | 56 | F | IS FIRST GROUP SHARED, = 0 NO, = 1 YES } J = 1 |
| GRNEI(J) | 57 | F | IS NEITHER OF ABOVE TRUE, = 0, NO, = 1 YES } J = 1 |

TABLE A-II (Cont.)

| INTERNAL SYMBOL | COLUMNS | TYPE | PURPOSE |
|---|---|---|---|
| | 58-62 | F | SAME AS COLUMNS 53-57 EXCEPT FOR MT. WILSON GR. = 2 & J = 2 |
| | 63-67 | F | SAME AS COLUMNS 53-57 EXCEPT FOR MT. WILSON GR. = 3 & J = 3 |
| | 68-72 | F | SAME AS COLUMNS 53-57 EXCEPT FOR MT. WILSON GR. = 4 & J = 4 |
| HAOREG | 73-77 | A | HAO REGION - PASSAGE IDENTIFICATION |
| DAILY DATA CARDS (1 FOR EACH DAY OF PASSAGE, MUST BE IN ORDER) | | | |
| SNAME(K) | 1-6 | A | CLASS (K = DAILY CARD ORDER) |
| SPOTN(K) | 7-9 | F | NO. OF SUNSPOTS |
| SPOTA(K) | 10-13 | F | TOTAL AREA OF SUNSPOTS |
| PLAGEA(K) | 14-18 | F | AREA OF REGION PLAGE |
| ZURICH(K) | 19 | F | ZURICH CLASSIFICATION (0 THRU 9) |
| PLAGEB(K) | 20-21 | F | PLAGE BRIGHTNESS |
| DURSF(K) | 22-23 | F | TOTAL DURATION OF DAY'S SUBFLARES |
| DURFI1(K) | 24-25 | F | TOTAL DURATION OF DAY'S IMPORTANCE 1 FLARES |
| DURFI2(K) | 26-27 | F | TOTAL DURATION OF DAYS'S IMPORTANCE 2 FLARES |
| DURFI3(K) | 28-29 | F | TOTAL DURATION OF DAY'S IMPORTANCE 3 FLARES |
| QUNSF(K) | 30-31 | F | NO. OF SUBFLARES |
| QUNFI1(K) | 32-33 | F | NO. OF IMPORTANCE 1 FLARES |
| QUNFI2(K) | 34 | F | NO. OF IMPORTANCE 2 FLARES |
| QUNFI3(K) | 35 | F | NO. OF IMPORTANCE 3 FLARES |
| CMWM(K) | 36 | F | MT. WILSON MAGNETIC CLASSIFICATION (0-7) |
| PRED(K) | 37 | F | IS THERE SUFFICIENT DATA TO MAKE A TEST SAMPLE FOR THIS DAY = 0, NO; ≠ 0, YES |
| DAY(K) | 38-40 | F | DAY OF YEAR |
| CMWMG(K, J) | 53 | F | MT. WILSON MAGNETIC CLASSIFICATION OF MT. WILSON GR. 1 } J = 1 |
| QPOLEN (K, J) | 54-55 | F | NO. OF NORTH POLES IN GROUP 1 } J = 1 |
| QPOLES(K, J) | 56-57 | F | NO. OF SOUTH POLES IN GROUP 1 } J = 1 |
| | 58-62 | | SAME AS COLUMNS 53-57 EXCEPT FOR MT. WILSON GR. 2, J = 2 |
| | 63-67 | | SAME AS COLUMNS 53-57 EXCEPT FOR MT. WILSON GR. 3, J = 3 |
| | 68-72 | | SAME AS COLUMNS 53-57 EXCEPT FOR MT. WILSON GR. 4, J = 4 |
| | 73-77 | A | HAO REGION-PASSAGE IDENTIFICATION |
| END OF SET FOR REGION PASSAGE | | | |
| END OF RAW DATA | | | |
| | 1-3 | A | LETTERS END |
| | 4-6 | A | MUST BE BLANK |

## TABLE A-III
## PREPARATION DATA CARDS (ALTERNATE 2 ONLY)

NOTE: 1. USED ONLY IF PREPERATION SUBPROGRAM IS CALLED BY EXECUTIVE PROGRAM
2. OLD PROPERTY TAPE ON TAPE UNIT 2
3. NEW PROPERTY TAPE ON TAPE UNIT 3

| INTERNAL SYMBOL | COLUMNS | TYPE | PURPOSE |
|---|---|---|---|
| | PROPERTY SELECTION CARD (1ST) | | |
| A | 1 - 6 | A | LETTERS PRKEPT, ANYTHING ELSE WILL TERMINATE PROGRAM |
| NG | 9 - 12 | I | NO. OF PROPERTY GROUPS TO BE RETAINED |
| NGF(J) | {8J + 1, 8J + 4} | I | POSITION NO. OF FIRST PROPERTY OF $J^{th}$ PROPERTY GROUP |
| NGT(J) | {8J + 5, 8J + 8} | I | POSITION NO. OF LAST PROPERTY OF GROUP |
| | ADDITIONAL PROPERTY SELECTION CARDS (IF NECESSARY) IF J > 7, ADDITIONAL CARD FOR EACH ADDITIONAL 8 GROUPS | | |
| NGF(J) | {8(J-N)+15, 8(J-N)+18} | I | FOR $7 < J \leq 15$, N = 7 ON CARD 2 ($NG_{MAX} = 20$) |
| NGT(J) | {8(J-N)+19, 8(J-N)+22} | I | $15 < J \leq 20$ N = 15 ON CARD 3 |
| | PROPERTY COMBINATION CARD(S) | | |
| A | 1 - 6 | A | LETTERS END ≡ THERE ARE NO MORE COMBINATION CDS. LETTERS COMBIN ≡ TWO OR MORE PROPERTIES TO BE SUMMED TO FORM NEW PROPERTY (ANY OTHER LETTERS HERE TERMINATES PROGRAM) |
| T1, T2 | 9 - 20 | A | 12 CHARACTER TITLE OF NEW PROPERTY |
| JPI | 25 - 28 | I | ON COMBIN CARD(S) NO. OF PROPERTIES TO BE SUMMED $JPI_{MAX} = 12$ ON END CARD, ARE DATA ON NEW PROPERTY TAPE TO BE NORMALIZED? = 0, NO; ≠ 0 YES |
| NPC(J,K) | {4J + 21, 4J + 24} | I | POS. NO. OF $J^{th}$ PROPERTY IN SUM (J = 1, JPI) (K = 1, NO. OF NEW PROPERTIES (COMBIN CARDS)) |

TABLE A-III (CONT.)

| INTERNAL SYMBOL | COLUMNS | TYPE | PURPOSE |
|---|---|---|---|
| | SAMPLE SELECTION CARD (1ST) | | |
| A | 1 - 6 | A | LETTERS SAKEPT, ANYTHING ELSE TERMINATES PROGRAM |
| NS | 9 - 12 | I | NO. OF SAMPLE GROUPS TO BE RETAINED |
| NSF(J) | $\{8J+1, 8J+4\}$ | I | POSITION NO. OF FIRST SAMPLE OF $J^{th}$ SAMPLE GROUP |
| NST(J) | $\{8J+5, 8J+8\}$ | I | POSITION NO. OF LAST SAMPLE OF $J^{th}$ SAMPLE GROUP |
| | ADDITIONAL SAMPLE SELECTION CARD(S) (IF NECESSARY)<br>IF $J > 7$, ADDITIONAL CARD FOR EACH ADDITIONAL 8 GROUPS | | |
| NSF(J) | $\{8(J-N)+15, 8(J-N)+18\}$ | I | FOR $7 < J \leq 15$, $N = 7$ CARD 2 |
| NST(J) | $\{8(J-N)+19, 8(J-N)+22\}$ | I | $15 < J \leq 20$, $N = 15$ CARD 3 $(NS_{MAX} = 20)$ |

## TABLE A-IV
## PROPERTY REPORTING DATA CARDS

**NOTE: USED ONLY IF PROPERTY REPORT SUBPROGRAM IS CALLED BY EXECUTIVE PROGRAM**

| INTERNAL SYMBOL | COLUMNS | TYPE | PURPOSE |
|---|---|---|---|
| REPORT TITLE CARD | | | |
| A(J)<br>J = 1, 12 | 1 - 72 | A | 72 CHARACTER TITLE TO BE USED AS HEADING TO PRINTED REPORT |
| SELECTION CARD(S) | | | |
| NI | 1 - 4 | I | > 0 POSITION NO. OF FIRST (NEXT) SAMPLE TO BE REPORTED<br>= 0 NO MORE SAMPLES TO BE REPORTED |
| NL | 5 - 8 | I | = 0 ALL REMAINING SAMPLES ON TAPE ARE REPORTED<br>> 0 ALL SAMPLES STARTING WITH ABOVE ARE TO REPORT UP TO THIS ONE, INCL. IF THERE ARE STILL MORE SAMPLES REMAINING ON TAPE, ANOTHER SELECTION CARD IS USED |

# TABLE A-V
# TRAINING DATA CARDS

NOTE: USED ONLY IF TRAINING SUBPROGRAM IS CALLED BY EXECUTIVE PROGRAM

| INTERNAL SYMBOL | COLUMNS | TYPE | PURPOSE |
|---|---|---|---|
| **TRAINING CONTROL CARD** | | | |
| NWTS | 1-4 | I | 0, INITIAL WEIGHTS ARE TO BE COMPUTED |
| | | | 0, INITIAL WEIGHTS ARE READ IN FROM CARDS |
| NSCRAT | 5-8 | I | ≠0, INTERMEDIATE TAPE AVAILABLE FROM PREVIOUS RUN |
| | | | =0, PREPARE INTERMEDIATE TAPE |
| NPUNM | 9-12 | I | ≠0, "HOLE-FILLING" VALUES ARE TO BE PUNCHED ON CARDS |
| | | | =0, "HOLE-FILLING" VALUES NOT TO BE PUNCHED ON CARDS |
| NPRNM | 13-16 | I | ≠0, "HOLE-FILLING" DATA ARE PRINTED |
| | | | =0, "HOLE-FILLING" DATA NOT PRINTED |
| NIT | 17-20 | I | MAX. NUMBER OF ITERATIONS PERMITTED IN TRAINING |
| NITP | 21-24 | I | NUMBER OF ITERATIONS PREVIOUSLY MADE |
| NDISF | 25-28 | I | ≠0, SAMPLE DISTANCES PRINTED PRIOR TO TRAINING |
| | | | =0, SAMPLE DISTANCES NOT PRINTED PRIOR TO TRAINING |
| NDISI | 29-32 | I | SAMPLE DISTANCES PRINTED AFTER EVERY NDISI ITERATION |
| | | | IF =0, NO INTERMEDIATE DISTANCE REPORTS |
| NDISL | 33-36 | I | ≠0, SAMPLE DISTANCES PRINTED AFTER TRAINING |
| | | | =0, SAMPLE DISTANCES NOT PRINTED AFTER TRAINING |
| NWTSF | 37-40 | I | ≠0, PROPERTY WEIGHTS PRINTED PRIOR TO TRAINING |
| | | | =0, PROPERTY WEIGHTS NOT PRINTED PRIOR TO TRAINING |
| NWTSI | 41-44 | I | PROPERTY WEIGHTS PRINTED AFTER EVERY NWTSI ITERATION |
| | | | IF =0, NO INTERMEDIATE WEIGHT REPORTS |
| NWTPU | 45-48 | I | ≠0, FINAL WEIGHTS TO BE PUNCHED ON CARDS |
| | | | =0, FINAL WEIGHTS NOT TO BE PUNCHED ON CARDS |
| DELTA | 53-60 | F | MIN. DISTANCE ALLOWED FOR HYPERPLANE FROM ORIGIN |
| NNØRM | 71 | I | =0, PHASE II HOLE FILLING TECHNIQUE IS USED |
| | | | ≠0, PHASE II HOLE FILLING TECHNIQUE NOT USED |
| NSTØP | 72 | I | =0, IF HYPERPLANE CLOSER THAN DELTA, PROGRAM TERMINATES |
| | | | ≠0, IF HYPERPLANE CLOSER THAN DELTA, PROGRAM CONTINUES |
| **CLASSIFICATION CARDS (2 CARDS)** | | | |
| CLASSM(J) | 1-6 | A | 6 CHARACTER NAME OF J SIDE OF HYPERPLANE |
| NSUB(J) | 9-12 | I | NO. OF SAMPLE CLASSES ON J SIDE (MAX. OF 6) |
| SUBCL(K,J) | {6K+10, 6K+15} | A | NAME OF $K^{th}$ CLASS ON J SIDE |
| | | | (J = 1 ON POS. SIDE. J = 2 ON NEG. SIDE) |
| **SAMPLE CARD ($1^{st}$)** | | | |
| F | 1-6 | A | LETTERS SAMPLE, ANYTHING ELSE TERMINATES JOB |
| NSP | 7-8 | I | NO. OF SAMPLE GROUPS USED FOR TRAINING |
| NSPF(J) | {8J+1, 8J+4} | I | POS. NO. OF FIRST SAMPLE OF GROUP J } $1 \leq J \leq 8$ |
| NSPT(J) | {8J+5, 8J+8} | | POS. NO. OF LAST SAMPLE OF GROUP J } |
| **ADDITIONAL SAMPLE CARD(S) (IF NECESSARY)** | | | |
| NSPF(J) | {8(J-n)+1, 8(J-n)+4} | I | IF $8 < J \leq 16$, n = 8, CARD 2 } $J_{max} = 20$ |
| NSPT(J) | {8(J-n)+5, 8(J-n)+8} | I | $16 < J \leq 20$, n = 16, CARD 3 } |

TABLE A-V (CONT.)
TRAINING DATA CARDS

| INTERNAL SYMBOL | COLUMNS | TYPE | PURPOSE |
|---|---|---|---|
| NORM CARD (1st) (USED ONLY IF NNØRM=0 ON TRAINING CONTROL CARD) | | | |
| F1 | 1-6 | A | LETTERS NORM , ANYTHING ELSE TERMINATES JOB |
| NP | 7-8 | I | NO. OF GROUPES TO BE NORMALIZED USING PHASE II TECHNIQUE |
| NPF(J) | {8J+1, 8J+4} | I | POSITION OF FIRST PROPERTY IN GROUP J } $1 \leq J \leq 8$ |
| NPT(J) | {8J+5, 8J+8} | I | POSITION OF LAST PROPERTY IN GROUP J } $1 \leq J \leq 8$ |
| ADDITIONAL NORM CARD (S) (IF NECESSARY) | | | |
| NPF(J) | {8(J-N)+1, 8(J-N)+4} | I | IF $8 < J \leq 16$, N = 8  J MAX = 20 |
| NPT(J) | {8(J-N)+5, 8(J-N)+8} | I | IF $16 < J \leq 20$, N = 16 |
| CHOICE CARD (1st) (USED ONLY IF NNORM = 0 ON TRAINING CONTROL CARD) | | | |
| F2 | 1-6 | A | LETTERS CHOICE, ANYTHING ELSE TERMINATES JOB |
| NCH | 7-8 | I | NO. OF PROPERTY GROUPS WITHIN WHICH A CHOICE IS MADE |
| NCHF(J) | {8J+1, 8J+4} | I | POSITION OF FIRST PROPERTY IN GROUP J } $1 \leq J \leq 8$ |
| NCAT(J) | {8J+5, 8J+8} | I | POSITION OF LAST PROPERTY IN GROUP J } $1 \leq J \leq 8$ |
| ADDITIONAL CHOICE CARD (S) (IF NECESSARY) | | | |
| NCHF(J) | {8(J-N)+1, 8(J-N)+4} | I | FOR $8 < J \leq 16$, N = 8  $J_{max} = 20$ |
| NCHT(J) | {8(J-N)+5, 8(J-N)+8} | I | $16 < J \leq 20$, N = 16 |
| WEIGHT CARD (1st) (USED ONLY IF WTS >0 IN TRAINING CONTROL CARD) | | | |
| F1 | 17-22 | A | LETTERS WEIGHT |
| DEN | 49-60 | F | DISTANCE OF HYPERPLANE FROM ORIGIN |
| NOPROP | 68-72 | I | NO. OF PROPERTIES USED IN TRAINING |
| ADDITIONAL WEIGHT CARD (S) AS NEEDED, 1 OR MORE CARDS | | | |
| TITLE(J,K) J = 1,2 | N+1,N+12 | A | 12 CHARACTER TITLE OF Kth PROPERTY |
| WTS (K) | N+13,N+24 | E | VALVE OF Kth PROPERTY WEIGHT<br>NOTE: $N = \left[24\,(J_{mod\ 3} - 1)\right]_{mod\ 72}$ ie 3 PROPERTIES/CARD |

TABLE A-V (CONT.)
TRAINING DATA CARDS

| INTERNAL SYMBOL | COLUMNS | TYPE | PURPOSE |
|---|---|---|---|
| HOLE FILLER CARDS FOR CONTINUOUS PROPERTIES, USED ONLY IF NWTS > 0, NSCRAT = 0, AND NNORM = 0 ON TRAIN CONTROL CARD. THIS SET OF CARDS PREPARED BY PREVIOUS RUN OF THIS PROGRAM IF NPUNM HAD BEEN ≠ 0. | | | |
| | 1-4 | | DATA |
| | 5-8 | | BLANK |
| | 9-36 | | PREP NORM. STATISTICS DATED |
| | 37-42 | | DATE OF PREVIOUS RUN |
| | 77-80 | | CTPD |
| HOLE FILLER CARDS FOR OBJECTIVE PROPERTIES USED ONLY IF NWTS > 0, NSCRAT = 0 AND NNORM = 0 ON TRAINING CONTROL CARD. THIS SET OF CARDS PREPARED BY PREVIOUS RUN OF THIS PROGRAM IF NPUNM HAD BEEN ≠ 0. FIRST CARD IDENTIFIED BY FOLLOWING PUNCHING | | | |
| | 1-4 | | DATA |
| | 9-41 | | PREP. OBJECTIVE STATISTICS DATED |
| | 42-47 | | DATE OF PREVIOUS RUN |
| | 77-80 | | CTPD |

TABLE A-VI

PREDICTION TEST DATA CARDS

NOTE: USED ONLY IF PREDICTION SUBPROGRAM IS CALLED BY EXECUTIVE PROGRAM

| INTERNAL SYMBOL | CARD COLUMNS | TYPE | PURPOSE |
|---|---|---|---|
| | PREDICTION REPORT TITLE CARD | | |
| A(J) | 1 - 72 | I | 72 CHARACTERS FOR HEADING OF PREDICTION REPORT |
| | PREDICTION CONTROL CARD | | |
| NWTS | 1 - 4 | I | = 0, PROPERTY WEIGHTS ARE ALREADY IN COMPUTER<br>≠ 0, PROPERTY WEIGHTS TO BE READ FROM CARDS |
| NSEP | 5 - 8 | I | = 0, CLASSIFICATION SETS ALREADY IN COMPUTER<br>≠ 0, CLASSIFICATION SETS TO BE READ FROM CARDS |
| NNRM | 9 - 12 | I | = 0, "FILL-IN" VALUES ALREADY IN COMPUTER<br>≠ 0, "FILL-IN" VALUES TO BE READ FROM CARDS |
| NNORM | 13 - 16 | I | = 0, PHASE II FILL-IN VALUES ARE USED<br>≠ 0, PHASE II FILL-IN VALUES ARE NOT USED |
| | CLASSIFICATION CARDS (2 CARDS) INCLUDED<br>ONLY IF NSEP≠0 ON PREDICTION CONTROL CARD | | |
| CLASSM(J) | 1 - 6 | A | 6 CHARACTER NAME OF J SIDE OF HYPERPLANE. |
| NSUB(J) | 9 - 12 | I | NO. OF SAMPLE CLASSES ON J SIDE (MAX. OF 6) |
| SUBCL(K,J) | {6K + 10, 6K + 15} | A | NAME OF $K^{th}$ CLASS ON J SIDE<br>(J = 1 ON POS. SIDE. J = 2 ON NEG. SIDE ) |
| | WEIGHT CARD (1ST) USED ONLY IF NWTS≠0<br>ON PREDICTION CONTROL CARD | | |
| FI | 17 - 22 | A | LETTERS WEIGHT |
| DEN | 49 - 60 | F | DISTANCE OF HYPERPLANE FROM ORIGIN |
| NOPROP | 68 - 72 | N | NO. OF PROPERTIES USED IN TRAINING |
| | ADDITIONAL WEIGHT CARD(S) AS NEEDED<br>1 OR MORE CARDS | | |
| TITLE (J,K) } J = 1, 2 | N + 1, N + 12 | A | 12 CHARACTER TITLE OF $K^{th}$ PROPERTY |
| WTS(K) | N + 13, N + 24 | E | VALUE OF $K^{th}$ PROPERTY WEIGHT<br>NOTE: $N = [24(J_{MOD3} - 1)]$ MOD72<br>IE 3 PROPERTIES/CARD |

TABLE A-VI (CONT)

| INTERNAL SYMBOL | CARD COLUMNS | TYPE | PURPOSE |
|---|---|---|---|
| HOLE FILLER CARDS FOR CONTINUOUS PROPERTIES, USED ONLY IF NNRM≠0 ON PREDICTION CONTROL CARD. THIS SET OF CARDS PREPARED BY PREVIOUS RUN OF THIS PROGRAM IF NPUNM HAD BEEN ≠0. FIRST CARD IDENTIFIED BY FOLLOWING PUNCHING | | | |
| | 1 - 4 | | DATA |
| | 5 - 8 | | BLANK |
| | 9 - 36 | | PREP. NORM STATISTICS DATED |
| | 37 - 42 | | DATE OF PREVIOUS RUN |
| | 77 - 80 | | CTPD |
| HOLE FILLER CARDS FOR OBJECTIVE PROPERTIES USED ONLY IF NNRM≠0 ON PREDICTION CONTROL CARD. THIS SET OF CARDS PREPARED BY PREVIOUS RUN OF THIS PROGRAM IF NPUNM HAD BEEN ≠0. FIRST CARD IDENTIFIED BY FOLLOWING PUNCHING | | | |
| | 1 - 4 | | DATA |
| | 9 - 41 | | PREP. OBJECTIVE STATISTICS DATED |
| | 42 - 47 | | DATE OF PREVIOUS RUN |
| | 77 - 80 | | CTPD |
| PREDICTION SAMPLE CARD (1ST) | | | |
| F | 1 - 6 | A | LETTERS PREDIC, ANYTHING ELSE TERMINATES JOB |
| NSP | 7 - 8 | I | NO. OF SAMPLE GROUPS USED FOR PREDICTION |
| NSPF(J) | $\left\{\begin{matrix} 8J + 1 \\ 8J + 4 \end{matrix}\right\}$ | I | POSITION NO. OF FIRST SAMPLE OF GROUP J } $1 \le J \le 8$ |
| NSPT(J) | $\left\{\begin{matrix} 8J + 5 \\ 8J + 8 \end{matrix}\right\}$ | I | POSITION NO. OF LAST SAMPLE OF GROUP J } $1 \le J \le 8$ |
| ADDITIONAL PREDICTION SAMPLE CARD(S) AS NEEDED | | | |
| NSPF(J) | $\left\{\begin{matrix} 8(J-N) + 1 \\ 8(J-N) + 4 \end{matrix}\right\}$ | I | FOR $8 < J \le 16$, N = 8   $J_{MAX} = 20$ |
| NSPT(J) | $\left\{\begin{matrix} 8(J-N) + 5 \\ 8(J-N) + 8 \end{matrix}\right\}$ | I | $16 < J \le 20$, N = 16 |