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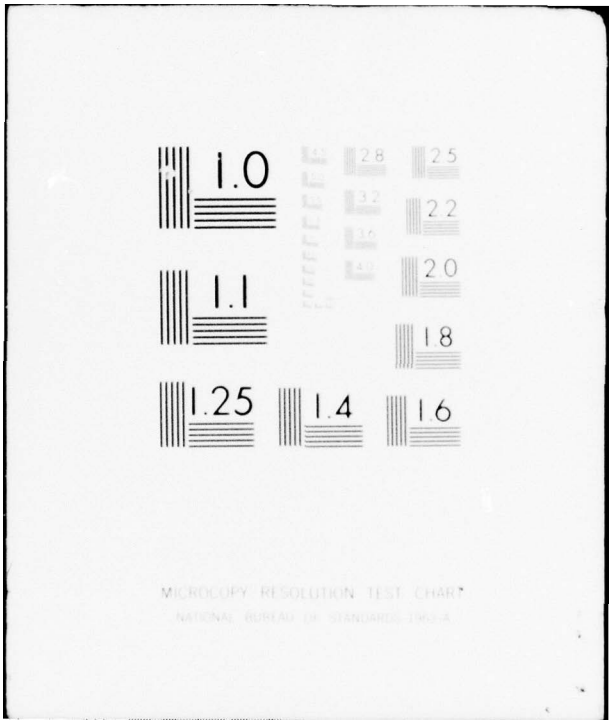
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MATHEMATICAL ANALYSIS AND IMPLEMENTING SOFTWARE FOR PHYSICAL AND ENGINEERING DATA

Edward Ziemba
Andre Lacroix
Muriel Hervey
Joanna Enzmann
Edward Odjaghian
George Bakalyar
John Crosby

Analytical Systems Engineering Corporation
5 Old Concord Road
Burlington, Massachusetts 01803

May 1977

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AIR FORCE SYSTEMS COMMAND
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The purpose of this report is to describe most of the numerical analysis, data analysis and computer programming problems performed under Contract F19628-76-C-0203. The problems vary in complexity from straightforward program adaptation to tasks requiring analysis, determining, implementing, and sometimes deriving algorithm best suited to perform the calculations. The problems discussed are done so in summary form. The analysis and programming techniques required are outlined. It should be noted that some of these problems are still being analyzed because of their complexity or continuing nature. Others are active →next

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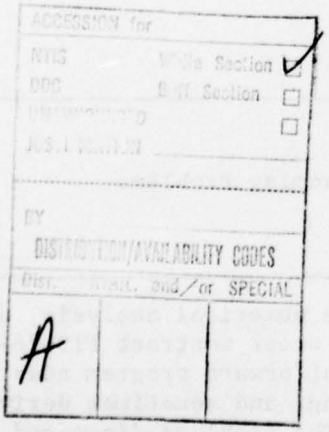

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PREFACE

The analysis and computer programs described in this report are the results of mathematical, analytical, and software development tasks performed for:

Analysis and Simulation Branch (SUA)
Air Force Geophysics Laboratory
Hanscom Air Force Base
Bedford, Massachusetts 01731

The writers express their thanks to Ms. Eunice C. Cronin, Branch Chief, and to Mr. John F. Kellaher and to Mr. Austin A. Almon, Contract Monitors, whose support and technical guidance were invaluable in the performing of the tasks described in this report.

In addition, the authors would like to thank the AFGL research personnel for whom the tasks were performed. Their cooperation and technical assistance is truly appreciated.

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1. INTRODUCTION

The purpose of this report is to describe most of the mathematical analysis, data analysis and computer programming problems performed under Contract Number F19628-76-C-0203. The problems vary in complexity from straightforward program adaptation to tasks requiring analysis, determining, implementing, and sometimes deriving algorithm best suited to perform the calculations. The problems discussed are done so in summary form. The analysis and programming techniques required are outlined. It should be noted that some of these problems are still being analyzed because of their complexity or continuing nature. Others are active because they were begun shortly before the writing of this report.

In the subject description, problem numbers are sometimes supplimented with an A or B. This is to indicate multiple requests under the same problem number. Problem descriptions which are for follow-on tasks or slight deviations from another task are described immediately after the primary task. Total request description is not always given, rather only the modifications are discussed.

Software developed for tasks completed have been documented separately. These programs can be obtained from The Analysis and Simulation Branch (SUA), Air Force Geophysics Laboratory (AFGL) upon request by referencing the appropriate problem numbers and project numbers listed with each task description.

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2. Probabilities and Correlations from Radar Data

INITIATOR: I. GRINGORTEN

PROBLEM NO.: 4862A PROJECT NO.: 8624

BACKGROUND

The purpose of this task was to statistically analyze the areal coverage, determined by radar echoes, of eight equal areas. The radar echoes were caused by precipitation. The radar pictures give the horizontal distribution of precipitation within a given radius from the radar station. There is a set of data from five stations for each day of the four mid-season months (January, April, July and October) in 1969-1974, for each 3-hourly interval. The data gives the amount of areal coverage by radar echoes of 64 cells of equal size surrounding a radar station.

With the 64 cells assembled into eight groups, the task was to find the frequency distribution and the cumulative probability distribution of areal coverage in each group. Then using normalized probabilities, the correlation between the groups was determined. In addition to the standard correlation, lag correlations between the seven groups used as predictors (groups 2 to 8) and the first group were calculated.

ANALYSIS AND RESULTS

Data on tape was available from five different stations, namely

STATION	NAME
1	Minneapolis, MN
2	Key West, FL
3	Wichita, KS
4	Cape Hatteras, NC
5	Evansville, IN

At each station, radar PPI pictures were taken once every three hours showing the horizontal distribution of rain clouds around the radar station. A copy of a transparent template (Figure 2-1) was placed over each radar picture and the projection was adjusted so that the outermost circle fitted on the 125-nmi circle of the template. The second largest circle of the template represents 100-nmi, the innermost circle has a scale-radius of 25-nmi. Between the 25-nmi and the 100-nmi circles, the area is divided by the remaining three circles and the radial lines into 64 equal cells numbered from 11 to 74. The cells numbered 11-18 form Group 1; those numbered 19-26 form Group 2; from 27-37, Group 3; and so on, for a total of eight groups.

In each radar picture, for each of the three hours throughout the day, for each day of the four months, for the six years, the fractional coverage of each cell (11-74) was determined to be either no coverage, or less than 1/16, 1/8, 2/8, up to 8/8 (full coverage), and recorded respectively as a blank, 0, 1, 2, up to 8 in that column of a punch card having the same number as the cell number.

Software was written to combine the cells into the eight groups. Each group could have 0 to 64 octas of rain-cloud coverage. (One octa is defined as 1/8 coverage.) The frequency distribution for each group was found in terms of the value of the cells. Then the cumulative probability that the number of octas exceeds 64, 63, ..., 0 was calculated. The case where all eight cells in a group were blank was handled separately. After the areal coverage in Groups 1 to 8 was determined for each radar picture, the correlation between groups was determined. Then the lag correlations between Group 1 and the eight groups were determined. The lags of interest were three-, six-, nine- and twelve-hour lags.

The input data for each station was on magnetic tape. The information for each of three hours for every day in the four months for the six years was provided on the tape.

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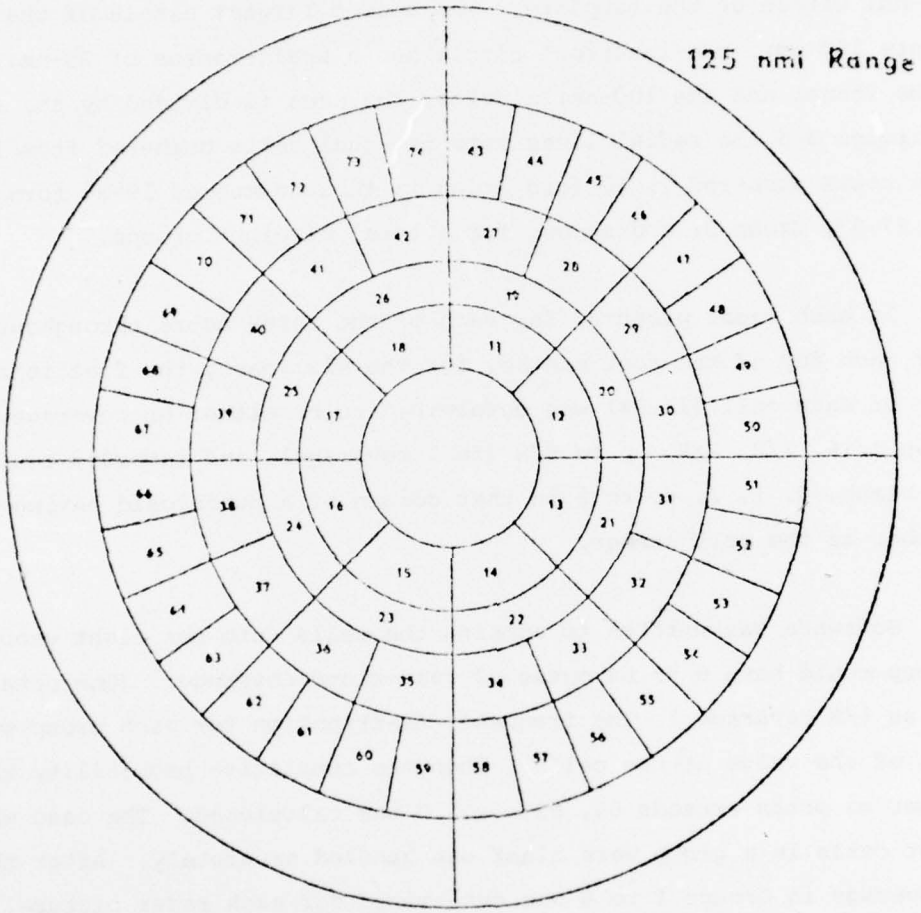

Figure 2-1 Copy of Transparent Template

The software written provided the following information (in tabular output) for each season/station combination:

Table 1 The cumulative relative frequency of coverage equal to or greater than L OCTAS in each group, for L = 64, 63, ..., 1, 0.

Table 2 the cumulative probability distribution for Table (1).

Table 3 The normalized probability values of Table (2).

Table 4 The matrix of the correlation coefficients (ρ_{ij}).

Table 5 The matrix of the lag correlation coefficients.

Table 6 Number of points used to calculate the various correlations.

DATA PREPARATION

In preparing the data to be run through the program, errors in the data base were detected. These errors were corrected before the program was run. The following is a description of the procedure used to prepare the total data base.

The data for five stations was originally on 9-track and 7-track tapes. The first step was to convert the 9-track tapes into 7-track tapes. All stations contained missing and/or mispunched data. The corrections were made by either merging two records, by deleting records, or by adding dummy records.

Two records were merged if they had the same year, day, hour and observation code (column 8 or 9), but different values for the cells. The subsequent records were merged into the superset record. If a record was repeated more than once the extra records were deleted. In the case of missing data, records with code 9 in column 8 or code 3 in column 9 were added depending upon the data surrounding the missing data. (Code 9 indicates no echoes existed within cells 11-74. Code 3 indicates observation not available.)

Finally, the corrected data for five stations was put on a 7-track tape. There are five files on the tape, one for each station.

SOFTWARE AND ALGORITHMS

The program written is composed of a main program and four subroutines. In the main program parameters are initialized and a matrix which contains the cell values for 8 groups for six years is obtained. Along with this matrix two vectors are formed; one for the days, and one for the hours. The frequency distribution (IFRD), probability distribution (P), normalized probability distribution (XR), correlation coefficients (CC), and the lag correlation coefficients (CCN) are calculated for a season. This process is repeated for four seasons. The program was run for all five stations. The probability matrix P is defined by:

$$P_{(i,\,j)} = \frac{\sum_{i=K}^{66} \text{IFRD}\ (i,\,j) - .375}{\text{sample size} + .25} \qquad K = 66,\ 65,\ \ldots,\ 2$$

For K = 1 (blanks), then

$$P_{(i,\,j)} = \frac{\sum_{i=2}^{66} \text{IFRD}\ (i,\,j) + \frac{\text{IFRD}\ (i,\,j)}{2} - .375}{\text{sample size} + .25}$$

The normalized probability matrix XR is defined by:

```
XR(L, j) = C*T - ANUM/DENOM
```

where

```
ANUM = A0 + A1*T

DENOM = 1 + B1*T + B2*T**2

A0 = 2.30753
A1 = 0.27061

B1 = 0.99229
B2 = 0.04481
```

```
If P(L, J) ≤ 0.5      C = 1
                      T = SQRT (ALOG(1/P(L,J)**2))
If P(L, J) > 0.5      C = -1
                      T = SQRT (ALOG(1/(1-P(L,J))**2))
```

The correlation coefficient equation used is:

$$\rho_{xy} = \frac{q}{\sigma_x \sigma_y}$$

where $$q = \frac{\Sigma (xy)}{N} - \left(\frac{\Sigma x}{N}\right)\left(\frac{\Sigma y}{N}\right)$$

σ_x = standard deviation of group x

σ_y = standard deviation of group y

3. Conditional Probabilities and Scores

INITIATOR: I. GRINGORTEN

PROBLEM NO.: 4862B PROJECT NO.: 8624

BACKGROUND

Given the frequency of a weather condition, it is possible to estimate the probability of its occurrence or to calculate its conditional probability following various antecedents. From Problem No. 4862A (Section 2), a matrix of correlation coefficients was found between seven predictors. Similarly, a vector of correlations between a predictand and each of the seven predictors was formed. The objective of this task was to use these correlations to find the conditional probabilities of a predictand, given each of the seven predictors. Also the ability to estimate the conditional probabilities was evaluated.

The purpose of this task was (1) to generate the software to calculate the necessary probabilities and other associated statistics; and (2) to calculate the necessary statistics. The results of this task and the task described in Section 2 were used by the researcher and published[1].

ANALYSIS AND RESULTS

The conditional probability was computed using the following equation:

---

1 Gringorten, I. I., "Multi-Prediction Conditional Probabilities," AFGL-TR-76-0239.

$$P(Y = y | X = x) = \frac{P(Y = y \cap X = x)}{P(X = x)}$$

In the more general case, if Y is the predictand, and $X_1, \ldots, X_n$ are n predictors, then it is desired to find

$$P(Y \geq Y_c | X_1, \ldots, X_n)$$

where Y_c is a threshold value of the predictand.

The following values, calculated in Problem 4862A (Section 2), were used in this analysis:

$$\rho_{ij} = E[X_i X_j]$$
$$\rho_i = E[Y X_i]$$

where ρ_{ij} are the correlation coefficients between predictors X_i and X_j, and ρ_i are the correlation coefficients between predictand Y and the i^{th} predictor, X_i.

The assumption of linear dependence of the predictand and the predictors is necessary to derive the following analytical model for conditional probability:

$$y = a_1 x_1 + \ldots + a_n x_n + b\eta \qquad (1)$$

where the a_i's are partial regression coefficients, b is a coefficient with magnitude such that the normality of y is preserved, and η is random and normally distributed.

By squaring both sides of equation (1) and calculating expected values, we get the following expression:

$$1 = \sum_{i=1}^{n} a_i^2 + 2 \sum_{i \neq j} a_i a_j \rho_{ij} + b^2 \qquad (2)$$

By multiplying both sides of equation (1) by X_i and taking expected values, we get:

$$\rho_i = a_i + \sum_{j \neq i} a_j \rho_{ij} \qquad (3)$$

In matrix form, equation (3) becomes

$$R = CA \qquad (4)$$

where

$$R = \begin{pmatrix} \rho_1 \\ \vdots \\ \rho_n \end{pmatrix}$$

$$C = \begin{pmatrix} 1 & \rho_{12} \cdots \rho_{1n} \\ \vdots & \\ \rho_{n1} & 1 \end{pmatrix}$$

$$A = \begin{pmatrix} a_1 \\ \vdots \\ a_n \end{pmatrix}$$

By multiplying both sides of equation (4) by the inverse of C, we have:

$$A = C^{-1}R = \hat{C}R/|C| \tag{5}$$

where $|C|$ is the determinant of matrix C

$\hat{C}$ is the adjoint matrix of C

From equation (2), we derive the expression:

$$b^2 = 1 - |A^T CA|$$

$$= 1 - |A^T R|$$

or

$$b = \sqrt{1 - a_1\rho_1 - \ldots - a_n \rho_n} \tag{6}$$

From equation (1) for specific values of $x_1, \ldots, x_n$, the value of η will exceed η_c as frequently as y exceeds an assigned minimum y_c. Thus

$$P(\eta \geq \eta_c) = P(y \geq y_c | x_1, \ldots, x_n) \tag{7}$$

The probability that η will exceed η_c is the conditional probability that y will exceed y_c. The solution for η_c is given by

$$\eta_c = (y_c - a_1x_1 - \ldots - a_nx_n)/b \tag{8}$$

where a_i are given by equation (5), and b is given by equation (6).

Once x_i and y_c are known, then η is determined by equation (8). We then use equation (7) to compute the conditional probability. A useful approximation used in this analysis is provided by the following algorithm*:

$$P(\eta_c) = \ell + m\,[2(1 + C_1\eta_c + C_2\eta_c^2 + C_3\eta_c^3 + C_4\eta_c^4)^4]^{-1}$$

where

$C_1 = 0.196854$
$C_2 = 0.115194$
$C_3 = 0.000344$
$C_4 = 0.019527$
$\ell = 0,\ m = 1$ for $\eta \geq 0$
$\ell = 1,\ m = -1$ for $\eta < 0$

For this task we modified the routine to calculate a matrix of correlation coefficients between seven predictors, and also a vector of correlations between a predictand and each of the seven predictors. The correlations previously calculated were used to find the conditional probability of a predictand, given each of the seven predictors. This predictand is linearly, but stochastically, dependent on the predictors, and all variables are normalized and Gaussianly distributed. In addition to the standard correlation, lag correlations were calculated between the seven groups (groups two to eight) used as predictors and the first group.

Given the probability matrix P, and the correlation coefficient vector R_i, the values calculated for Problem 4862A (Section 2), additional software was written to

1) Calculate $\hat{P}$ and $|P|$

---

* National Bureau of Standard (1964) Handbook of Mathematical Functions with Formulas, Graphs and Mathematical Tables, Applied Mathematics Series No. 55, U. S. Government Printing Office, Washington, D. C.

2) Determine $A = \hat{P}R/|P|$ where $A = \begin{vmatrix} a_1 \\ \vdots \\ a_7 \end{vmatrix}$

3) Find $b = (1 - A^T R)^{1/2}$

4) Extract the values $X_1, \ldots, X_7$ (calculated previously) for each hour in the sample.

Also extract four selected values of Y_c from previous results and calculate

$$\eta_c = \frac{Y_c - a_1 x_1 \ldots - a_7 x_7}{b}$$

Then calculate the conditional probability

$$\text{Prob } (\eta \geq \eta_c) = \frac{1}{2[1 + C_1\eta + C_2\eta^2 + C_3\eta^3 + C_4\eta^4]^4} \qquad \text{for } \eta \geq 0$$

and

$$\text{Prob } (\eta \geq \eta_c) = 1 - \frac{1}{2[1 + C_1\eta + C_2\eta^2 + C_3\eta^3 + C_4\eta^4]^4} \qquad \text{for } \eta < 0$$

where $C_1 = .196854$

$C_2 = .115194$

$C_3 = .000344$

$C_4 = .019527$

5) Find the distribution of values of Prob $(\eta \geq \eta_c)$

6) Determine the score $(C - T)/C$

where $C = \Sigma(\text{Prob } (1, L) - V)^2$

$T = \Sigma(\text{Prob } Y - V)^2$

and $V = 1$ when the number of octas on the Nth hour equals or exceeds the chosen value of L

$V = 0$ when the number of octas is less than the chosen value of L

Prob (1, L) = the unconditional probability that the number of octas in Group 1 will equal or exceed L

Prob Y = the conditional probability that the number of octas in Group 1 will equal or exceed L; i.e., Prob Y = Prob ($n \geq n_c$)

The above parameters were calculated and printed for four seasons and five sites.

4. In Flight Line of Sight

INITIATOR: E. BERTONI

PROBLEM NO.: 4863 PROJECT NO.: 8624

BACKGROUND

The purpose of this task was to calculate vertical profiles of the probability of clear, cloudy and hazy lines of sight from aircraft, at 1000-foot increments over selected areas of the Northern Hemisphere. Seasonal as well as total data calculations were performed. Similar requests had been performed previously and software existed from these tasks.

ANALYSIS AND RESULTS

We received four programs necessary for performing this task. However, they required modifications to complete the task as requested (e.g., to output the total number of observations for each season). The documentation was outdated and did not describe the programs as we received them. Hence, a new set of documentation was required in addition to the programming changes.

The first subtask was to verify the programs. The programs were checked out by using all four previous copies of the data tapes and the data set on the private desk file. The results were compared to those of prior runs. (Problems occurred and will be discussed briefly later in this section.) After this check was completed, the last program of the package was modified to make calculations at 46 intervals instead of the original eight. This change was checked by summing over a number of intervals and comparing the sum with the results of an eight-interval run. Once this was done, four additional boxes were added to the old data, and the resulting file was processed.

The new data was input to the first program (LANLAT) which performs checks for valid data, such as

1) $1 \leq \text{MONTH} \leq 12$
2) $63 \leq \text{YEAR} \leq 76$
3) $-90 \leq \text{LATITUDE} \leq 90$
4) $-180 \leq \text{LONGITUDE} \leq 180$
5) $\text{ALTITUDE} \geq 0$

Data not within the specified ranges was rejected. Latitude was then converted to $0° \leq \text{LAT} \leq 180°$ and sorted in hundredths of a degree, where 0° is the south pole. Longitude was converted to $0° \leq \text{LONG} \leq 360°$ west longitude and stored in hundredths of a degree. All line of sight indicators (+60°, +30°, HOR, -30°, -60°) which are not equal to 1 (clear), 2 (cloudy) or 3 (hazy) are set to zero.

Valid sorted data was stored on disk and then sorted by longitude and output to tape. The second program used the SORT/MERGE utility program to merge the output file from the first program with the old data file. The old data file is also sorted by longitude. (This is the output from the previous run.)

A third program (CRESIS) was then run, using the merged data to create a SCOPE INDEXED SEQUENTIAL (SIS) file with a key based on the longitude. This program aborted if the input file was not sorted by longitude. Since the operating system of the CDC 6600 had been changed since the last run by the addition of the RECORD MANAGER, there were problems with getting this program to run properly. Modifications were made to the software in order to run under the existing system.

Additional complications arose while trying to process the data through the fourth program (LOSANL) which performed the actual calculations for percent occurrence of cloud-free-lines-of-sight. Cards were read to select the months, altitudes, and area of the world desired for a particular

run. The problem was in determining what specific input the program had been designed to accept. A number of modifications had to be made. For example, the longitude values stored were between 0 degrees and 360 degrees, but when calculations for the hemisphere were requested, the interval had to be specified as 0 - 359.99, since 0 and 360 were treated as the same point. In addition to this, the program was not designed to process an interval which crossed 0 degrees. This situation was analyzed. However, it had never occurred, and since it was not anticipated that it would, no attempts were made to correct this. Another problem with the program was that it could not accept more than one set of data at a time, despite indications that it could.

Subject to these limitations, the program was run for 20 geographic areas for four seasons and also for the whole year. The printed output from these runs displayed the altitude intervals involved and the number of observations of each type (clear, hazy, cloudy) at each altitude and at each of five angles to the horizon (horizontal, +30°, +60°, -30°, -60°). The probabilities for each of these were also printed. The program was modified so the total number of observations for each altitude interval and overall intervals were calculated and displayed.

5. KWAJALEIN MISSILE RANGE RADAR CONVERSION

INITIATOR: A. FAIRE

PROBLEM NO.: 4896A PROJECT NO.: 6690

BACKGROUND

Tracking of missiles is performed at different sites. The data from these sites was compared to obtain the optimum representation of the flight characteristics of the missile. Each site has its own type of computer hardware for obtaining the data. Before the analysis of the data could begin, the data tape was converted to a format compatible with the computer that was to be used in the analysis.

Conversion of the data tapes required a knowledge of the manner in which the data was obtained. It was necessary to be informed of the computer type, its word size, byte size, character code used and method of storing floating point arithmetic numbers. Also, quite often in order to decrease tape reading time, data was blocked with more than one record per block. The units of the data also had to be known before processing could begin. Once conversion was accomplished, data was printed and plotted for comparison and further analysis.

ANALYSIS AND RESULTS

The radar trajectory data tapes were processed at the Honolulu Data Reduction Facility on an IBM 7094 computer. This machine has 36-bit words. The tapes were 7-track with a density of 800 B.P.I. The record size was 24 words with a block size of 1 record per block. Table 5-1 shows the data as it appeared on the tape, with associated units. The record format type is U. Accordingly, the input/output processor of the computer did not search for record delimiters or control words; and if they did exist,

they would have been considered as part of the data. In addition, each block was read as if it contained one logical record. The layout of a record is shown in Figure 5-1. Each word was composed of an exponent (bits 31 through 34), its associated sign (bit 35), the number (bits 1 through 30) and its associated sign (bit 36). This can be represented mathematically by the following:

$$F = S_N J \ (2)^{S_E E} \qquad (1)$$

where F is the true value of the data and S_N, N, S_E, and E are as described in Figure 5-1.

In order to arrive at the final converted value, two important computing steps were required. The first is to unpack each 36-bit 7094 word into a CDC floating point number. The CDC floating point arithmetic is described in Section 29 of this report.

Processing of data was begun by buffering the 24 words (36 bits/word) into 15 CDC 60-bit words. It can readily be seen that 5 IBM 36-bit words equal 3 CDC 60-bit words. If we process 5 input words at a time, a loop can be set up to convert all the data. This was accomplished by shifting bits until each CDC word contained 36 bits of data (see Figure 5-2). A loop was then used to shift the bits associated with each component of the 36-bit word (that is, number, exponent, sign of number and sign of exponent), separate the components, and apply equation (1) to obtain F. At this point, the data was in the desired format.

The SUA CDC 6600 Radar Tape Format is shown in Table 5-2. Header information was supplied by the user, and data was output to the printer as well as to tape. Provision was made for processing more than one tape if desired.

Plots of the data were also obtained. Becuase of the large volume of data being processed, it was necessary to plot only a part of the data for each parameter at a given time. The plots gave a representation of the raw data as it appeared on the data tape. Plot limits were set automatically by the program. The data was read once to determine maximum and minimum values, then the tape was rewound for actual processing. The program allowed scaling of the axis in desired units.

Once conversion was completed, the data was then compatible both in format and units for use by all users at AFGL. Determination of velocities, densities, etc. could then be determined. Future tapes can be converted with little, if any, loss of time and a minimum of supervision. It is expected that data to be processed will be received at monthly intervals.

In addition to the conversion of this particular data set, these algorithms offer a basis for conversion of other data sets produced on similar 36-bit machines.

TABLE 5-1 FORMAT OF RADAR INPUT TAPE

WORD NO.	DATA ELEMENT	UNITS
1	Dummy Word	zeros
2	Edited GMT	seconds
3	Range Time	seconds = (GMT - Nearest second before lift-off)
4	Edited Range	feet - corrected for zero-set only
5	Edited Azimuth	degrees - corrected for zeroset only
6	Edited Elevation	degrees - corrected for zeroset only
7	Range Correction due to Refraction	degrees
8	Elevation Correction due to Refraction	degrees
9	Signal-to-Noise Ratio	decibels
10	Range Error	feet - not currently used
11	Azimuth Monopulse Error	degrees
12	Elevation Monopulse Error	degrees
13	Edited Doppler Range Rate	feet/second - not currently used
14	Refraction Correction for Doppler Range Rate	feet/second - not currently used
15	Processed Range	feet
16	Processed Azimuth	degrees
17	Processed Elevation	degrees
18	Processed Doppler Range Rate	feet/second - not currently used
19	Range Variance	$feet^2$
20	Azimuth Variance	$degrees^2$
21	Elevation Variance	$degrees^2$
22	Range Correction due to Transmit Time	feet
23	Azimuth Correction due to Transmit Time and Vertical Deflection	degrees
24	Elevation Correction due to Transmit Time and Vertical Deflection	degrees

NOTE: Processed = Measured + Corrections

TAPE DATA RECORD FORMAT (U)

LOGICAL RECORD (24 WORDS 864 BITS)

WORD 24						WORD 23						WORD 22					
P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
6 N	12 N	18 N	24 N	30 E	36 S_N	6 N	12 N	18 N	24 N	30 E	36 S_N	6 N	12 N	18 N	24 N	30 E	36 S_N
5 N	11 N	17 N	23 N	29 E	35 S_E	5 N	11 N	17 N	23 N	29 E	35 S_E	5 N	11 N	17 N	23 N	29 E	35 S_E
4 N	10 N	16 N	22 N	28 E	34 E	4 N	10 N	16 N	22 N	28 E	34 E	4 N	10 N	16 N	22 N	28 E	34 E
3 N	9 N	15 N	21 N	27 N	33 E	3 N	9 N	15 N	21 N	27 N	33 E	3 N	9 N	15 N	21 N	27 N	33 E
2 N	8 N	14 N	20 N	26 N	32 E	2 N	8 N	14 N	20 N	26 N	32 E	2 N	8 N	14 N	20 N	26 N	32 E
1 N	7 N	13 N	19 N	25 N	31 E	1 N	7 N	13 N	19 N	25 N	31 E	1 N	7 N	13 N	19 N	25 N	31 E

WORD 2						WORD 1					
P	P	P	P	P	P	P	P	P	P	P	P
6 N	12 N	18 N	24 N	30 E	36 S_N	6 N	12 N	18 N	24 N	30 E	36 S_N
5 N	11 N	17 N	23 N	29 E	35 S_E	5 N	11 N	17 N	23 N	29 E	35 S_E
4 N	10 N	16 N	22 N	28 E	34 E	4 N	10 N	16 N	22 N	28 E	34 E
3 N	9 N	15 N	21 N	27 N	33 E	3 N	9 N	15 N	21 N	27 N	33 E
2 N	8 N	14 N	20 N	26 N	32 E	2 N	8 N	14 N	20 N	26 N	32 E
1 N	7 N	13 N	19 N	25 N	31 E	1 N	7 N	13 N	19 N	25 N	31 E

TAPE MOTION OXIDE DOWN
BITS MARKED ONE (1) ARE LSB

ABBREVIATIONS:

N - NUMBER

E - EXPONENT

S_N - SIGN OF NUMBER $\left(\begin{smallmatrix}0 = +\\ 1 = -\end{smallmatrix}\right)$

S_E - SIGN OF EXPONENT $\left(\begin{smallmatrix}0 = +\\ 1 = -\end{smallmatrix}\right)$

P - ODD PARITY

NOTES: 1) A negative GMT signifies end of data (-9999. in Word 2)
2) An EOF marker signifies end of tape

Figure 5-1 Tape Data Record Format

CDC WORD

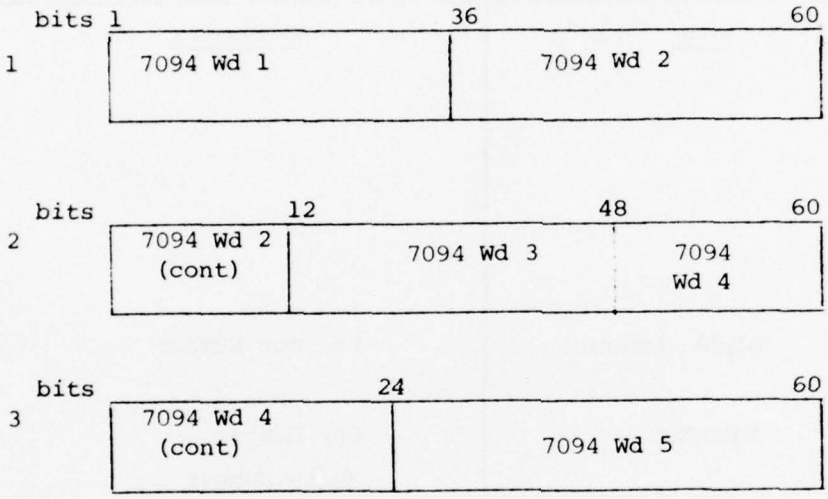

Figure 5-2

TABLE 5-2 SUA CDC 6600 RADAR FORMAT

The radar data type format consists of a 20 word header record followed by 96 word data records. The 96 word data record contains 6 samples of 16 words each. At the end of the header record and the 96 word data records is an end of record word.

20 Word Header Record		
Word	Mode	Parameter
1		
2		
3		
4		
5		
6	Alpha-Numeric	Project Number
7		
8	Integer	Day Number
9	"	Month Number
10	"	Year Number
11		
12		
13		
14	Integer	Radar Site
15	"	Rocket Number
16		
17		
18		
19		
20		

TABLE 5-2 SUA CDC 6600 RADAR FORMAT (CONTINUED)

16 Word Data Records, 6 Samples per 96 Words Record			
Word	Mode	Parameter	Units
1	Floating	Time of Day (GMT)	Milliseconds
2			
3			
4			
5			
6	Floating	Slant Range	Yards
7	"	Range Rate	Yds/sec
8	"	SNK	dB
9	"	Azimith	Degrees
10	"	Elevation	Degrees
11			
12	Integer	Auxilliary Word 1	
13	Integer	Auxilliary Word 2	
14			
15			
16			

6. Conversion Of ALCOR KMR Metric Data Tape

INITIATOR: A. FAIRE

PROBLEM NO: 4896B PROJECT NO: 6690

BACKGROUND

Four metric data tapes generated by Lincoln Laboratory in Lexington, MA, were received for further processing. These data tapes were produced on an IBM 370 computer but the data was formatted to be compatible with standard CDC 6600 hardware. This data is similar to the Kwajalein Missile Range Radar Data (see Section 5). Both sets of data describe trajectory information from Rocket All.605. The purpose of this analysis was to convert the data into the British Unit System and to re-format the data eliminating unused data. This data was made available for printer output, and subsequently plotted. Checks were performed to determine missing data and an asterisk placed as a flag on printer output when this occured.

ANALYSIS AND RESULTS

Problems due to errors in the documentation arose in the conversion of these data tapes. The tape was expected to be a 9-track, 800 (or 1600) BPI, multi-file tape, with a record size of 50 32-bit words and blocked 50:1. However, we determined that the tape was actually 7-track, 800 BPI, with a record size of 50 60-bit words and blocked 10:1. Thus, it is uncertain if future tapes will be compatible to the present method of obtaining data. These differences were conveyed to Analysis and Simulation Branch personnel who then conveyed the information to Lincoln Laboratory.

The contents of the header and data records of the input data tape are explained in Tables 6-1 and 6-2 respectively as they apply to each radar. The header record is almost identical from radar to radar. Data records differ in content and definition for each radar.

Once the data could be read and converted into the British Unit System, other problems were encountered. The data rate was expected to be 1000 points/second, but was found to be 200 points/second. The time changes were not in even increments and occasionally differed by .00003 seconds from the expected. This made it necessary to interpolate the time in order to obtain the data for every .1 second as desired for SUA tape format. Word #19, the qualifier word, did not meet specification. After discussions, it was decided to ignore it. To find missing data, the words were checked to see if they were zero.

Table 5-2 in Section 5 lists the format for SUA CDC Radar Format used for this task. The header was created from input card data. The program, regardless of the number of files on the input tape, generates one output tape composed of all files of the input tape.

Plots of the data were created by: (1) plotting 180 data points for each variable at one time; (2) re-initiating plot parameters; and (3) returning to the first graph to plot another 180 points. Checks were made to insure that the data variables were not zero. These plots were used for comparison of the raw data generated from different sites.

Four tapes have been processed according to the procedure described above. Although these tapes were in agreement, it may be necessary to make modifications to account for any discrepancies in future tapes. This data, along with that received from KENTRON Honolulu, will be used in analysis of density data. It is expected that more tapes will be recieved for Rocket #A10.712-1 and Rocket #A10.712-2 which will require similar formatting.

Table 6-1 Header Record

Word	Definition
1	Tape identifier = X where: X = 21 for ALCOR
2-4	File designator = MTXXY _ _ ABC where: MT = Metric Tape XX = Any integer Y = Letter identifying the company/computer for which a tape has been tailored. AMC = Three-digit number for Lincoln Laboratory identification purposes.
5	Mission date = XXYYY where: XX = The last two digits of the year of launch YYY = Julian day
6-7	Object - Tracked object to which metric data in this file applies.
8	Launch time (GMT)
9-10	Computer Name (The original tapes are generated for IBM 360/370 computers. If a tape is tailored to a user's computer, the computer's name is entered here.)
11	Program version date (Each radar has a separate magnetic tape-generating program whose version dates are entered here.)

Table 6-1 Header Record (cont.)

Word	Definition
12	Number of time spans (The number of tracking intervals or data spans included in this file. The maximum number has been arbitrarily set to 10.)
13	Span 1, start time (GMT) - Begin time of first interval.
14	Span 1, stop time (GMT) - End time of first interval.
15	Span 1, data rate (pts/sec) = X (X ≈ 200)
43	Source of beacon/skin separation = X* where: X = 1 for the comparison of beacon and WB range trajectories 2 for the comparison of beacon and NB range trajectories 3 for the determination from a NB pulse shape 4 for the nominal value in the LEXCAL array (Words 649-642)

*The ALCOR data users manual may be referenced for interpretation and units.

Table 6-2 Data Record

Word	Definition
1-2	GMT = time at incidence
3	Time after launch = TAL at incidence = GMT - launch time (sec) where: GMT = Word 1 of MT data record. Launch time (sec) = Word 8 of MT header record.
4	Mode Word 1, range tracking Status = T (track) = N (not in track) Mode = C (Centroid) = E (Edge) = G (Gated edge) Waveform = N (NB) = W (WB) = B (Beacon)
5	Mode Word 2, angle tracking Status = T (track) = N (not in track) Waveform = N (NB) = W (WB) = B (Beacon)
6	Range (km)
7	Azimuth (rad.)
8	Elevation (rad.)

Table 6-2 Data Record (cont.)

Word	Definition
9	Not used.
10	Azimuth offset (rad.)
11	Elevation offset (rad.)
12	Beacon/skin separation (km)
13-14	Range tropospheric refraction correction (km) = R_T Elevation tropospheric refraction correction (rad.) = El_T where: $R_T = \Delta R$ $El_T = -\Delta El$
16	Not used.
17	S/N (dB) = Signal (dB) - Noise (dB)
18	Not used.
19	Qualifier Word - The quality of each raw data point is checked. Plots of the raw data and plots of the residuals from a polynominal fit to the raw data are used as a basis. A bit set to one in the bits listed below indicates a message to the user. If the message (flag) refers to a particular span of data, it should <u>not</u> be used. The following qualifiers are reserved for ALCOR. <u>Bit</u> 32 Range 31 Azimuth 30 Elevation 29 Range rate 28 Azimuth offset 27 Elevation offset 26 S/N range

Table 6-2 Data Record (cont.)

Word	Definition
	25 Undefined 24 Undefined 23 Marks the last data records of a file. "Zero" records are added until the last block is filled. The end-of-file mark is then added. 22,21 Undefined 20 Bit is set for every data point (containing coherent range rate, its associated TAL, and intervening zeros) over the interval for which coherent range is available. 1-19 Undefined
20	Altitude (km) = $\left[R^2 + R_e^2 + 2RR_e\ El\right]^{1/2} - R_e$ where: R = Range (km) = [Word 6 + Word 12 + Word 13 of MT data record] R_e = Earth radius (km) = 6378.135 El = Elevation (rad.) = [Word 8 + Word 14 of MT data record]
21	A = Azimuth error (rad.)
22	E = Elevation error (rad.)
23	Corrected range (km) = [Word 6 + Word 12 + Word 13 of MT data record] The corrected range is set to zero if Word 6 is flagged (Bit 32 of Word 19 is set). The corrected range is provided at maximum available data rate.
24	Corrected azimuth (rad.)
25	Corrected elevation (rad.)

Table 6-2 Data Record (cont.)

Word	Definition
26	GMT = Time at incidence associated with the coherent range rate. By adding Word 2 of the data record, AICOR's precision may be retained.
27	Coherent range rate.

7. Conversion of Unnormalized Composite Interplanetary Plasma Tape

INITIATOR: D. SMART

PROBLEM NO: 4894 PROJECT NO: 8600

BACKGROUND

A tape of solar wind plasma parameters was received from NASA, NSSDC. This unnormalized composite solar wind tape contains data from numerous space-crafts such as IMP/AIMP, Explorer, VELA, HEOS1, and OGO5. The data was generated on an IBM 360 computer. The tape format is 9-track, 1600 B.P.I., with spanned variable-blocked binary records. The logical record length is 64 bytes, including a 4 byte segment description word and fifteen 4 byte data words. The block size is 25604 bytes. (Each byte contains eight bits.)

It was necessary to convert the data on this tape into a SCOPE compatible binary tape, with 15 words per record, 1 record per block. This prerequisite was necessary before any analysis could be done on the data set.

In order to accomplish this task, it was necessary to have a knowledge of the manner in which the floating point values, characters, and integer values were stored in the IBM 360 words. Once this was established, conversion was done by bit manipulation.

ANALYSIS AND RESULTS

The format of one logical record is described in Table 7-1. With some exceptions, the data is as submitted by the experimenters, with no normalization performed at NSSDC for mutual consistency. The data is in sequential time order, with as many records (between 0 and 9) for a given hour as there were contributing data sets for that hour. The exceptions are described below.

Table 7-1 SOLAR WIND PLASMA LOGICAL RECORD FORMAT

DATA ITEM	DATA TYPE	COMMENT
1. Year	I*4	64, 65, 66
2. Decimal day of year	I*4	January 1 = day 0
3. Hour	I*4	0, 1, 2, ..., 23
4. Spacecraft ID	I*4	1 = HEOS 1 3 = Vela 3A/Vela 3B 5 = OGO 5 33 = Explorer 33 34 = Explorer 34 (IMP F) 35 = Explorer 35 43 = Explorer 43 (IMP I) 99 = See following notes
5. Number of fine time scale points	I*4	Points in hour averages
6. Temperature	R*4	^{o}K (blanks for ID = 1 and 99 record)
7. Ion density	R*4	$(cm)^{-3}$ (blanks for ID = 99 records)
8. Bulk speed	R*4	km/sec, aberration corrected
9. Flow longitude	R*4	In degrees; aberration corrected; positive for flow from west of sun; solar ecliptic coordinates; word contains blanks for ID = 1, 34, 43 and 99 records.
10. Flow latitude	R*4	In degrees, positive for flow from south of sun; solar ecliptic coord; word contains blanks for ID = 1, 3, 34, 43 and 99 records.
11. Standard Deviation in temperature	R*4	^{o}K; word contains blanks for ID = 1, 5, 43 and 99 records.
12. Standard Deviation in density	R*4	$(cm)^{-3}$; word contains blanks for ID = 1, 5, 43 and 99 records.
13. Standard Deviation in Bulk Speed	R*4	km/sec; word contains blanks for ID = 1, 5, 43 and 99 records.
14. Standard Deviation in Flow longitude	R*4	Degrees; word contains blanks for ID = 1, 5, 34, 43 and 99 records.
15. Standard Deviation in Flow latitude	R*4	Degrees; word is non-blank only for ID = 33 and 35.

Vela 3 data was provided as three hour averages with their associated standard deviations and with the number of measurements contributing to each 3 hour average. These values have been assigned to each of the three appropriate hours.

For Explorer 33 and 35, temperature and associated standard deviations were not provided, but an equivalent parameter (most probable thermal speed w_o) and its standard deviation σw_o were provided. The relation $\frac{1}{2}M_p w_o^2 = kT$ (M_p = proton mass, k = Boltzmann constant) was used to obtain temperature (T) from the given information. The relation $\sigma_T = (\delta T/\delta w_o)\ \sigma w_o$ was used to obtain σ_T from the given w_o and σw_o.

To establish consistency in the sign conventions used for the flow longitude and latitude angles, (see Table 7-1) Explorer 33 and 35 longitude and latitude angle values were multiplied by minus one, as were the OGO 5 longitude angle values.

The data associated with spacecraft ID = 99 was provided by the Los Alamos Scientific Laboratory solar wind plasma team. The data comes from VELAS's 2, 3, 4, 5, 6, from IMPS 6, 7, 8 and from Explorer's 43, 47, 50; however, individual data values are not linked with specific spacecraft. The data supplied to NSSDC consisted of time, 3-hour averaged bulk speeds, and numbers of find time scale values in the 3-hour average. The 3-hour averages have been distributed over individual hours (as for VELA 3 data discussed earlier.)

The HEOS 1 data was extracted by NSSDC from Diodato, et al., "Astron. Astrophys, Suppl.", 20, pp. 313-362, 1975. These 3-hour averages have been distributed over individual hours.

PROCESSING PROCEDURE

The following is the procedure used to process the data. One IBM 360 word contains 32 bits or 4 bytes; for the CDC 6600, each word contains 60 bits. Therefore, each CDC 6600 word is equal to 15/8 of an IBM

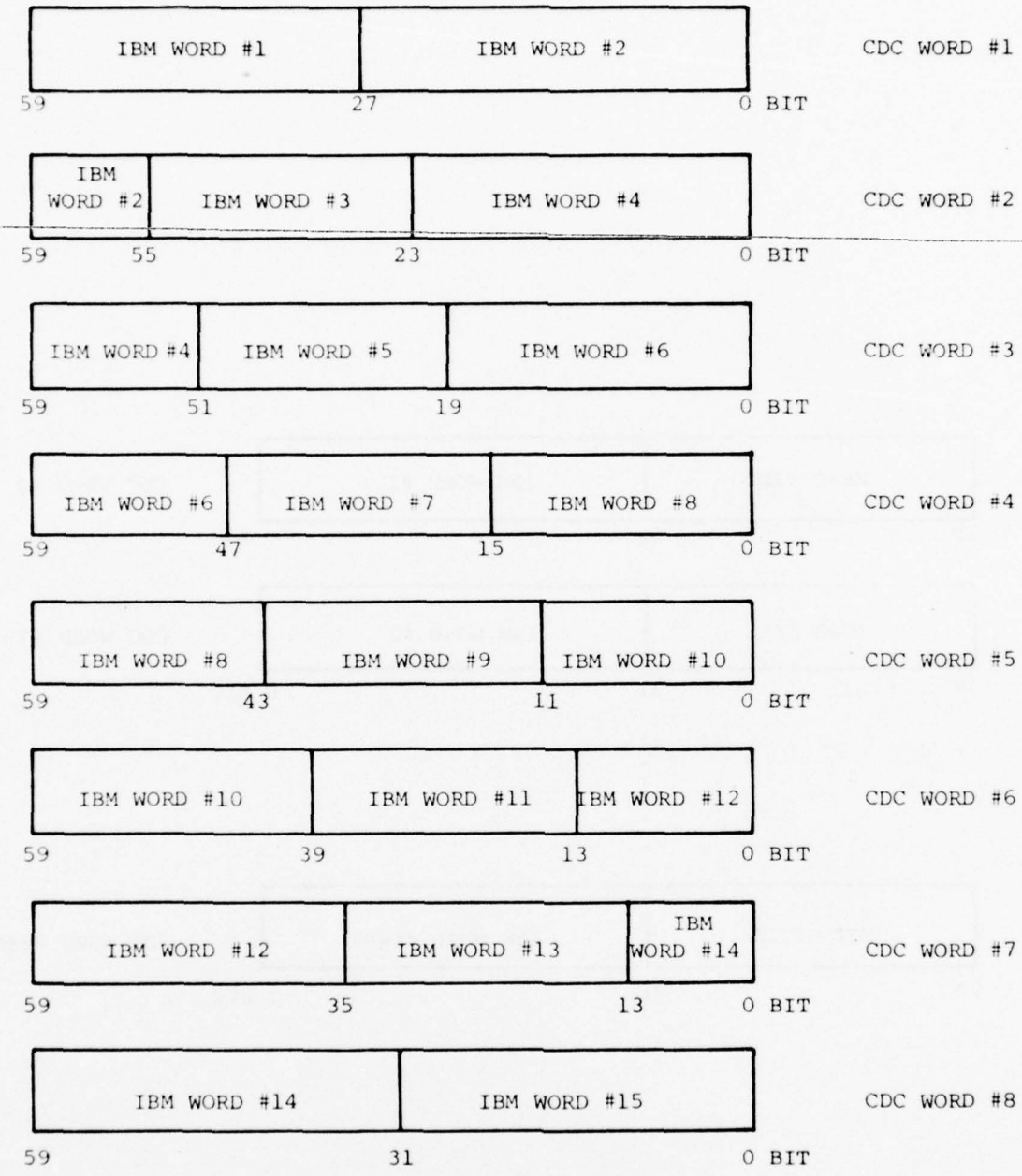

Figure 7-1 IBM WORD STORAGE ON THE CDC 6600

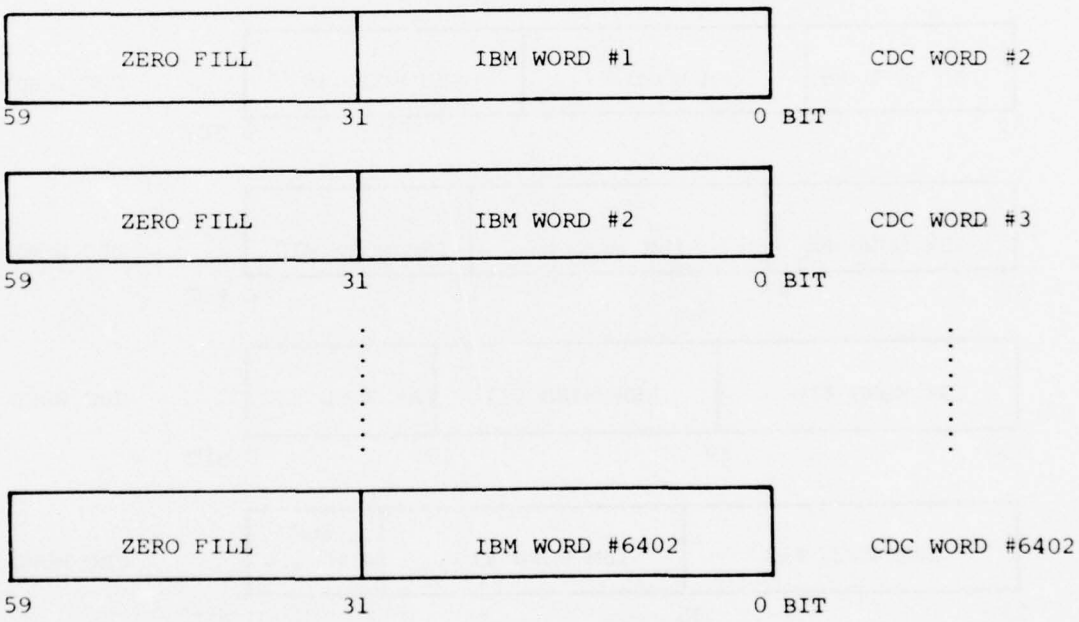

Figure 7-2 RESULT OF UNPACKING

360 word, or 8 CDC 6600 words will represent 15 IBM 360 words. Figure 7-1 represents how these eight CDC 6600 words appear in storage. It takes 3414 CDC 6600 words to store the first block of data. An array of this size was set up and one block of data buffered in. The subroutine to unpack the data was then called. This subroutine shifts each 32-bit IBM 360 word into one CDC word of 60 bits. An array was set up to accept these values. The array size was 3414 x 15/8 = 6402, rounded to the nearest integer. This was accomplished by setting up 2 loops, one to unpack 15 IBM 360 data words at a time, and one to increment a counter by 15 to process the entire block. Once this was completed, the values were then converted into compatible CDC 6600 integer numbers, as shown in Figure 7-2.

The next step was to convert the IBM 360 floating point numbers from their integer representation to CDC 6600 floating point representation. An IBM 360 floating point value was represented as shown in Figure 7-3.

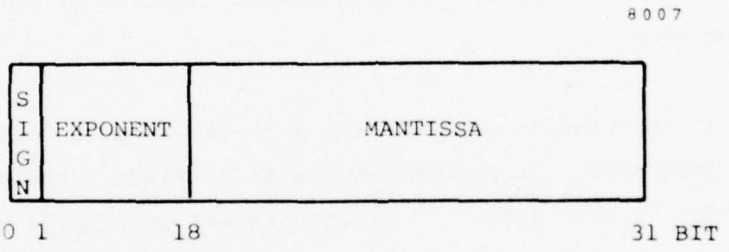

Figure 7-3 FLOATING POINT WORD

The binary point of this word is just before bit 8, and the exponent has a base of 16 associated with it. It also has a bias of 64; that is, 64 must be subtracted from the exponent before conversion. Thus, mathematically the number may be represented as

$$x = (S)\ (M)\ (16)^{EX-64}$$

where

S = Sign, M = Mantissa, and EX = Exponent

For a description of the CDC 6600 floating point arithmetic, see section 29.

To convert each IBM 360 floating point number, the bits of each word segment were shifted into separate words. Since the binary point is to the left of the mantissa, the mantissa was multiplied by 2^{-24} to shift the decimal point to the right. The formula for conversion to a CDC 6600 floating point word is

$$x = (2^{-24}) \text{ SM } (16)^{\text{EX-64}}$$

In this data set, words 7 through 16 of each record were converted to floating point. This was accomplished by setting up a loop to call a subroutine which does the conversion as described above. After completion of the loop a record was written, and the next record of the block was processed. A new block of data was buffered in after the 400 records of the block were processed and written.

When an end-of-file was reached, a check was made to determine if all files were processed. If processing was to continue, the program returned to buffer in more data. If processing was to stop, a message was printed indicating the last file processed, and the program then terminated.

The general method used to convert this tape may be employed in the future, with modifications made to block length and size of record to correct future tapes. This tape was submitted for approval and accepted. No further analysis was done at that time.

8. Conversion Of OPAQUE Data Tapes

INITIATOR: E. SHETTLE

PROBLEM NO: 4907 PROJECT NO: 7621

BACKGROUND

The purpose of this task was to generate software to decode data received from NATO's Atmospheric Optics Measurement Program (OPAQUE). This data is in American Standard Code for Information Interchange(ASCII) character format on paper tape. A sample paper tape was supplied. The paper tape was decoded and the data put on a magnetic tape with each block containing three logical records. This magnetic tape was then used to transform the packed data values into their true values by one of the conversion factors and codes provided. After the true values were successfully obtained, these values were then converted back to their original form and placed on a second tape. A program was written to read the tapes. The first tape generated was sent to the OPAQUE data bank in Germany for verification. The software was made flexible so that if changes in blocking or record size were made, this could easily be incorporated into the program.

ANALYSIS AND RESULTS

The data was punched on 8-channel paper tape in American Standard Code for Information Interchange (ASCII). Each channel transfers into one bit, and the 8 channels represent one frame. Each frame was converted on input from ASCII to internal BCD. The data was buffered-in, 15 words (150 characters) at a time. A carriage return character and new line character were the only separations between data.

Figure 8-1 is a representation of one block of data as it appears on the paper tape. This data was represented in core memory as one continuous record. Each word buffered-in was decoded into ten words containing one character and each was compared with a carriage return and new line character. Each character was saved until a carriage return and new line character was reached. The saved words represented one line of data. These words

were decoded according to the format in Figure 8-2 (required for OPAQUE) with each output word representing a data item. After decoding one line, comparison of characters continued until either a new set of carriage returns and line feed characters were reached, or until the 15 words were processed. When the 15 words were processed, 15 more words were buffered-in, and the process continued. Output consisted of 63 data words and was blocked from one to three logical records per block. Output was desired on both printer and tape.

Once the sample tape was generated, a second program was developed to read the generated tape and print out the data with headings for each data item for identification. The program simply read the binary words into an array, and set up a loop to output the words to the printer along with headings, one record at a time.

Another program was developed which converted the scaled values obtained from the tape into their true values by means of conversion codes set up when the OPAQUE format was established. Each data item, as can be seen from Figure 8-2 (not including the meteorological parameter, identified in the records by M, which begins the data record) is composed of five characters. A decimal point follows the third character; the fourth is the exponent; and the fifth is the reliability. Negative exponents were avoided by use of factors which could be added to the exponent. For example, a number 12345 is represented as $123.0X10^{4+D}$ where 5 is the reliability and D is as follows:

Extinction coefficients	D = -6
Horizontal illuminance	D = -6
Path luminance at night	D = -8
Path luminance at day	D = -8
Eppley filter order	D = -6
Banes filter code	D = -6

The meteorological parameters are coded as follows:

Word #59 M is used to indicate start of meteorological data

Word #59 9 - cloud cover value in eighths with 9 used to indicate no measurement.

Word #59 (32) - wind direction at 10 m, the integer value indicating the nearest 10° value from true North.

8 = Situation outside OPAQUE scheme

9 = No observation

13 = Rainfall

mm/hr in the past hour

No observation or failure: 999

A loop was set up in the program to process each of the three records in the block. The filter options were read in from cards and listed on the printer. The converted data was written on a magnetic tape in binary and listed on the printer with headings.

The last of the group of programs reads the tape which contained the true values, and converted it back to the original packed data words by taking out the conversion factors and codes, and encoding it to an output array. The format of this output is identical to the first portion of this analysis. This program was necessary in order to convert data obtained from the AFGL/OPA group into the tape format compatible with the OPAQUE Data Bank. This data could then be read by OPAQUE.

SUMMARY

Four different programs comprise this package of software. These programs make it possible to convert the data from paper tape to a magnetic tape, from packed values to actual values, and from actual values to packed

data. Also, generated tapes may be read and printed. It is expected that some data will be generated at AFGL which must be converted into packed values. These tapes will be sent to OPAQUE Data Bank to be concatenated with data from other countries and a new tape generated from this new data file. Also tapes will be received for conversion into the actual values from the packed format.

```
CC
C241
8612186421864218612l008
4168141681416814168100911481204812458115481
60111601116011160111001
706517065170651706510048895l6595115831
000000000000000000000000000000000000000000000000000
0000000000000000000000000
00000
M93202000002019271800000000
R140007
```

Figure 8-1 PARTIAL LISTING OF PAPER TAPE

```
WORD #1   STATION No. (I71) Not on Paper Tape
WORD #2   DATE,  Year, Month, Day (760716) Not on Paper Tape
          to be added
WORD #3   TIME (1300)  Not on paper tape. To be added in increments of
          100.  Range (0000 to 2300)
WORD #4   DURATION OF MEASUREMENT CYCLE (07)  Not on First Record
WORD #5   THRU WORD #9  COMMENTS    IF (CC) No Comments
WORD #10  SCATTERING X 100 + FILTER OPTION X 10 + HUMIDITY (D241)
WORD #11  SCATTERING BEGINNING   Not on this Paper Tape, but must be
          allowed for  (00000)
WORD #12  SCATTERING FINAL   Not on this Paper Tape, but must be allowed
          for (00000)
WORD #13  SCATTERING MAXIMUM   Not on this Paper Tape, but must be
          allowed for (00000)
WORD #14  SCATTERING MINIMUM   Not on this Paper Tape, but must be
          allowed for (00000)
WORD #15  NUMBER OF VALUES   Not on this Paper Tape, but must be allowed for
WORD #16  EXTINCTION COEFFICIENT BEGINNING  (86121)
WORD #17  EXTINCTION COEFFICIENT FINAL  (86421)
WORD #18  EXTINCTION COEFFICIENT MAXIMUM  (86421)
WORD #19  EXTINCTIOM COEFFICIENT MINIMUM  (86121)
WORD #20  NUMBER OF VALUES  (008)
WORD #21  HORIZONTAL ILLUMINANCE BEGINNING (41681)
WORD #22  HORIZONTAL ILLUMINANCE FINAL  (41681)
WORD #23  HORIZONTAL ILLUMINANCE MAXIMUM  (41681)
WORD #24  HORIZONTAL ILLUMINANCE MINIMUM  (41681)
WORD #25  NUMBER OF VALUES (009)
WORD #26  HORIZONTAL ILLUMINANCE (NORTH)  (11481)
WORD #27  HORIZONTAL ILLUMINANCE (EAST)  (20481)
WORD #28  HORIZONTAL ILLUMINANCE (SOUTH)  (24581)
WORD #29  HORIZONTAL ILLUMINANCE (WEST)  (15481)
WORD #30  PATH LUMINANCE AT NIGHT BEGINNING  (60111)
WORD #31  PATH LUMINANCE AT NIGHT FINAL  (60111)
WORD #32  PATH LUMINANCE AT NIGHT MAXIMUM  (60111)
WORD #33  PATH LUMINANCE AT NIGHT MINIMUM  (60111)
WORD #34  NUMBER OF VALUES (001)
WORD #35  PATH LUMINANCE AT DAY BEGINNING  (70651)
WORD #36  PATH LUMINANCE AT DAY FINAL  (70651)
WORD #37  PATH LUMINANCE AT DAY MAXIMUM  (70651)
WORD #38  PATH LUMINANCE AT DAY MINIMUM  (70651)
WORD #39  NUMBER OF VALUE (004)
WORD #40  PATH LUMINANCE AT DAY (SOUTH)  (88951)
WORD #41  PATH LUMINANCE AT DAY (WEST)  (65951)
WORD #42  PATH LUMINANCE AT DAY (NORTH)  (15831)
WORD #43  EPPLEY FILTER ORDER #1  (00000)
WORD #44  EPPLEY FILTER ORDER #2  (00000)
WORD #45  EPPLEY FILTER ORDER #3  (00000)
WORD #46  EPPLEY FILTER ORDER #4  (00000)
WORD #47  EPPLEY FILTER ORDER #5  (00000)
WORD #48  EPPLEY FILTER ORDER #6  (00000)
WORD #49  EPPLEY FILTER ORDER #7  (00000)
WORD #50  EPPLEY FILTER ORDER #8  (00000)
WORD #51  EPPLEY FILTER ORDER #9  (00000
WORD #52  EPPLEY FILTER ORDER #10  (00000)
WORD #53  BARNES FILTER ORDER #1  (00000)
WORD #54  BARNES FILTER ORDER #2  (00000)
WORD #55  BARNES FILTER ORDER #3  (00000)
WORD #56  BARNES FILTER ORDER #4  (00000)
WORD #57  BARNES FILTER ORDER #5  (00000)
WORD #58  DATA WORD TO BE DETERMINED  (00000)
WORD #59  LETTER (M) TO DESIGNATE BEGINNING OF METEOROLOGICAL PARAMETERS,
          CLOUD COVER VALUE IN EIGHTS (9), 9 BEING NO MEASUREMENT, WIND
          DIRECTION AT 10 m (32), WIND SPEED AT 10 m (02)
WORD #60  WIND DIRECTION AT 2m (00)  WIND SPEED AT 2m (00)
WORD #61  PRESSURE  (020), TEMPERATURE  (192)
WORD #62  RELATIVE HUMIDITY  (718),  TEMPERATURE AT DEWPOINT  (000)
WORD #63  RAINRATE  (000),  GROUND CODE  (0)
```

Figure 8-2 REQUIRED OUTPUT FORMAT

9. Conversion Of OPAQUE Data Tapes (Modification)

INITIATOR: E. SHETTLE

PROBLEM NO: 4911 PROJECT NO: 7621

BACKGROUND

The purpose of this task was to modify the software generated for problem 4907 (Section 8), to accept slightly different input data and to process the data.

ANALYSIS AND RESULTS

Additional paper tapes were received that contained blanks between each data item as shown in Figure 9-1. It was necessary to create tapes similar to those previously described (Section 8 of this report), but with the omission of the blanks. This was done by skipping a character whenever the blank was expected after processing the data item.

In addition, it was desired that these data items be output to the tape in packed format. Hence, instead of having one word for each data item, 370 characters comprised one record. Therefore, there are 37 words/record and 111 words per block. This tape was sent to the OPAQUE data bank for verification of acceptability.

```
I 61 760802 2200 07
CC
D241
1 1021 10821 11021 10821 000
54921 53721 54921 53721 009 24521 15821 15821 40721
21321 21321 21321 21321 001
00000 00000 00000 00000 000 00000 00000 00000
00000 00000 00000 00000 00000 00000 00000 00000 00000 00000
00000 00000 00000 00000 00000
00000
M 9 26 02 00 00 030 141 640 000 000 0
I 61 760802 2300"07
CC
D241
13821 14121 14321 13821 000
28121 28121 28121 28121 009 54911 61611 61611 32321
12821 12821 12821 12821 000
```

Figure 9-1 Partial Listing of New Paper Tape

10. Breakdown Problems Associated With Satellites

INITIATOR: P. ROTHWELL

PROBLEM NO: 4903 PROJECT NO: 7661

BACKGROUND

In support of analyses to investigate the electomagnetic problems associated with magnetospheric fluxes incident on synchronoous satellites, ASEC conducted a literature search. The objectives were to locate, organize and evaluate reference material relevant to:

> The breakdown and/or excitation of plasma external to the satellite; and
>
> The breakdown of insulator-coated conducting surfaces subjected to the radiation of the magnetospheric environment.

ANALYSIS AND RESULTS

The literature search resulted in two reports. The first is "Electronic Radiation in the Vicinity of Synchronous Orbit Satellites: Literature Search", AFGL-TR-77-0024. The contents are briefly described in the report's abstract as follows:

> A categorized list of representative references is presented that applies to the task of estimating and predicting undesireable radiation incident to a satellite in synchronous orbit. The categories on references address basic elements of the task. That is, some references apply to estimating the particle and field environment about the satellite and other references are relevant to estimating the behavior of the medium, either as support for electrical discharge or the excitation of radiation through instability and/or the presence of plasma boundaries. Both theoretical and experimental references are included in each category where possible.

The breakdown of plasma, which is a "necessary" prerequisite to the generation of discharge currents in plasma, is a much studied phenomenon both theoretically and experimentally. The plasma breakdown category of references, together with the bibliographies associated with each reference, provide a representative information base to support a critical review of important elements of breakdown and electrical discharge literature from about 1960 to the present time.

The second report, concerned with insulator breakdown, is "Breakdown of Insulators: Literature Search" (To be published). The following abstract briefly summarizes this report:

The irradiation of dielectric coated metal surfaces by incident magnetospheric fluxes generates problems related to the charging, breakdown and discharging of the dielectric insulator. The overall search objective is to locate and organize reference materials that address significant aspects of the problem. The study divides into ten somewhat independent subjects.

Emphasis is placed on the readily available literature during the period up to and including 1961. The experimental measurements during this period were conducted under idealized conditions to achieve reproductibility. That is, the breakdown E field is externally generated and surface breakdown and premature breakdown through voids are suppressed.

To unify material, certain basic references concerned with solid state, transport and kinetic theory are cited where appropriate. A few references investigating recent breakdown theory are cited and briefly discussed. The bulk of the theoretical breakdown references and all of the experimental references were cited for the time period prior to 1961.

PRELIMINARY ANALYSIS

A preliminary analysis using an idealized plasma model, breakdown criteria and charge-discharge model was mathematically formulated, but not implemented.

11. Reduction Of Meppen, FRG Meteorological Data

INITIATOR: E. SHETTLE

PROBLEM NO: 4866 PROJECT NO: 7621

BACKGROUND

Meteorological data was obtained from a field station in Northern Germany in support of the atmospheric optics measurements being conducted by AFGL/OPA. The data was supplied on magnetic tape. The description of the tape is as follows. The tapes are 9-track and use IBM compatible format. The meteorological data is packed into 20 words per data set with 8 characters/word, six bits/character, and 108 data sets per block.

The purpose of this task was to read and decode the meteorological data tapes, and to obtain a complete listing of the meteorological data. Then, for particular times supplied as input, specific meteorological data was selected from one of the towers. Data from two meteorological towers were available on the tapes. This data was made available to a calling program, and was output to the printer, punch, or tape. The data includes: the temperature and dewpoint at 2 meters; wind direction; and wind speed, interpolated at a height of 11 meters.

ANALYSIS AND RESULTS

The following is the list of information available on the data file. Information was updated each ten minutes.

- Identification
- Year, month, day, hour, minutes, change of measuring procedure
- Data from Tower A

  Wind direction at 16m height
  Dewpoint at 2m and 80m heights
  Wind speed at 1, 2, 4, 8, 16, 32, 64, 85m height
  Temperatures at 1, 2, 16, 48, 80m heights

- Data from Tower B

  Wind speeds at 1, 2, 4, 8, 16, 32, 64, 80m heights
  Temperatures at 2, 16, 48, 80m heights

The program buffered in one block of data (17,280 characters) from the tape and decoded it onto a 7-track tape, 80 characters per record. A check was made for an end of file at the beginning and end of the tape. As many files as are on the tape can be created on the new tape. This process served two purposes: one, it created a copy of the original tape for backup; two, the records were in a form which can be processed more easily.

Since data on the tape was for both towers, disk files were used to separate the data related to each tower. These files were later rewound and copied to the output file for printing. Headers were first written onto each file. Then the first 2 records of the input tape were read and a counter was incremented. The data was then written out onto each appropriate tape. This was continued until 50 records were read and written for each tower. The counter was reset to zero, and a new header was written on the files along with a carriage control to cause the printing to begin at the top of the next page. A page counter was also inserted for ease of handling. When an end of file was reached, the process terminated. The disk files were then rewound, and copied out to the printer.

To obtain specific meteorological data for a desired time span, a new computer program was developed which would read from an input card the tower (A or B), starting date and time, and ending date and time for the data desired. The input parameters were first printed to assure the user of the dates he chose. The input tape was read one block at a time, and a loop was set up to search for the starting date and time. When it was present, the wind speed at a 10 meter height was linearly interpolated and the rest of the desired data was placed in an array to be printed or punched on cards, as selected by the user as an option. This process continued until the ending date and time was reached, whereupon the program terminated. The data was inclusive, so the meteorological parameter for the ending date and time was included in the output. To obtain data for one specific date and time, the starting and ending dates must be the same.

If data is desired for more than one range of time points, new input cards must be read. They do not have to be in sequential date and time order.

These programs were run and processed test tapes. These programs are now avaiable to process future meteorological data tapes as they are received.

12. Modification Of Satellite Ephemeris Program (Part I)

INITIATOR: J. KLOBUCHAR

PROBLEM NO: 4887 PROJECT NO: 4643

BACKGROUND

The Trans-ionospheric Propagation Branch works with the Air Weather Service Global Weather Central (AWS/AFGWC) in providing real time Total Electron Content (TEC) measurements for military systems users. The satellites used for these real time measurements are in near geostationary orbits. Because of the remote locations of the observing sites, computer sheets of the conversion tables from measured polarization values to final TEC values must be prepared up to four or five months in advance. The problem presented to ASEC was to provide AWS with an accurate program compatible with their UNIVAC 1108.

ANALYSIS AND RESULTS

The task was completed by merging two existing programs, namely ROPLOK and LOKANG2. (LOKANG2 will be described in this section. ROPLOK will be discussed in Section 13.) The input/output (I/O) statements and logical steps of these programs were modified to meet the requirements of the UNIVAC 1108 to be used.

Initially this task was to be performed by generating the program LOKANG2. LOKANG2 is a combination of a satellite ephemeris program called LOKANGL and the NASA program MGEOS. The resultant program calculates a table of M-values, look angles for a geostationary satellite as a function of satellite latitude and longitude, and a Faraday-to-TEC conversion table. These tables can be used by AWS observers as hourly look-up tables. While this program was not the final version sent to AWS, many

of the the techniques used, as well as the M-value generation portion, were used in the final version.

The program LOKANG2 was adapted to accept only a specific 5-card input deck. The original program accepted other inputs as well. Program LOKANG2 was optimized with the 5-card input in mind. All unnecessary subroutines were eliminated. Some were considerably shortened and included in their calling routines. The entire program was thoroughly combed for duplication of efforts.

The purpose of this version of the program is to enable use of LOKANG2 on the UNIVAC 1108 at the AWS-AFGWC. To do this, all input/output is done by calling GREAD and GPRINT subroutines which are compatible on UNIVAC 1108. For a test case, these subroutines are simulated on CDC 6600 using Buffer In and Buffer Out statements.*

The resultant program consists of the following main section. The description of the routines gives a functional description of the program.

I - EPHEMERIS SECTION

NAME	DESCRIPTION
LOKANG2	Main program - reads input data - calls necessary routines.
WRSTA	Reads M-Value and TEC Conversion Table output options and prints predictions. Extracts predictions from binary tape.
MNTOSC	Converts mean elements to position-velocity.
SHPRDC	Computes short periodic terms.
KEPECN	Converts mean anomaly to eccentric anomaly.
SPSETC	Sets constants and program initializations for all routines.

*For further description of LOKANG2, see Johanson, J., "Satellite Beacon Studies," Emmanuel College, Physics Research Division, Nov. 1976.

I - EPHEMERIS SECTION (Continued)

NAME	DESCRIPTION
SPRFCO	Computes refraction correction due to atmosphere.
NEW	Converts units of output data.
CRMXA	Prints heading on each output page.
SPTRAN	Transformation matrix and station coordinates routine.
SPROU	Prints out BCD.
MULTIP	Performs matrix multiplication
ANGLE1	Reduces an angle to interval $-\pi$ to $+\pi$.
ANGLE2	Reduces an angle to interval 0 to 2π.

II - M FACTOR (MAGNETIC FIELD) SECTION

NAME	DESCRIPTION
MGEOS	Calculates M-Value as function of satellite positions.
GEO	Sets initializations and performs geometric calculations.
FIELDG, FIELD	Calculates geomagnetic field, updates the POGO (geomagnetic field) coefficients to time of observation and prints out the M-Value table.

III - TEC CONVERSION TABLE ROUTINE

NAME	DESCRIPTION
TABLE	Produces the following output: 1) TEC (Constant M) to TEC (Varying M) conversion table 2) Faraday rotation to TEC conversion table

In order to obtain the above program, the original software was studied and the following changes made.

OPTIMIZATION AND CHANGES

SUBROUTINE	ACTION	REASON
CONVRT	Deleted	This subroutine was called only from the main program if a 5-card input was not used. (IXYZ ≠ 5)
DELEM	Deleted	The only paths to this subroutine from the main program are taken if a one (1) in the input is used. No other calls are made to DELEM.
DREV	Deleted	DREV is called only by DELEM (deleted above).
NUMINT	Deleted	NUMINT is called only by DREV (deleted above).
INTGND	Deleted	INTGND is called only by NUMINT (deleted above).
DENSEL	Deleted	DENSEL is called only by DELEM and INTGND, which are both deleted above.
OSCTMN	Deleted	OSCTMN is called only by DELEM (deleted above).
PVTELM	Deleted	PVTELM is called only by OSCTMN (deleted above).
MNTOSC ELMTPV }	Combined	ELMTPV is called only by MNTOSC and essentially does the calculations supposedly done by MNTOSC.
ANGLE1 ANGLE2 }	Combined via an Entry Statement	These Function subprograms are very similar and were therefore combined into one subprogram.
SPTRAN	Shortened	Several lines were deleted since there was no path to them.
SPROU	Shortened	With the 5-card input, certain "variables" in LOKANGL become constants. (Example: IDV = IPOS = IELE = ISTA = 0) Therefore, all IF statements (and their references) which involve these variables were deleted. Subroutine SPROU also prints a table which was not discussed in LOKANG2 (per discussion with J. Johanson 8/10/76). Therefore, the lines which generate the table were deleted.

OPTIMIZATION AND CHANGES
(Continued)

SUBROUTINE	ACTION	REASON
JDATE	Deleted	JDATE was referenced several times with constant parameters. Therefore, it was included in each calling program (usually as one line) instead of the line CALL JDATE (-----) and JDATE itself was deleted.
CDATE	Deleted	CDATE was referenced only by SPROU and therefore was incorporated into SPROU.
WRSTA, WRTAP	Combined via Entry Statement	These two subroutines are essentially the same. Since many of the calculations were duplicated in both subroutines, they were combined.
TABLE	Shortened	Approximately 50 lines were deleted since there was no path to them.
MGEOS, GEOMGI	Combined	Since MGEOS was the only subroutine to call GEOMGI, GEOMGI was incorporated into MGEOS.
SINDF, COSDF	Deleted	Since subroutine GEO was the only place in which these subfunctions were used, they were placed at the beginning of GEO and defined as functions there.
HEAD, HEADER	Combined	Subroutine HEADER is called only by HEAD, and therefore, has been included in HEAD.
ARSIN, ARCOS	Deleted	These subprogram functions are acceptable names on the CDC 6600 and are therefore deleted.

The following subroutines are essentially unchanged:

SHPRDC	NEW
KEPECN	CRMXA
SPSECT	MULTIP
QUAD	GEO
AATAN	XYZ
SPRFCO	AZIM
ARCCHK	FIELDG
HOUR	FIELD

All subroutines were modified where appropriate to delete any unused variables or statement labels. All unnecessary statements were deleted. The COMMON block was modified to reflect usage of the variables. Certain programming errors were corrected. For example: in subroutine AATAN, a card was changed to read 1 RESULT = 1.5707963. In subroutine SPROU, AXRATE was punched instead of AZRATE and DERATE instead of DCRATE. These were corrected.

Array DVP was deleted and replaced by dimensioning DV(6) instead of DV(3). In the original program, DV(3) and DVP(3) are placed in COMMON, causing all references to DV(4), DV(5), or DV(6) to pick up the values in DVP(1), DVP(2) or DVP(3).

In LOKANG2 all the information which was written on tapes in LOKANGL has been put into dummy arrays (e.g. XTAP2, XTAP3, XTAP4). These arrays have been put into common statements and inserted into the proper routines.

A new variable (HEIGT) has been read into LOKANG2 which is a constant in LOKANGL. This new variable is the $\bar{M}$ factor which was set equal to a constant in LOKANGL. This variable is read in subroutine WRSTA, and printed out in subroutine HEAD.

Some of the output which was first printed on tapes then rewound and printed out in LOKANGL has been stored in dummy arrays (XTP1, XTP5) and then printed out in subroutine WRSTA.

Further corrections were needed and changes were incorporated after conversations with AFGL/PHP personnel. In subroutine HOUR one of the statements has been changed. The original statement ZX = 9 has been changed to ZX = Z. In the output page of LOKANG2 a new column has been

added, TEC/PI. In LOKANGL, one of the output pages has two identical columns (RTASC = DECL). The second column has been changed to its correct values. Also, in the output section, two more columns have been changed. In the chart, "Prepared by For ...," the altered column is E. Longitude. The original program was W. Longitude. E. Longitude = 360 degrees - W. Longitude. In the chart "Look Angles for ...," the value under E. Longitude has been changed. E. Longitude (new) = 360 degrees + E. Longitude (old).

1108 SIMULATION

In order to run Program LOKANG2 on the 1108 machine, certain other changes were made to LOKANGL. For example, the POGO coefficients, which were read from permanent file in LOKANGL, are now read from a data deck included at the end of LOKANG2. This allows the program to be run independently of permanent files located at only one facility.

Also, all I/O is done via BUFFER IN (GREAD) and BUFFER OUT (GPRINT) statements so that the format is compatible with the I/O subroutine which is utilized at AWS-AFGWC. Finally, the card deck was punched by an 026 keypunch, again to be compatible with AWS-AFGWC.

13. Modification of Satellite Ephemeris Program (Part II)

INITIATOR: J. KLOBUCHAR

PROBLEM NO: 4912 PROJECT NO: 4643

BACKGROUND

Before the program LOKANG2 was sent to AWS, it was determined that the original LOKANGL program had problems in its ability to accurately predict the satellite longitudinal drift. The problem was traced to high order terms in the earth's gravitational field. LOKANGL did not predict correctly the changes in satellite position over extended periods of time. It was then requested that the necessary modifications be included to take into account the drift of mean-geostationary satellites with time for periods of up to several months. Positional accuracy of sub-satellite longitude of approximately one degree was deemed sufficient. However, satellite latitude positional accuracy of .2 degrees was necessary because the conversion tables are generally more dependent upon satellite latitudes.

Rather than make the corrections to the original LOKANGL program, it was decided that it would be easier and more efficient to modify a version of LOKANGL called ROPLOK. (Rapid Orbit Prediction Table). (For a further description of ROPLOK refer to references 1, 2, 3, at the end of this section.)

ANALYSIS AND RESULTS

After the necessary changes were made to ROPLOK, it was combined with LOKANG2. The ROPLOK program also contained unnecessary and duplicate statements which were eliminated. The input to this program was changed to accept a specific 5-card input deck. It was noted that both programs originally had some erroneous statements which were corrected and tested many times to ensure the accuracy of the algorithm. To do this, the program was run on different input samples and cross-checked with theoretical results. The new

combined program produces a Rapid Orbit Prediction Table, a table of M-values, look angles for a geostationary satellite as a function of satellite latitude and longitude, and a Faraday-to-TEC conversion table.

All subroutines in ROPLOK were modified to minimize compile and execution time as well as storage space. The unnecessary statements and unused variable were deleted. Nine subroutines from LOKANG2 were added to ROPLOK program. These subroutines compute the M-value table. The resulting program is called ROPLK2.

In order to run program ROPLK2 on UNIVAC 1108 machine, similar changes made to LOKANG2 were made to ROPLK2, and the program was converted from 029 keypunch code to 026. Again all I/O is done via GREAD and GPRINT subroutines. These are the UNIVAC 1108 I/O routines at AWS-AFGWC.

The following M-Value routines from LOKANG2 were added to ROPLOK program:

1. MGEOS (MCON)
2. GEO
3. FIELDG
4. FIELD
5. HOUR
6. HEED
7. TABLE
8. XYZ
9. AZIM

In order to optimize the program, the following ROPLOK routines were deleted or altered as follows:

SUBROUTINE	ACTION	REASON
PRTCON	Deleted	This subroutine only prints the J(L,M) Coeff., LAMDA (L,M) Coeff., Subscripts (6 Sets), other constants, and Perturbations Present.
LABEL	Deleted	Called only by PRTCON (Deleted Above)
INPREF	Deleted	Used for Tape 7 (Name List) not desired.
MEANIN	Altered	Several lines were deleted since they checked for U or X (more than one element set).
POVLIN	Deleted	Called only by MEANIN if more than one element set.
CCDAM	Deleted	Reads in a second set of elements.
PVTELM	Deleted	Called by POVLIN and CCDAM (Both deleted).
NODSTR	Deleted	Called only by MOON and is therefore incorporated therein.
XCROSS	Deleted	Called only by EPHSET and is therefore incorporated therein.
BLOCK DATA	Deleted	Inserted into main program.

The final step was to guarantee that the program be compatible with the UNIVAC 1108 at the AWS-AFGWC. It was determined that an 1108 compiler or simulated compiler did not exist at AFGL. Several routines which simulate 1108 input/output functions did exist. However, the primary one of interest, IOWAIT, was not running properly on the AFGL 6600 system. It was then decided to perform all input/output operations by using BUFFER IN, BUFFER OUT, ENCODE and DECODE routines (i.e., GREAD and GPRINT subroutines). Special routines were designed to simulate the UNIVAC 1108 input/output system routines. One last problem had remained, that of temporary mass storage units. This problem was overcome by partial storage of the values in the central memory and re-allocating the storage as it was needed.

REFERENCES

1) Wexler, D.M., "Rapid Orbit Prediction Program (ROPP)", TRW-09967-6001-R0-00, prepared under AFCRL Contract No. F19628-68-C-0170, October 1968.

2) Sparks, S.T., "User's Manual for the TRW Rapid Orbit Prediction Program", TRW-09967-600L-R0-00, prepared under AFCRL Contract No. F19628-68-C-0170, October 1968.

3) Bhavnani, K.H., "Modifications to ROPP for no-drag environment, addition of resonance geopotential terms, two element set estimation of mean motive, and simplified input", prepared under AFGL Contract No. F19628-76-0304.

14. Persistence, Recurrence And Runs Of Various Weather Elements

INITIATOR: I. LUND

PROBLEM NO: 4841 PROJECT NO: 8624

BACKGROUND

Past climatological studies have been performed to investigate various weather elements. A software system has been available to extract the data and perform the calculations. Portions of the software have been determined to be both slow and cumbersome to use. New, more efficient algorithms have been added and program code improvements have been made to part of the software system. Additional effort is required to complete the system optimization.

ANALYSIS AND RESULTS

The data base for past climatological studies consisted of 13 years of hourly weather observations from nine weather stations on the east coast of the United States. The stations are:

1. Andrews AFB, D.C.
2. Raleigh-Durham, NC (Airport)
3. Philadelphia, PA (International Airport)
4. Byrd Field, Richmond, VA
5. Washington, D.C. (National Airport)
6. New York (LaGuardia Airport)

7. Newark, NJ (Airport)

8. Baltimore, MD (Friendship International Airport)

9. New York (J.F.K. International Airport)

Included in the computations for these studies was the computation of frequency and cumulative frequency distributions for various weather elements for each station and all combinations of stations. The probabilities of occurrence, persistence and recurrence of specified ranges of values for different seasons were calculated. Based on these, probabilities and distributions of various weather elements can be categorized.

Weather elements of interest include:

- Ceiling
- Visibility
- Wind Speed
- Temperature (Dry Bulb)
- Dew Point
- Sea Level Pressure
- Total Cloud Amount
- Opaque Cloud Amount

Previous analyses produced a set of programs which were used to organize the data and to calculate the probabilities. From examination of the software, it was easy to identify areas which could be improved to facilitate the analysis of the climatological data. Two of the programs

in the analysis software package have already been updated. It is anticipated that future similar work will improve the total software and, with the more efficient procedures, facilitate the analysis. Specifically, the software has been improved in four areas:

- Computer Run Time
- Flexibility
- Code
- Output

The original algorithm used to calculate the joint probability distribution was slow. For a sample case, the execution time was 950 seconds. The new algorithm performs the calculations in 56 seconds.

In a binary system (that is, either the event occurred or it didn't) we have

$$p(X_i) = \frac{N}{\text{Total number of points in data set}} = p(X = X_i)$$

where N = number of occurrences for an event (number of favorable cases)

X = random variable in the set of observation

To simplify, assume X = 1 for an event occurring, then $p(X_i) = p(1 = X_i)$.

For a two dimensional case, we have

$$p(X_i, X_j) = p(X = X_i \text{ and } X = X_j) = p(X_i) \wedge p(X_j)$$

$$= p(X_i = 1 \text{ and } X_j = 1)$$

For a three dimensional case, we have

$$p(X_i, X_j, X_k) = p(X_i = 1 \text{ and } X_j = 1 \text{ and } X_k = 1)$$
$$= p(X_i) \wedge p(X_j) \wedge p(X_k)$$

$$= \frac{\text{number of times } X_i, X_j \text{ and } X_k \text{ all occur at the same time}}{\text{Total number of observations}}$$

Similar equations can be written for four through nine dimensional cases.

For this study, there was data from nine locations. Probabilities were desired for each site and all combinations of sites. That is, the probability of occurrence at sites up to nine at a time were required. Two basic counters were required: one to indicate number of data points available for each site and each combination of sites; the other was a counter of occurrence, i.e., number of times site and/or sites met the criterion, for each combination of sites. The total number of counters required is

$$2 \times \left(\binom{9}{1} + \binom{9}{2} + \binom{9}{3} + \binom{9}{4} + \binom{9}{5} + \binom{9}{6} + \binom{9}{7} + \binom{9}{8} + \binom{9}{9} \right) = 2 \times 511 = 1022$$

Originally the program was written to search through all combinations of sites to determine if the criteria was met for that combination. However, if for example only two sites met the criterion there is no reason to search through the combinations of three or more sites. This portion, i.e., the section to determine how many and which sites had an occurrence, was rewritten. If no sites indicated an occurrence, no searching would be performed. The total possible data counters would be increased and additional data would be examined. Second if all sites had an occurrence, all counters would be increased. Third, combinations would be searched up to the number of combinations possible. That is, if for example three sites indicated an occurrence, no combination of four or more would be searched. Further, sites were ordered so that additional searching would be minimized. For example, assume sites 2, 3, 4 and 7 indicated an occurrence. The counter array would be increased based on an algorithm keying on the site identifying number. Further, for the cases where the number of sites at a particular time was five through eight, keying on the sites without an occurrence could be performed. That is, increase all counters by one, then decrease the counters for the sites where there was no occurrence. Hence, if eight sites reported an occurrence, increase all counters then decrease all counters including M, the site with no occurrence. Inclusion of these simple changes produced a significant decrease in execution time.

Not all changes are expected to produce such a dramatic effect; however, additional savings are anticipated. The original programs required the repunching and substitution of many cards within the program to change the running of a category (range, season, element combination) of interest. The programs were changed to allow for various categories to be run with minor changes in the input. The program code was cumbersome and at times redundant. Portions of the code were rewritten, thereby reducing code and improving the logic of the original program. Various additional output parameters were added to the program. These parameters, such as number of occurrences, provided more input to the categorization procedure.

No major difficulties are anticipated in the continuation of this effort. The continued effort will include the following steps: review the total system, data base and software; in conjunction with analyst input, determine the amount of use this system will be exercised for future analyses; then, depending upon anticipated activity, either

1) optimize the data base handling,

or 2) continue to optimize individual program,

or 3) combine portions of individual programs to optimize the system,

or 4) combinations of 1), 2) and 3).

That is, some efficient procedures for calculating probabilities of occurrence, persistence and recurrence of specified ranges have already been identified and included. Additional improvements could be identified and added to the total system to enhance its performance in providing a detailed analysis of the climatological data.

15. White Sands Missile 3 x 80 Range Tape Conversion

INITIATOR: E. ROBINSON

PROBLEM NO: 4904 PROJECT NO: 0001

BACKGROUND

Data tapes were received from White Sands Missile Range (WSMR). These tapes, generated on a UNIVAC 1108, contain multiple radar station data. Each record is composed of 80 words and each block of data contains 3 records. Thus, if there are 2 radar stations, Record one will contain the header for Station #1; Record two, the header for Station #2; Record three, data for Station #1; Record four, data for Station #2; etc.

ANALYSIS AND RESULTS

A program was supplied to read tapes containing data for a single radar station. This program was modified to accept the additional radar stations. The program originally buffered in 1 block of input data and set up a loop to convert the 36 bit floating point words into 60 bit floating point words in a manner similar to that explained in Section 5 of this report. Once a block of data was processed, the data was output to a tape file and to the printer; whereupon the program returns to read more data.

The program was modified by first reading from cards the number of radar stations contained on the tape, and then setting up a 3-dimensional array for output instead of the original 6 x 16 array. This array is in the form of (I x 6 x 16). I corresponds to the number of Radar Stations. Each input block contains 3 data records. The data is made available for output to separate files for each Radar Station only after the array is filled with data. The array is then cleared after output and new data processed.

The coordinates of the origin and of the radars were extracted from the headers. This information was not contained in the original program. A conversion for integer numbers was included in the conversion package to obtain these data values. This conversion method is also explained in Section 5.

Five tapes were processed. These tapes included both single and multiple radar stations. Problems with the units of the time value associated with each data point were encountered. A time conversion algorithm was included to obtain the proper units.

16. Coordinate Conversions And Graphical Presentations

INITIATOR: W. BARRON

PROBLEM NO: 4908 PROJECT NO: 433L

BACKGROUND

Often computer-based graphical presentations are useful for analysis and as pictorial descriptions of systems under study. They are used to display values commonly associated with different but equivalent geometric bases. For example, there exists a requirement to display the astronomical altitude-azimuth coordinate system and the astronomical hour angle-declination coordinate system, centered around any specific geographic location. On the display or graph, an example of which is shown in Figure 16-1, various other information such as satellite tracks can be displayed to aid in the analyses. The algorithm performing the coordinate conversion is useful to locate accurately any object in either coordinate system given one set of coordinates.

The celestial sphere provides a convenient framework for fixing the relative positions of the heavenly bodies. A point on the celestial sphere directly above the observer's position is the zenith. The point on the celestial sphere directly opposite the zenith is the nadir. The plane perpendicular to zenith-nadir line at the observer's position intersects the celestial sphere in the horizon. This is the great circle whose points are 90 degrees from the zenith everywhere. A northward prolongation of the earth's axis of rotation pierces the celestial sphere at a point called the north celestial pole. It is marked by a moderately bright star -- Polaris. However, there is no pole star in the southern hemisphere. The observer's meridian is a great circle through the zenith and the north/south poles. The position of a celestial object is given by its altitude and its azimuth. The latitude is the angle in degrees measured from the horizon along the vertical circle to the celestial object. The zenith distance is 90 degrees minus latitude. The azimuth is the angle in degrees measured from the

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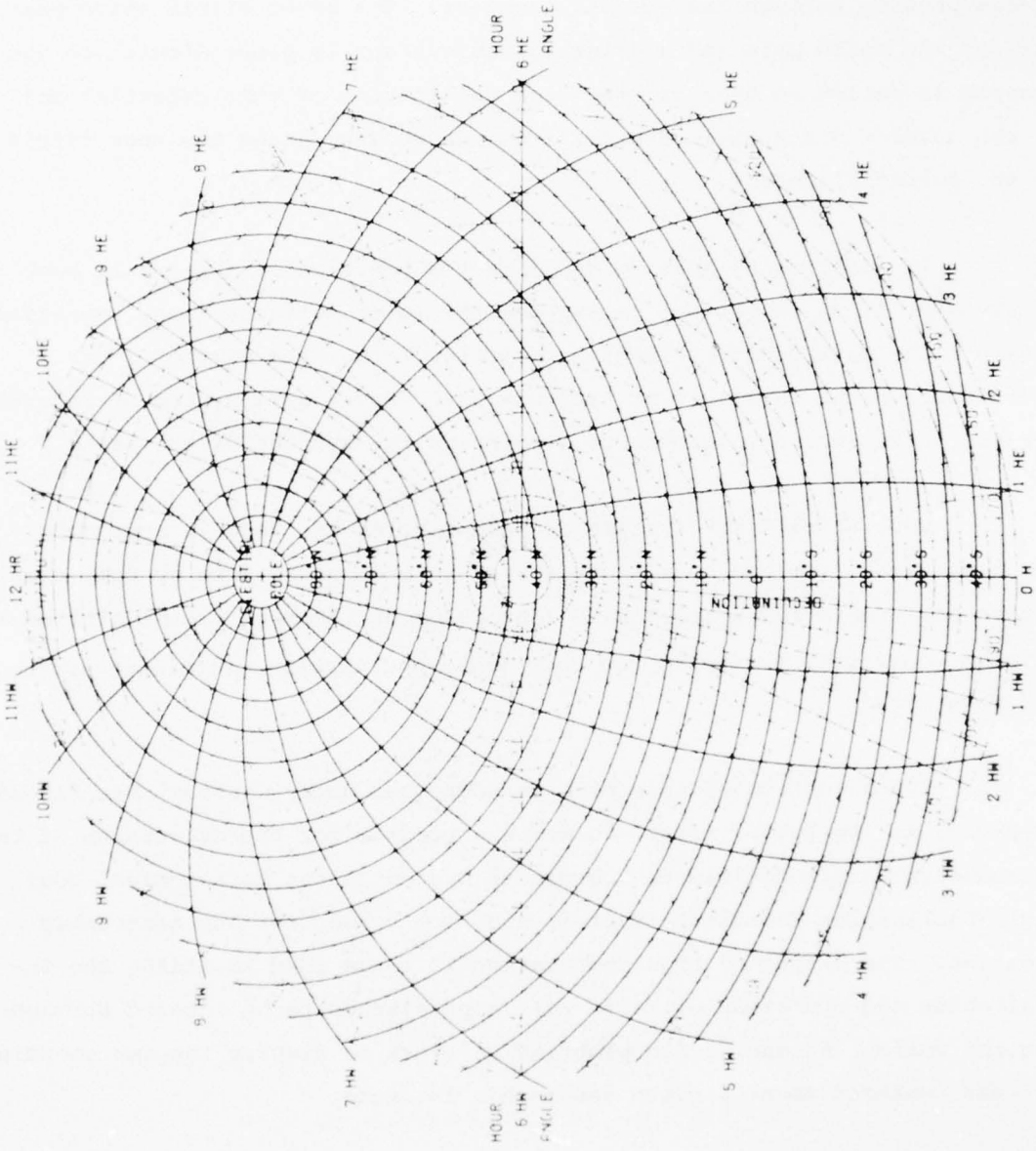

Figure 16-1 Sample Celestial Sphere

north point toward the east along the horizon to the foot of the vertical circle passing through the celestial object. The great circle which passes through the north pole and a celestial object and is perpendicular to the equator is called an hour circle. The declination of this celestial object is the angular distance in degrees from the equator along the hour circle to the celestial object.

In order to be able to describe the position of a heavenly body in the sky, it is convenient to suppose the inner surface of the celestial sphere to be marked off by imaginary circles (e.g., the equator), the meridians and the parallels of latitude which serve as a system of reference for the latitude and longitude of a point on the surface of the earth.

Several distinct systems of such circles are used in astronomy. The conversion from one coordinate system to another is done by some simple equations. The primary coordinate conversion of interest is the altitude-azimuth coordinate system to the hour angle-declination coordinate system and vice versa.

The objective of this problem addressed under Contract No. F19628-76-C-0203 is two fold: first, to write a program for the conversion of the Astronomical Altitude-Azimuth Coordinate System to the Astronomical Hour Angle-Declination Coordinate System, and vice versa, for any geographic location. The output of this computation is to be used in aiding the installation and operation of radio telescope systems to be located throughout the world. Second, write plotting software to display the two coordinate systems centered about a given geographic latitude.

ANALYSIS AND RESULTS

Based on the geometry shown in Figure 16-2, the equations used in the coordinate conversions are derived as follows:

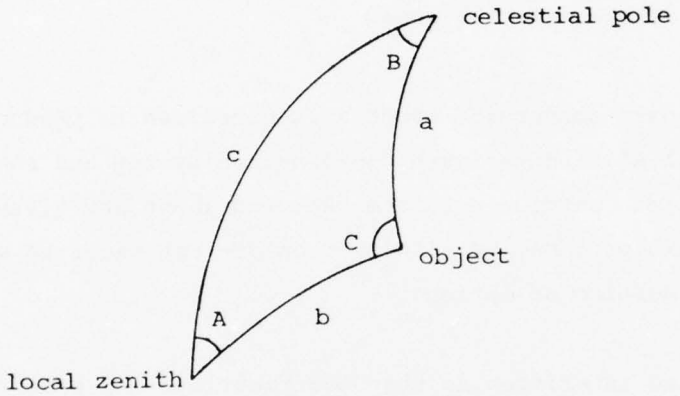

Figure 16-2 Geometry for Coordinate Conversion

Equation 1: azimuth-zenith angle to hour angle-declination

For a given

c = co-latitude
A = azimuth
b = zenith angle,

use the following equations

$$\cos a = \cos b \cos c + \sin b \sin c \cos A$$

$$\cos B = \frac{\cos b - \cos a \cos c}{\sin a \sin c}$$

to compute

B = hour angle
$\delta = 90 - a$ = declination

Equation 2: hour angle-declination to azimuth-zenith angle

For a given

c = co-latitude
B = hour angle
$a = 90 - \delta$ = co-declination,

use the following equations

$$\cos b = \cos a \cos c + \sin a \sin c \cos B$$

$$\cos A = \frac{\cos a - \cos b \cos c}{\sin b \sin c}$$

to compute

A = azimuth
b = zenith angle

The coordinate conversion program is exercised to produce the plot of the Astronomical Altitude-Azimuth Coordination System and the Astronomical Hour Angle-Declination Coordinate System centered about any given latitude including zero. This plot may be displayed on 30-inch paper as well as 12-inch paper with multicolor options.

The software is written so that modifications and extensions can readily be made for future use. Preliminary discussions have focused on the following expansions of the capability of the software:

1) Display a satellite track (centered about some geographic latitude) both on the plot and in digital form.
2) Magnify portions of any plot (for a given altitude, declination, and hour angle).
3) For a given time range (usually a month) and latitude, plot the visible constellation.
4) Add additional coordinate system to the software for conversion and display information; e.g., Right Ascension - Declination
   Latitude - Longitude
   Galactic Latitude - Galactic Longitude

17. Contour Plotting Routines

INITIATOR: E. SHETTLE

PROBLEM NO: 4909 PROJECT NO: 7621

BACKGROUND

A package of subroutines was developed to plot a contour map for a given function. The main subroutine, CONTOUR, accepts as input an array of function values f(X, Y) on a grid of points (X(I), Y(J)) and plots a contour map (or maps) of the function. Two interpolation algorithms are provided to find values of f(X,Y) when X and Y do not fall on the specified data points. More interpolation procedures may easily be added to the existing ones. For eight X values and nine Y values (i.e., 72 f(X, Y) values), this subroutine produces two sets of contour plots, one with two contour values and the other with seven contour values, in five CPU seconds.

ANALYSIS AND RESULTS

This subroutine package is composed of a drive subroutine and nine other subroutines. The driver subroutine accepts the array values as well as a set of parameters which determines type of interpolation desired, and the scale and level of contours to be displayed. The output is the plot of a contour map of a given function. The function of each subroutine is to evaluate a set of variables and/or to perform a chain of interactive operations.

Individual subroutines were written to

1. Accept a set of parameters and check for possible errors

2. Draw frame, axes and labels

3. Label contours

4. Generate a set of contour values

5. Generate second set of contour values

6. Interpolate the values of the function when X and Y do not fall on the specific data points for either linear or logarithmic values

7. Check continuity of the contour curves

8. Relocate coordinates of contour map to smooth the curve

9. Sort values and obtain least upper bound and greatest lower bound for a specified value

The interpolation algorithms used to find values of f(X, Y), when X and Y do not fall on the specified data points X_i, (i = 1, 2, ..., NX) and Y_j, (j = 1, 2, ..., NY), are given below.

When f is linear in both X and Y the following equations are used:

$$f(X, Y) = (1 - h_x)(1 - h_y) f_{i, j} + (1 - h_x) h_y f_{i, j + 1}$$

$$+ h_x (1 - h_y) f_{i + 1, j} + h_x h_y f_{i + 1, j + 1}$$

where $h_x = (x - x_i)/(x_{i + 1} - x_i)$

$$h_y = (y - y_j)/(y_{j + 1} - y_j)$$

When log (f) is linear in both X and Y, the following equations are used:

$$\text{Log } f(x, y) = (1 - h_x)(1 - h_y) \text{ Log } f_{i, j} + (1 - h_x) h_y \text{ Log } f_{i, j + 1}$$

$$+ h_x (1 - h_y) \text{ Log } f_{i + 1, j} + h_x h_y \text{ Log } f_{i + 1, j + 1}$$

where h_x and h_y are the same as above.

This subroutine package was designed to be user oriented. Much care was taken in the writing of the software to facilitate its use. The software code itself has much documentation via comment cards. The following was taken from the program documentation. It is a detailed explanation of the input required. It also indicates that this package is sufficiently general in nature to have varied applications and that with minor modifications the range of applications could be expanded further.

The input to this subroutine is provided by the user. The principal subroutine CONTOUR is independent of the main program and has no READ or WRITE statements. It is the user's responsibility to provide the input to this subroutine by passing it as the parameters when a call is made to this subroutine. The input to this subroutine is explained in details on the following pages.

For simplicity, the following codes are used for variable description:

RU = Returned Unchanged

R = Real Value

INT = Integer Value

Call to this subroutine is made by:

```
CALL CONTOUR (F, X, Y, NX, NY, INTERP, NFC, FCON, XCALE,
XNAME, YNAME, HEADER, INFO, XCONTR, YCONTR, BEGINX,
BEGINY, MESS)
```

Variable Description:

F = A2 - Dimensional array such that:

$F(I, J) = F(X_i, Y_j)$ with $X_i = X(I)$ and $Y_j = Y(J)$

Dimensions of this matrix is NX by NY.
For every call, the dimension of F in the calling program must be exactly F(NX, NY). (RU) (R)

X = A vector of X values sorted in ascending or descending order for which F(X, Y) is specified. Dimension of X is NX, (RU) (R)

Y = The corresponding vector of Y values where F(X, Y) is given. Dimension of Y is NY. (RU) (R)

NX = Number of points in the X vector (RU) (INT)

NY = Number of points in the Y vector (RU) (INT)

INTERP = The name of an external subroutine to be used for interpolation when the coordinates of a contour curve do not fall on the specified data points. (RU)

= INTRPØ, if f is linear in both X and Y.

$$f(X, Y) = (1 = h_x)\ (1 - h_y)\ f_{i,\ j} + (1 - h_x)\ h_y\ f_{i,\ j+1}$$

$$+ h_x\ (1 - h_y)\ f_{i+1,\ j} + h_x h_y\ f_{i+1,\ j+1}$$

where: $h_x = (x - x_i)/(x_{i+1} - x_i)$

$h_y = (y - y_j)/(y_{j+1} - y_j)$

= INTRP1, if Log (f) is linear in both x and y.

$$\text{Log } f\ (x, y) = (1 - h_x)(1 - h_y)\ \text{Log } f_{i,\ j}$$

$$+ (1 - h_x)\ h_y\ \text{Log } f_{i,\ j+1}$$

$$+ h_x\ (1 - h_y)\ \text{Log } f_{i+1,\ j}$$

$$+ h_x h_y\ \text{Log } f_{i+1,\ j+1}$$

where: h_x and h_y are the same as above.

These subroutines are provided for the use in this program. The user must pass one of the subroutine names to this program and it must be declared external in the calling program.

NFC = Number of contours to be plotted. (INT)

= Positive, NFC contours at the values given by FCON(I), I = 1, 2, ..., NFC are drawn. (RU)

= 0, the contours such that FCON(1) + N*FCON(2) = FCON(3) where N = 0, 1, 2, ... are drawn. Upon return NFC = Number of contours.

= Negative, -NFC contours between FMIN and FMAX, inclusive, where FMIN and FMAX are the smallest and the largest values in the array F(I, J) are drawn. Upon return NFC = ABS(NFC).

FCON = An array of contour values. (R)

a - if NFC > 0, then FCON must contain NFC contour values. (RU)

b - if NFC = 0, then FCON(1) = Initial contour value, FCON(2) = Increment value and FCON(3) = Maximum contour value. Upon return FCON contains the evaluated contour values.

c - if NFC < 0, then FCON is evaluated between FMIN and FMAX. If NFC = -1, then FCON(1) = FMIN. Upon return FCON contains the evaluated contour values.

Note: Dimension of FCON is L, where L is as follows:

L = NFC if NFC > 0.

L = |NFC| if NFC < 0.

L = INT(FCON(3) - FCON(1))/FCON(2) + 1 if NFC = 0.

XSCALE (I) = A vector defining the X-axis of the plot. (RU)(R)

(1) = Left most X value to be written on the X-axis of the plot.

(2) = Right most X value to be written on the X-axis of the plot.

(3) = Number of divisions per 10 inches

= 10. means 1 tick mark/inch.

= 5. means 1 tick mark/2inches.

= 20. means 1 tick mark/half inch.

(4) = Length of X-axis in inches

Note: Dimension of XSCALE is 4.

YSCALE (I) = A vector defining the Y-axis of the plot. (RU)(R)

(1) = Bottom most Y value to be written on the Y-axis of the plot.

(2) = Top most Y value to be written on the Y-axis of the plot.

(3) = Same as XSCALE(3).

(4) = Length of Y-axis in inches.

$\leq$ 10 for 12-inch width paper.

$\leq$ 28 for 30-inch width paper.

XNAME = An alphanumeric array containing up to 40 characters to label the X-axis.

Note: Dimension of XNAME is 4.

YNAME = An alphanumeric array containing up to 40 characters to label the Y-axis.

Note: Dimension of YNAME is 4.

HEADER (I) = An alphanumeric array containing up to 110 characters. First 3 words are used as identification for plot. Words 4 through 11 are printed above the contour plot.

(1) = 10H ... Programmer's name.

(2) = 10H ... Problem number.

(3) = 10H ... Information meaningful to the programmer.

Note: Not all words from (4) to (11) must necessarily be used. Dimension of HEADER is 11.

INFO (I) = Control Parameters. (RU) (INT)

(1) = Number of characters in XNAME.

(2) = Number of characters in YNAME.

(3) = Number of characters in HEADER(4) through HEADER(N), where $4 \leq N \leq 11$.

(4) = Control for using symbols.

= 0, line plot without symbols.

= 1, line plot with a symbol at every point.

= Negative will suppress lines between the points.

(5) = Symbol code used for plotting.

= 3 -- symbol = +.

= 4 -- symbol = X.

= 11 -- symbol = *

(6) = Number of times this subroutine will be called. This determines the number of frames.

(7) = Total length of X-axis in inches for all frames. That is, sum of all XSCALE(4) for all calls.

Note: INFO(6) and INFO(7) must be the same for all calls. Dimension of INFO is 7.

XCONTR = Dummy array to store X values of the same level contour curves. (R)

YCONTR = Dummy array to store the corresponding Y values of the contour curves. (R)

BEGINX = Dummy array to store the starting X coordinates of contour curves of the same level. (R)

BEGINY = Dummy array to store starting Y coordinates which correspond to X coordinates in BEGINX. (R)

Note: Dimensions of these 4 dummy arrays are to be determined by the user.

MESS (1) = Error or warning check. (INT)

(2) = Dimension of XCONTR and YCONTR declared in the calling program.

(3) = Dimension of BEGINX and BEGINY declared in the calling program.

IMPORTANT POINTS

1. Plotter requires the information in HEADER(1) through HEADER(3). It must be the same for all calls.

2. This subroutine may be called as many times as desired. Define the parameters as described above for every call. For every call the dimension of F in the calling program must be exactly NX by NY.

3. CALL ENDPLT must be used to obtain a plot. Insert this statement before the end of the main program.

4. F values must be passed as follows:

	X(1)	X(2)	---	X(NX)
Y(1)	F(1, 1)	F(2, 1)	---	F(NX, 1)
Y(2)	F(1, 2)	F(2, 2)	---	F(NX, 2)
.	.	.	---	.
.	.	.	---	.
.	.	.	---	.
Y(NY)	F(1, NY)	F(2, NY)	---	F(NX, NY)

The following read statement would do the job:

```
READ 100, ((F(I, J), I = 1, NX), J = 1, NY)
100 FORMAT (nx Fw.d)
```

18. Program And Tape Conversion For ATS-6 Satellite Data

INITIATOR: D. HARDY

PROBLEM NO: 4923 PROJECT NO: 7661

BACKGROUND

Tapes of the data generated by the ion and electron spectrometers on board the ATS-6 satellite were furnished. These tapes were generated on the UNIVAC 1108 computer which has a 36-bit word size. A program that reads the data tapes and obtains particle counts, velocities, and distribution functions was obtained from University of California, San Diego (UCSD). This program was prepared on a CDC 3600 computer with a 48-bit word. It was desirable to have the program operational on the CDC 6600 computer, and to be able to read the tapes with this program.

ANALYSIS AND RESULTS

This task is two-fold in nature, since neither the tape nor the program was compatible with the CDC 6600. Modifications were made to the program, and then subroutines were added to the program to read the tape properly.

The program was first duplicated and compiled. All compilation errors were removed. Logical operations had to be checked and modified as needed. The output header formatting had to be changed because of differences in the word sizes for the two computers. A routine for tape positioning was written to replace an internal reference to tape positioning available on the CDC 3600, but not available on the CDC 6600.

The major problems encountered arose when processing the first records of the tape began. Each file is preceded by a record in external Binary Coded Decimal (BCD). Parity cannot be changed during the execution of a program. Therefore, for the processing of input, a conversion had to

be written to change the characters from external BCD to internal BCD, with minor modifications for masking and decoding of the record. The starting time is obtained from this record; thus, it was an essential step in the processing.

In addition to this file header record problem, the data records caused problems because of lack of compatibility of word sizes. The program supplied assumed a tape word size of 36 bits, but assumed an internal computer word size of 48 bits. However, 60 bits are normally used when programming on a CDC 6600. Therefore, we chose to unpack 48 bits of tape information into a 60-bit word, right justified, to obtain a compatible process, and let the program conversion do the rest. This was considered preferable to modifying each step of the program to account for the extra 12 bits in the CDC 6600 word size. This operation was accomplished by setting up loops and shifting three 60 bit words of information into five 60 bit words containing 48 bits of information, right justified, with zero fill for the remainder of the word.

The initial output values obtained were relatively smaller than expected, and further inspection of the program showed that there is an option to obtain the counting rates either in counts/second or Log_{10} (counts/sec). The sample listing supplied was in counts/second. The Log_{10} conversion was by-passed, and a duplicate of the sample listing was obtained. Other periods of interest were processed with satisfaction and duplicate copies of the new deck were made for future use.

In general, this program reads data generated from the University of California, San Diego (UCSD) experiments. Observations are made of trapped particles and their interrelations in the following regions:

- trapped radiation belts toward the equator.
- N-S auroral zones
- Daytime magnetopause and interplanetary sphere
- Nighttime tail plasma sheets.

Also observed in these regions will be the energy spectrum of ions above 50 eV, density versus magnetic field depression, and fluxes of auroral particles and their associations with electrons above 50 KeV and ions above 50 eV.

Digital data (particle counts) is processed by use of accumulators. In all cases, the values will be log compressed from the 16-bit accumulators to either 10 or 9 bits. The program converts the values on tape from the log compressed values back to the particle counts before outputting the results.

For the 16 bits, the compressor will accumulate the number of shifts required to reach, but not include, the first "1." The number of shifts required will then be represented in the 9 bit readout word by the 4 most significant bits (MSB) of the nine ($2^8 - 2^5$). This is called the exponent. The compressor will then load the next five bits following, but not including, the first "1" into the five least significant bits LSB's ($2^4 - 2^0$) of the 9 bit word. For 10 bit compression, six bits will be taken and the last, or LSB, will be loaded into another word for readout.

This effort will be continued under a different problem number. Output will include averages, and plots of the data, along with further analysis of the data tape supplied.

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MATHEMATICAL ANALYSIS AND IMPLEMENTING SOFTWARE FOR PHYSICAL AN--ETC(U)
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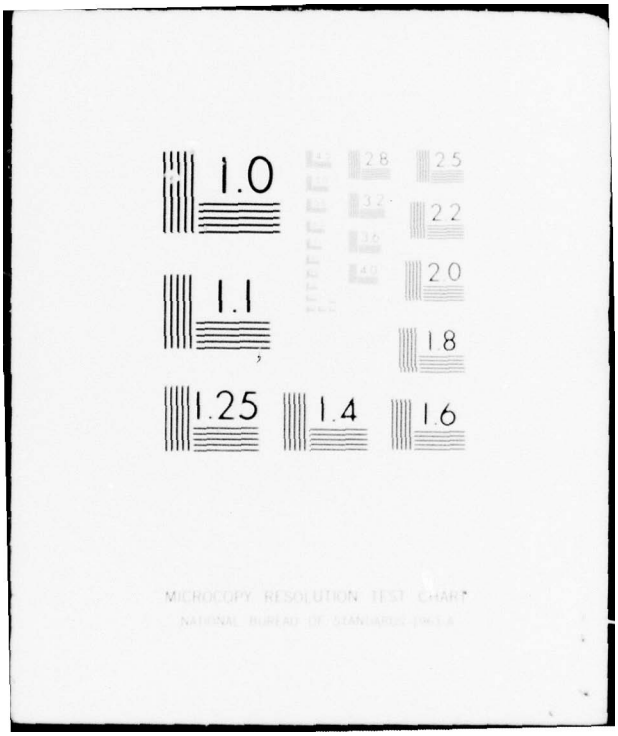
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19. Accuracy Of f_0F_2 Prediction Techniques

INITIATOR: C. PIKE

PROBLEM NO: 4825 PROJECT NO: 7663

BACKGROUND

A copy of a program "ITS Coefficient Program," was furnished for modification. This program, along with information obtained from the ISIS satellite, were part of this analysis task. The objective of the analysis was to determine the accuracy of the ITS predicted f_oF_2 and the accuracy of a second f_oF_2 prediction technique which is based upon input from ionograms obtained from the ISIS satellite.

ANALYSIS AND RESULTS

The program, "ITS Coefficient Program" calculates the following coefficients:

(1) f_oF_2

(2) M(3000) F_2

(3) $h'_{min}F_2$

(4) f_oE

(5) f_oE_s (Upper Decile)

(6) f_oE_s (Medium)

(7) f_oE_s (Lower Decile)

The original purpose of the problem was to:

1) Determine exactly the logic of the program to facilitate use and modification of the program.

2) Document the original program obtained.

3) Modify the program so that, if desired, it will produce only the value of f_oF_2 at a particular point, i.e., eliminate the worldwide tables.

4) Merge the modified version of the coefficient program to accept as input the output from SUA's program Ephemeris Extrapolation Program (LOKANGL).

After all of the above tasks had been completed, the modified program was further changed to accept, as input, either daily or monthly sunspot numbers. Sunspot data had been supplied. To check the program, it has been run to generate predictions for specific periods. These predicted values, based both on daily and monthly median sunspot values, have also been prepared for future analysis.

An additional program was required and written to aid in the analysis of determining the accuracy of the predicted f_oF_2 generated from the modified program and the accuracy of an f_oF_2 prediction technique based on input from the ionograms. The program reads in actual f_oF_2 values and values obtained from the ionograms. Then the program extracts and interpolates when necessary from the previously generated output the predicted f_oF_2 from the modified ITS Coefficient Program. Differences and differences squared, are calculated. The values are displayed and saved for future analysis.

Periods of interest for this analysis have been August, September, November and December 1972. Values have been obtained for approximately 1000 data points. These values, from both prediction techniques, will be analyzed and the results published in a report. (Sample output is shown in Figure 19-1.) The analysis will consist of comparing the accuracy of the two prediction techniques. Preliminary statistics will include sums of differences for various time periods and rms values. Sufficient data exists to permit comparison among seasons, times of day, and geographic locations. The modified ITS Coefficient Program, or some version thereof, is being used in another f_oF_2 analysis task.

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DAY	TIME	FOF2	FIN	PFOF2	LAT	LONG	FOF2-FIN	FOF2-PFOF2	DIF1**2	DIF2**2
237	0 7 5	4.40	4.80	3.49	31.542	265.953	-.4[illegible]E+00	.91E+00	.16E+00	.83E+00
237	205654	7.20	8.00	5.93	47.170	286.076	-.8[illegible]E+00	.13E+01	.64E+00	.16E+01
237	205714	7.30	8.00	5.88	48.223	286.066	-.7[illegible]E+00	.14E+01	.49E+00	.20E+01
237	205844	7.50	8.50	5.67	52.955	286.068	-.1[illegible]E+01	.18E+01	.10E+01	.34E+01
237	21 0 14	7.80	8.50	5.50	57.679	286.157	-.7[illegible]E+00	.23E+01	.49E+00	.53E+01
237	21 124	6.80	8.50	5.38	61.346	286.325	-.17E+01	.14E+01	.29E+01	.2[illegible]E+01
237	224620	5.30	9.10	7.09	33.741	257.880	-.8[illegible]E+00	.12E+01	.64E+00	.15E+01
237	224727	7.70	8.00	6.64	37.284	257.771	-.3[illegible]E+00	.11E+01	.90E-01	.11E+01
237	224857	7.30	8.30	6.19	42.037	257.65[illegible]	-.1[illegible]E+01	.11E+01	.10E+01	.12E+01
237	224920	7.20	8.40	6.10	43.251	257.626	-.12E+01	.11E+01	.14E+01	.12E+01
237	225052	7.20	8.40	5.80	48.098	257.559	-.12E+01	.14E+01	.14E+01	.20E+01
237	225157	7.20	9.50	5.65	51.617	257.549	-.23E+01	.16E+01	.53E+01	.24E+01
237	25327	7.20	9.50	5.47	56.243	257.611	-.23E+01	.17E+01	.53E+01	.30E+01
237	225516	7.20	9.20	5.31	62.111	257.863	-.2[illegible]E+01	.19E+01	.40E+01	.38E+01
238	65356	5.40	5.90	3.42	42.726	312.690	-.5[illegible]E+00	.20E+01	.25E+00	.39E+01
238	65416	4.80	5.80	3.40	41.678	312.667	-.1[illegible]E+01	.13E+01	.10E+01	.17E+01
238	85057	4.60	4.90	3.40	32.209	283.879	-.3[illegible]E+00	.12E+01	.90E-01	.13E+01
238	85117	4.70	4.80	3.51	31.159	283.841	-.2[illegible]E+00	.12E+01	.40E-01	.14E+01
238	193616	8.20	9.51	7.49	32.259	304.336	-.13E+01	.71E+00	.17E+01	.51E+00
238	193721	8.00	9.20	7.05	35.698	304.224	-.12E+01	.95E+00	.14E+01	.91E+00
238	193743	7.80	9.20	5.92	36.861	304.189	-.14E+01	.88E+00	.20E+01	.77E+00
238	193851	7.70	9.20	5.58	40.452	304.092	-.15E+01	.11E+01	.23E+01	.13E+01
238	194021	7.50	9.70	5.23	45.198	303.998	-.15E+01	.13E+01	.23E+01	.16E+01
238	194043	7.20	8.80	6.16	46.357	303.983	-.16E+01	.10E+01	.26E+01	.11E+01
238	194217	6.70	8.70	7.93	51.092	303.952	-.20E+01	.77E+00	.40E+01	.60E+00
238	194321	6.70	7.80	5.78	54.663	303.984	-.11E+01	.92E+00	.12E+01	.84E+00
238	194343	6.70	7.40	5.74	55.817	304.006	-.7[illegible]E+00	.96E+00	.49E+00	.92E+00
238	194513	6.90	7.20	5.58	60.534	304.171	-.13E+01	.32E+00	.17E+01	.10E+00
238	212749	9.30	10.20	8.49	25.510	276.079	-.9[illegible]E+00	.81E+00	.81E+00	.65E+00
238	212859	9.00	9.50	7.92	29.222	275.936	-.5[illegible]E+00	.12E+01	.25E+00	.14E+01
238	212919	8.90	9.50	7.69	30.281	275.897	-.7[illegible]E+00	.12E+01	.49E+00	.13E+01
238	213027	8.20	8.40	7.12	33.881	275.773	-.2[illegible]E+00	.11E+01	.40E-01	.12E+01
238	213157	7.90	8.20	6.57	38.678	275.63[illegible]	-.3[illegible]E+00	.13E+01	.90E-01	.18E+01
238	213327	7.60	8.20	6.16	43.387	275.521	-.6[illegible]E+00	.14E+01	.36E+00	.21E+01
238	213627	7.10	8.20	5.67	52.859	275.454	-.12E+01	.14E+01	.14E+01	.19E+01
238	213649	6.70	8.20	5.58	54.014	275.466	-.15E+01	.11E+01	.23E+01	.13E+01
238	213757	6.60	8.60	5.45	57.581	275.541	-.20E+01	.11E+01	.40E+01	.13E+01
238	213819	6.70	8.50	5.42	58.733	275.583	-.18E+01	.13E+01	.32E+01	.16E+01
238	213927	6.30	8.50	5.31	62.293	275.774	-.22E+01	.99E+00	.48E+01	.98E+00
238	214128	6.70	8.50	5.13	68.611	276.468	-.18E+01	.15E+01	.32E+01	.27E+01

Figure 19-1 Sample f_oF_2 Output

20. Conversion Of Pioneer Spacecraft Data

INITIATOR: D. SMART

PROBLEM NO: 4930 PROJECT NO: 2331

BACKGROUND

Four tapes containing complete trajectory information of Pioneer 6, 7, 8, and 9 were received for processing. These tapes were generated at NSSDC (National Space Science Data Center) by taking the most accurate information from each ephemeris tape provided by JPL (Jet Propulsion Laboratory) and eliminating time overlap. The data tapes, generated on an IBM 7094, are 7-track, 800 B.P.I. Each logical record contains 89 words, and each block contains 20 logical records. Table 20-1 is a listing of the information that is available on the tape. It was requested that these tapes be converted and written on CDC SCOPE tapes with one logical record per block.

ANALYSIS AND RESULTS

This request was relatively simple, since a conversion routine had previously been written to convert IBM 7094 tapes. Section 5 of this report gives an explanation of the conversion. Changes were made to previous software by increasing the size of the input array and output formats. The rest was duplicated from the existing routine.

There was one problem. This was the double precision time word. The manner of representing a double precision word was quite different between the two machines. It was further noted that, because of the smaller word size (36-bits) in the IBM 7094 computer, a double precision word could almost be accommodated into the CDC 60-bit word. This indicated a loss of 12 bits. However upon inspection of the dump, it was found that the last 6 bits contained zeros, and precision was lost in only 6 bits. This was more than was needed by the requestor.

This double precision word was then packed into one CDC 6600 word and the value output as a single precision word. The four tapes received were converted and new tapes generated for the task initiator.

TABLE 20-1 PIONEER SPACECRAFT DATA

WORD WITHIN RECORD	PARAMETER	UNIT OF MEASUREMENT
001	FIRST WORD DOUBLE PRECISION TIME	SEC
002	SECOND WORD OF DOUBLE PRECISION TIME	SEC
003	JULIAN DATE	DAYS
004	JULIAN DATE	DAYS
005	FIRST WORD OF GREG. CALENDAR DATE	YYMMDDDHH
006	SECOND WORD OF GREG. CALENDAR DATE	MMSSFFF
007	SINGLE PRECISION TIME	SEC
008	TIME FROM LAUNCH	SEC
009	RADIUS EARTH TO PROBE	KM
010	DECLINATION OF PROBE	DEG
011	RIGHT ASCENSION OF PROBE	DEG
012	GEOCENTRIC VELOCITY VECTOR MAG	KM/SEC
013	INERTIAL PATH ANGLE	DEG
014	INERTIAL AZIMUTH ANGLE	DEG
015	RADIUS EARTH TO SUN	KM
016	DECLINATION OF SUN	DEG
017	RIGHT ASCENSION OF SUN	DEG
018	RADIUS EARTH TO MOON	KM
019	DECLINATION OF MOON	DEG
020	RIGHT ASCENSION OF MOON	DEG
021	HELIOCENTRIC RADIUS VECTOR MAGNITUDE	KM
022	CELESTIAL LATITUDE OF PROBE	KEG
023	CELESTIAL LONGITUDE OF PROBE	DEG
024	INERTIAL VELOCITY	KM/SEC
025	INERTIAL PATH ANGLE	KEG
026	CELESTIAL LATITUDE OF EARTH	DEG
027	CELESTIAL LONGITUDE OF EARTH	DEG
028	X COMPONENT OF SC IN SUN EARTH LINE	KM
029	Y COMPONENT OF SC IN SUN EARTH LINE	KM
030	Z COMPONENT OF SC IN SUN EARTH LINE	KM

TABLE 20-1 (Continued)

WORD WITHIN RECORD	PARAMETER	UNIT OF MEASUREMENT
031	RADIUS SUN TO PROBE	KM
032	EARTH SUN PROBE ANGLE	DEG
033	LONGITUDE OF SC IN SUN EARTH LINE SYS	DEG
034	GEOCENTRIC X COORDINATE OF SC	KM
035	Y	KM
036	Z	KM
037	MOON X COORDINATE OF SC	KM
038	Y	KM
039	Z	KM
040	SUN X COORDINATE OF SC	KM
041	Y	KM
042	Z	KM
043	VENUS X COORDINATE OF SC	KM
044	Y	KM
045	Z	KM
046	MARS X COORDINATE OF SC	KM
047	Y	KM
048	Z	KM
049	SATURN X COORDINATE OF SC	KM
050	Y	KM
051	Z	KM
052	JUPITER X COORDINATE OF SC	KM
053	Y	KM
054	Z	KM
055	GEOCENTRIC VELOCITY X COORDINATE OF SC	KM/SEC
056	Y	KM/SEC
057	Z	KM/SEC
058	CENTRAL BODY	
059	TARGET BODY	
060	GEOCENTRIC LATITUDE	DEG

TABLE 20-1 (Continued)

WORD WITHIN RECORD	PARAMETER	UNIT OF MEASUREMENT
061	GEOCENTRIC LONGITUDE	DEG
062	ALTITUDE ABOVE EARTH	KM
063	HINGE ANGLE OF EARTH	DEG
064	SWIVEL ANGLE	DEG
065	HINGE ANGLE	DEG
066	ALTITUDE ABOVE ECLIPTIC PLANE	KM
067	R(SUN)*COSB	KM
068	R(SUN)*SINB	KM
069	EARTH PROBE SUN ANGLE	DEG
070	EARTH PROBE TARGET ANGLE	DEG
071	EARTH PROBE NEAR LIMB OF TARGET ANGLE	DEG
072	SUN EARTH PROBE ANGLE	DEG
073	SUN PROBE NEAR LIMB OF EARTH ANGLE	DEG
074	SUN TARGET PROBE ANGLE	DEG
075	MOON EARTH PROBE ANGLE	DEG
076	MOON PROBE SUN ANGLE	DEG
077	EARTH PROBE MOON ANGLE	DEG
078	TARGET PROBE SUN ANGLE	DEG
079	CANOPUS CLOCK ANGLE EARTH CENTER	DEG
080	MOON CLOCK ANGLE EARTH CENTER	DEG
081	TARGET CLOCK ANGLE EARTH CENTER	DEG
082	RADIUS TARGET TO SC	KM
083	VELOCITY SO WRT TO TARGET	KM/SEC
084	ALTITUDE ABOVE TARGET	KM
085	ANGULAR SEMI-DIMETER	DEG
086	EARTH CLOCK ANGLE	DEG
087	CANOPUS-PROBE-EARTH ANGLE	DEG
088	CANOPUS-PROBE-SUN ANGLE	DEG
089	DAYS PAST MIDNITE FROM LAUNCH	DAYS

21. Modification Of IEMCAP

INITIATOR: P. ROTHWELL

PROBLEM NO: 4915 PROJECT NO: 7661

BACKGROUND

AFGL PHG has received a copy of the Intrasystem Electromagnetic Compatibility Analysis Program (IEMCAP) from RADC. IEMCAP,consisting of two programs, models the electrical properties of an aircraft. The purpose of this problem was to get the software supplied by RADC operational at AFGL. The software was supplied via a card image tape. A sample data deck was supplied. It is intended that the programs will be used with future PHG modeling efforts.

ANALYSIS AND RESULTS

The software package obtained consisted of two programs. A sample data deck was supplied. (We were not made aware of the availability of the user's manuals until the task was completed. However this did not impede the performance of the task. Rather, it gave us the opportunity to investigate the logic of the software.) The codes for the first of the two programs was modified to allow for the running at AFGL. Calculations were performed and the results were checked to validate the program. After validating,TART, the second of the two programs, was modified to allow for the processing on the CDC 6600. The input cards required by TART were determined by investigation of the program. Further study resulted in the matching of the input files required (and their designation) by TART with output files generated by the first of the two programs supplied. Sample outputs were generated for both programs and results were submitted for validation. The output generated has been judged accurate. This software package will possibly be modified and incorporated in future modeling efforts at AFGL/PHG.

DESCRIPTION OF IEMCAP*

The purpose of IEMCAP is to determine whether signals from one or more emitters entering a receptor port cause interference with the required operation of that receptor. Electromagnetic interference (EMI) is assessed in the program. This is done by computing "EMI Margin" for each receptor port. This EMI Margin is the ratio of power received at a receptor port to that receptor's susceptibility. The program computes the margin in decibels. The more positive the number in decibels the greater is the interference while the more negative the number in decibels the greater is the compatibility.

The program performs the interference analyses by exercising various programmed formulae corresponding the mathematical models of emitters, receptors, and the signal transfer mechanisms between emitters and receptors. The mathematical models of emitters and receptors in the program correspond to the required portion of their spectra. The program contains routines to compute the non-required spectra of emitters and receptors. These non-required spectra are initially based on the interference curves from military standards displaced in level by the user.

The following is a brief description of the software package provided. The first step in using IEMCAP is to assemble the appropriate data for the system to be analyzed on punched cards. This data is then fed into the Input Decode and Initial Processing Routine (DIPR) section of IEMCAP.

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* For additional information on the basic mathematical functions required, see Intrasystem Electromagnetic Compatibility Analysis Program, Volumes I and II, McDonnell Aircraft Corporation, December 1974, RADC-TC-34L.

The first section of IDIPR decodes the punched cards and checks for errors. If an error is detected a diagnostic message is printed, the card is deleted, and the program continues processing the rest of the data. The program normally stops after all data has been read if there were errors.

If there were no input card errors, the Initial Processing Routine (IPR) section of IDIPR is executed. For the first run of a system, the spectrum math models are accessed for each port. These models use the user-supplied spectrum parameters to generate the spectra. The processed user and spectrum data is written on a disk file called the Intrasystem File or Intrasystem Signature File (ISF). This ISF can be used as input for subsequent runs, either as is or modified by additional card inputs. Also, a new ISF can be generated containing the modifications. Thus, an updated ISF can be maintained for changes in system design. The data is also written on a number of working files for use by the Task Analysis Routine (TART) program of IEMCAP, and a printed report of the data is generated.

The TART section of IEMCAP performs four basic analysis tasks. These tasks are summarized below:

- Specification Generation - Adjusts the initial non-required emission and susceptibility spectra for system compatibility. The user-specified adjustment limit prevents too stringent adjustments. A summary of interference situations not controllable by EMC specifications is displayed. The adjusted spectra are the maximum emission and and minimum susceptibility specifications for use in EMC tests. Analysis results are stored on the Baseline Transfer File (BTF) for subsequent runs.

- Baseline System EMC Survey - Surveys the system for interference. If maximum EMI margin over the frequency range for a coupled emitter-receptor port pair exceeds the user-specified printout limit, a summary of the interference is printed. Total received signal into each receptor from emitters is printed. The results are stored on the BTF for subsequent runs.

- Trade-off Analysis - Compares the interference for a modified system with values stored on the BTF from previous run. This is to determine the effect on interference of antenna changes, filter changes, spectrum parameter changes, wire changes, or other changes.

- Specification Waiver Analysis - Shifts specified portions of specific port spectra and compares the resulting interference to that stored on the BTF. The effect of granting waivers for specific ports can be assessed.

TART is composed of two basic routines. The Specifications Generation Routine (SGR) which performs the first task above, and the Comparative EMI Analysis Routine (CEAR) which performs the other three. These access the coupling math model routines to compute the transfer ratios between emitter and receptor ports. The two parts of IEMCAP are executed separately with data files used for intermediate storage between parts. Central Processing Unit (CPU) core memory to load and execute each part of IEMCAP on CDC 6600 at AFGL are as follows:

IDIPR - 235K words (octal)

TART - 225K words (octal)

The program uses 4 permanent and 10 working files, in addition to normal card input and printed output. The permanent files are presently disk files at AFGL. For the working files, disk is used because of the number of files and large number of accesses per run. All files are sequential.

The amount of file space needed depends on the size of the system being analyzed. Except for the BTF, the size depends primarily on the number of ports. The size of the BTF depends on the number of coupled port pairs since it stores the analysis results.

The execution time also depends on the system size and analysis task desired. TART run time primarily depends on the number of coupled

port pairs. This potentially increases as the square of the number of ports. However, each emitter port is not generally coupled to each receptor port so the actual time will be less. Specification generation requires three passes through the emitters per receptor and two passes through the receptors per run and runs longer than the other tasks.

DATA STORAGE FILES

As discussed above, IEMCAP uses a number of data files. Each physical file and device is assigned a logical unit number which is stored in each section of the program as a mnemonic variable name. For example, on the CDC 6600 the card input is designated as logical unit number 5. In IDIPR and TART, the variable INN is set to 5, and all card input read statements reference INN. The logical unit numbers are assigned to files in the job control cards. Also, a number of files are assigned to the same logical unit. This allows multiple usage of the same physical file space.

The files are categorized as permanent, working and scratch. Permanent files are used to store data and analysis results for use in subsequent runs. Working or intermediate files provide temporary storage of the data for efficient use by the various routines. They also provide intermediate data storage between IDIPR and TART. Scratch files are used for temporary storage within IDIPR and TART.

The discussion in the paragraphs immediately following is a discussion of the system mathematical model employed in IEMCAP.

SYSTEM MATHEMATICAL BASIS

The basis for all calculations performed by each of the functions of IEMCAP is the linear relationship for power coupled from an emitter, through a transfer medium, and received by a receptor. The general communication theory equation relating power spectral density at the detector of a receptor to power spectral density present at an emitter's output port is expressed as follows:

$$PSD = \eta_{Sj}(f)\ T_{ij}(f)\ \beta_i(f) \qquad (1)$$

where

PSD = output power spectral density (in watts/Hz) received by receptor i (at its detector) from emitter j,

$\eta_{Sj}(f)$ = output power spectral density (in watts/Hz) at the terminals of source j (including cw power as delta functions),

$T_{ij}(f)$ = power transfer function of the coupling medium between source j and receptor i,

$\beta_i(f)$ = receptor response function relating power at the detector to power at the input terminals.

The broadband and narrowband components of the received power spectral density may be computed separately by considering the broadband and narrowband components of the output power spectral density of the source j. Thus, the power spectral density of source j is expressed as:

$$\eta_{Sj}(f) = \eta_{SNj}(f) + \eta_{SBj}(f) \qquad (2)$$

where

$\eta_{SBj}(f)$ = the broadband power spectral density of source j

and

$\eta_{SNj}(f)$ = the narrowband power spectral density of source j (composed of delta functions at the frequencies of the cw signals.)

22. Spectral Analysis

INITIATOR: T. Conley

PROBLEM NO.: 4865 PROJECT NO.: 7670

BACKGROUND

ASEC is currently generating software to:

1. Modify a real or synthetic digital input spectrum by an appropriate atmospheric transmittance function;
2. Convolve it with an instrument function;
3. Process and plot the resultant spectrum. The digital processing scheme provides the framework for comparison of synthetic spectra, infrared backgrounds, integrated measurements, and synthetic spectra generation models.

The following describes what has been accomplished to date.

ANALYSIS AND RESULTS

Convolution of two functions is an important operation in many scientific fields. In particular, this analysis of measured infrared spectra convolves the synthetic spectrum with an instrument function.

The convolution integral, which is the basis of the many convolution methods, is given by:

$$Y(t) = \int_{-\infty}^{\infty} X(\tau)\, h(t - \tau)\, d\tau$$

$$= X(t) * h(t)$$

That is, the convolution of the functions X(t) and H(t) yields the function Y(t).

The procedure for convolving by the integral method is as follows:

1. Take the mirror image of $h(\tau)$ about the ordinate axis.
2. Shift $h(-\tau)$ by the amount t.
3. Multiply the shifted function $h(t - \tau)$ by $X(\tau)$.
4. Area under the product of $h(t - \tau)$ and $X(\tau)$ is the value of the convolution at time t.

The general convolution limits are $-\infty$ to $+\infty$. It is desired to find the lower and upper limits so that they will contain limits of both functions. To do so, we choose the smaller of the two lower limits and the larger of the two upper limits. These two limits will give us the common least upper bound and greatest lower bound for both functions.

Applications of the Fast Fourier Transforms (FFT) in digital filtering, power spectrum analysis, simulation, etc., are based on a specific implementation of the convolution integral which employs the FFT as an approximation to the continuous Fourier transform. The FFT is simply a procedure for rapidly computing the discrete Fourier transform. It is advantageous to use the FFT in computing the convolution due to its tremendous increase in computational speed.

The FFT convolution of finite duration for the discrete case may be defined as follows:

$$Y(K) = \sum_{i=0}^{N-1} X(i)\ h(K - i)$$

where both X(K) and h(K) are periodic functions with period N. The discrete convolution, if correctly performed, will produce a replica

of the continuous convolution provided that both the functions X(t) and h(t) are of finite duration. Evaluation of the N samples of the convolution using the above equation requires a computation time proportional to N^2 (the number of multiplications).

Special care must be taken if the two functions have different periods or if at least one of the functions has unevenly spaced samples. Impulse functions are of the unevenly spaced type. It is important to make sure that the function being shifted can be evaluated for all values of the impulse function.

On Contract F19628-76-C-0203, ASEC developed a special routine to convolve such functions. The problem was to convolve the intensity function with an instrument function approximated by $((\sin X)/X)^2$.

In theoretical discussions the wave number $\nu = \nu^1/c = 1/\lambda$ is generally used. (λ is wave length of the spectral lines in the infrared; c is speed of light in a vacuum; $\nu^1 = c/\lambda$ is frequency). Wave number is proportional to the frequency and is measured in cm^{-1} (number of waves per cm). The frequency and wave number depend on the energy E according to Planck's relation $E = h\nu^1 = h\nu c$, where h is Planck's constant. According to the Maxwell-Boltzmann distribution law the number of molecules that have a classical vibrational energy between some E and $E + \Delta E$ is proportional to $e^{-E/kt}dE$ where k is Boltzmann's constant and T is the absolute temperature. In quantum theory, only discrete values are possible for vibrational energy. The number of molecules in each vibrational state is again proportional to the Boltzmann factor $e^{-E/kT}$. The zero-point energy can be left out.

The wave number ν of a spectral line can be represented as the difference between two quantities called terms. Terms are negative energy values divided by hC. They can be obtained empirically for the observed spectrum. The first term is always given by the wave number of the limit of the series of spectral lines in question. Often the word term is used interchangeably with energy state or quantum state.

In order to determine the total number of molecules N, one must consider that N is proportional to the sum of the Boltzmann factor over all states, i.e., the state sum of partition function.

The number of molecules in the state v is

$$N_v = \frac{N}{Q_v} e^{-G_o(V)hc/kt}$$

where

$$Q_v = 1 + e^{-G_o(1)hc/kt} + e^{-G_o(2)hc/kt} + \ldots.$$

and

$$e^{-G_o(v)hc/kt} = e^{-E/kt} \text{ for state v}$$

The probabilities of transition under the influence of radiation are determined by the eigenfunctions of the states involved. The intensities of the emitted or absorbed spectral lines can be determined. When the eigenfunctions are known one can calculate whether or not two states can combine with each other. Transitions that cannot occur are considered forbidden transitions.

The intensity of a spectral line in emission is defined as the energy emitted by the source per second. Given N_n atoms in the initial state and A_{nm} fractions of atoms in the initial state carrying out the transition to m per second then $I_{em}^{nm} = N_n hc\nu_{nm} A_{nm}$.

$hc\nu_{nm}$ is the energy of each light quantum of wave number ν_{nm} emitted in transition.

A_{nm} is the Einstein transition probability of spontaneous emission. The intensity of absorption is given by $I_{abs}^{nn} = \rho_{nm} N_m \beta_{mn} \Delta x hc\nu_{nm}$ where N_m is the number of atoms per cm^3 in the lower state m and β_{mn} is the Einstein

transition probability of absorption. $\rho_{nn} N_m \beta_{mn}$ represents the number of transitions per cm^3 per second produced by incident radiation, ΔX is the thickness of the layer. For this task we were primarily interested in the absorption intensities.

In the software the partition function values were computed using the given equation,

$$Q_V(T) = \sum_{J=.5}^{15.5} (2J + 1) \text{ EXP } \left[\frac{-HC}{KT} E_V(J)\right]$$

$E_V(J)$ = rotational energy

where

$H = 3.3356 \times 10^{-11}$ cm^{-1} sec (Plank constant)

$C = 3 \times 10^{10}$ cm/sec (speed of light)

$K = 6.95 \times 10^{-1}$ cm^{-1} $°K^{-1}$ (Boltzmann constant)

$T = 220°K$ (Temperature)

$E_V(J) = J(J + 1)B_\upsilon$, where B_υ is an array of constant values corresponding to molecules of interest

J = total angular momentum (rotational level)

Second, intensities were computed by:

$$N(J, V) = N_V \frac{(2J + 1)}{Q_V(T)} \text{ EXP } \left[\frac{-HC}{KJ} E_V(J)\right]$$

where N_V is an array of population values.

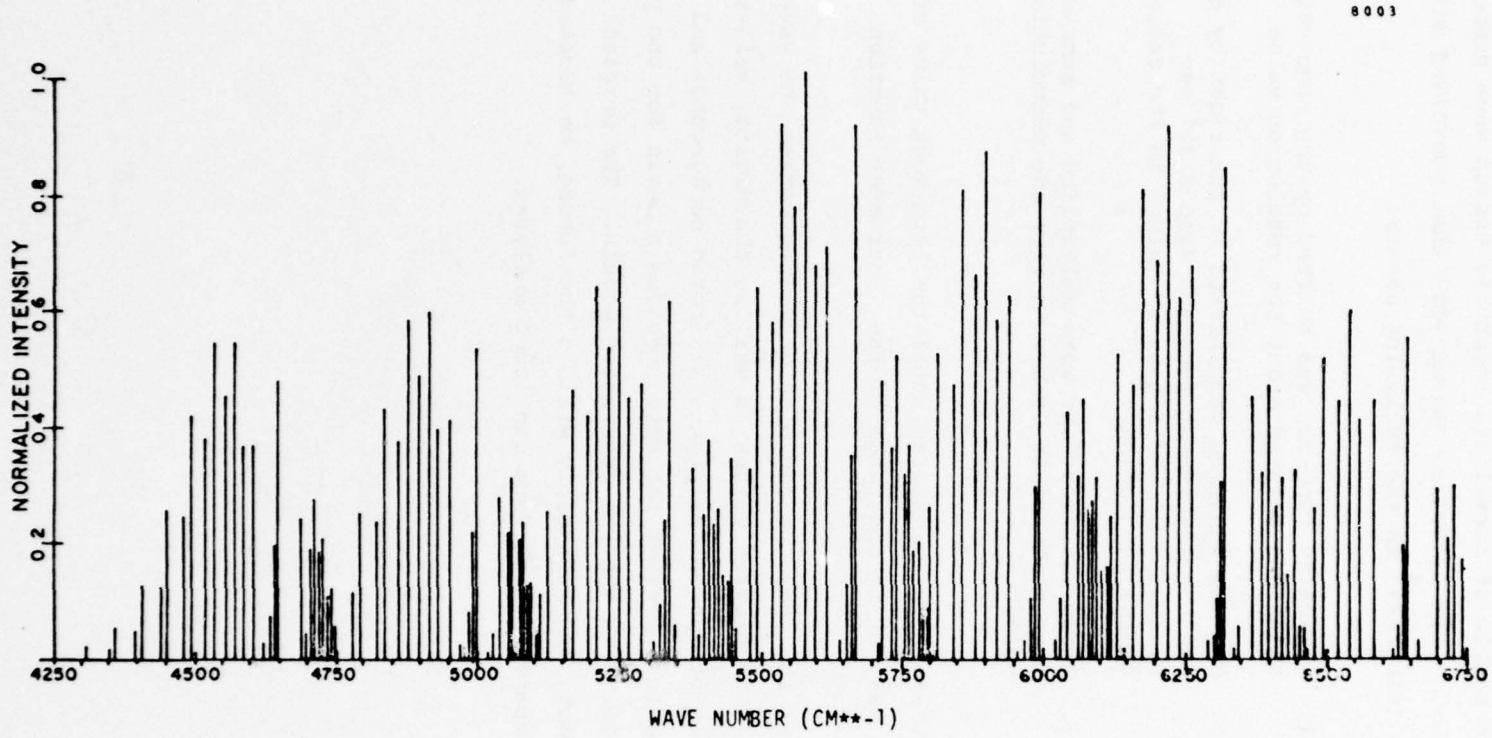

Figure 22-1 Plot of Normalized Intensity Versus Wave Number

A sample of normalized intensity versus wave number is given in Figure 22-1. The intensity values were then convolved with the instrument function $(\sin X/X)^2$ in the following manner:

1. Intensity function was shifted by the resolution value and rotated about the resolution value.

2. The new function was shifted to the right by dX and the instrument function $(\sin X/X)^2$ was evaluated at the intensity values in the range of the resolution.

3. These two functions were multiplied and summed over the product values to give one convolution value.

The above steps were repeated until the left-most value of intensity function was out of the range of the instrument function.

At the end, the convolution values versus the wave number were plotted. The plotted values as well as the digital values are used in comparison of synthetic spectra, infrared backgrounds and integrated measurements. Present software provides a basis for the presentation of the synthetic spectra generation models. The original software has, in the past, and presumably will in the future, be adopted, modified and/or expanded to perform continued analyses.

23. Signal Statistics Of Scintillation

INITIATOR: H. WHITNEY

PROBLEM NO: 4893 PROJECT NO: 4643

BACKGROUND

F-layer irregularities in the ionosphere can cause variations in radio signals which traverse a disturbed region of the ionosphere. These signal variations are known as ionosphere scintillations. Performance of satellite communications at UHF will be affected when scintillations exceed the fade margin. The effect is most noticeable when propagation paths cross through the auroral and equatorial ionosphere.

Ionosphere scintillation data are being analyzed by ASEC on the current contract. Software was written and digitized data tapes were processed. The results were used for comparison with those of earlier studies. The digitized sampling rate of the data was varied from six samples/second to 36 samples/second to determine the effect on the analysis.

ANALYSIS AND RESULTS

Data from Peru is being used for this study. The signal amplitude from satellite beacons was recorded on FM analog tape and then digitized. Calibration of equipment was accomplished and recorded prior to and subsequent to acquisition of data. Computer programs were written to convert the digitized values into readable form by taking the data values from the original tape and writing them out on another tape in CDC 6600 format words. The original tapes contain both calibration files and data files.

After the data was written onto CDC tapes, the calibration files are used to convert the digitized data into signal amplitudes in dB. All dB numbers are negative, with 0 as the maximum. The dB values are written

onto magnetic tapes for permanent storage, and onto permfiles for use with the analysis programs.

Data was originally analyzed in 15-minute intervals. In addition, the cumulative distribution was calculated on 1.5-minute intervals, as well as for 15-minute intervals, to determine if a shorter interval size is more representative of broad changes in the data. Plots of the data were obtained for each 1.5-minute interval (Figure 23-1) and for cumulative amplitude distribution (Figure 23-2).

Software used for the analysis represents a combination of both totally new routines and adaptation of existing ones. A program was written to calculate a number of different statistical relationships for the given scintillation data. First, the data in dB levels, is plotted on a graph, giving dB versus time in seconds, for each channel.

Second, the autocorrelations of data in power are found for each channel, for 0 - to 16-second time lags, at intervals of $\Delta\tau = 1/6$ second. The dB levels (D_i) are converted to power (W_i) by using the conversion formula:

$$W_i = 10^{(10\ D_i)}$$

These autocorrelations are plotted versus time lag. The subroutine FTAUTO is used to find the autocorrelations, with the formula:

$$AC_j = \frac{1}{N} \sum_{i=1}^{N-J} \frac{(W_i - \bar{W})\ (W_{i+j} - \bar{W})}{\sigma^2}$$

for the Jth autocorrelation. ($\bar{W}$ = mean of time series W, σ^2 = variance of W).

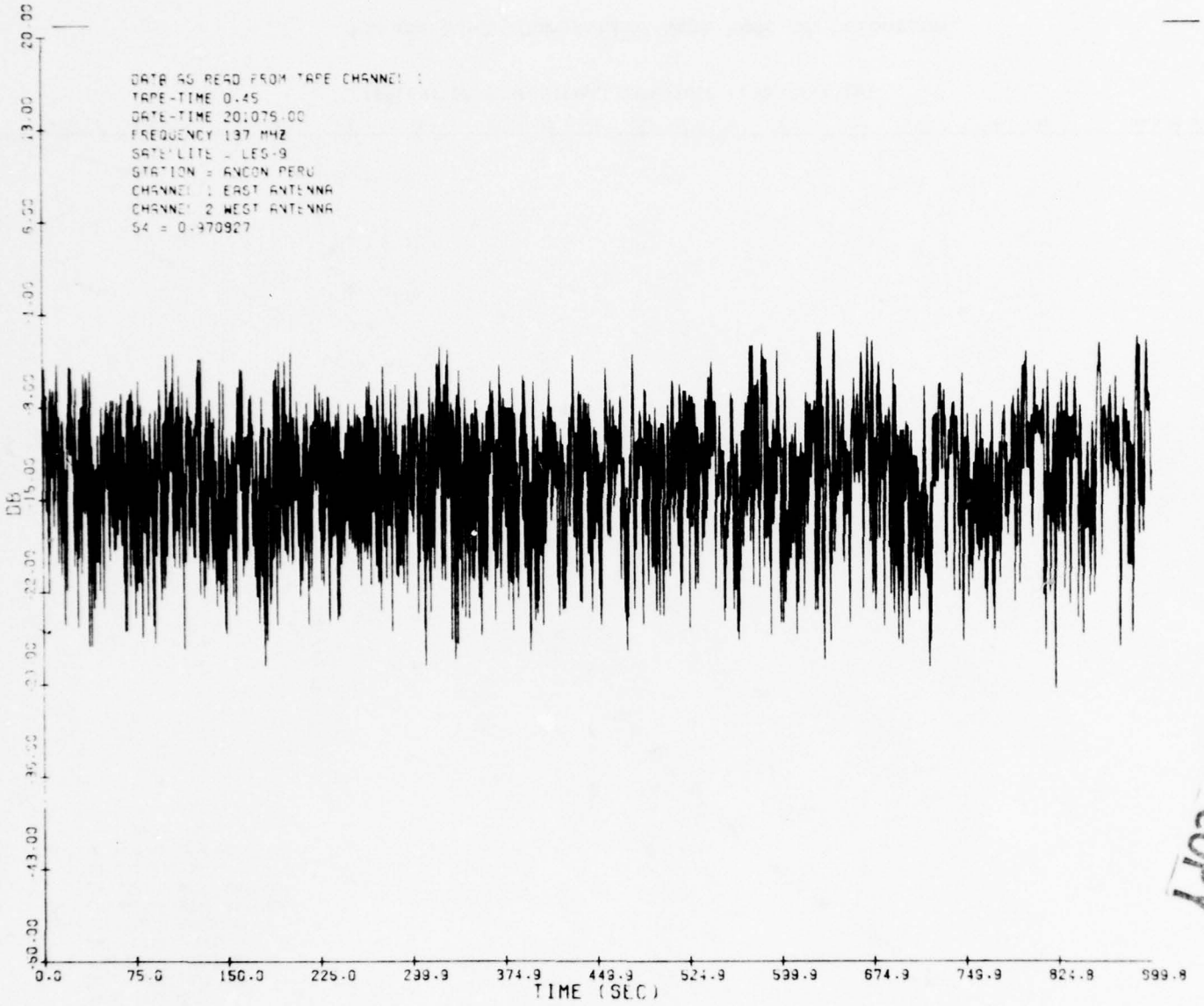

Figure 23-1 Sample Peru Data

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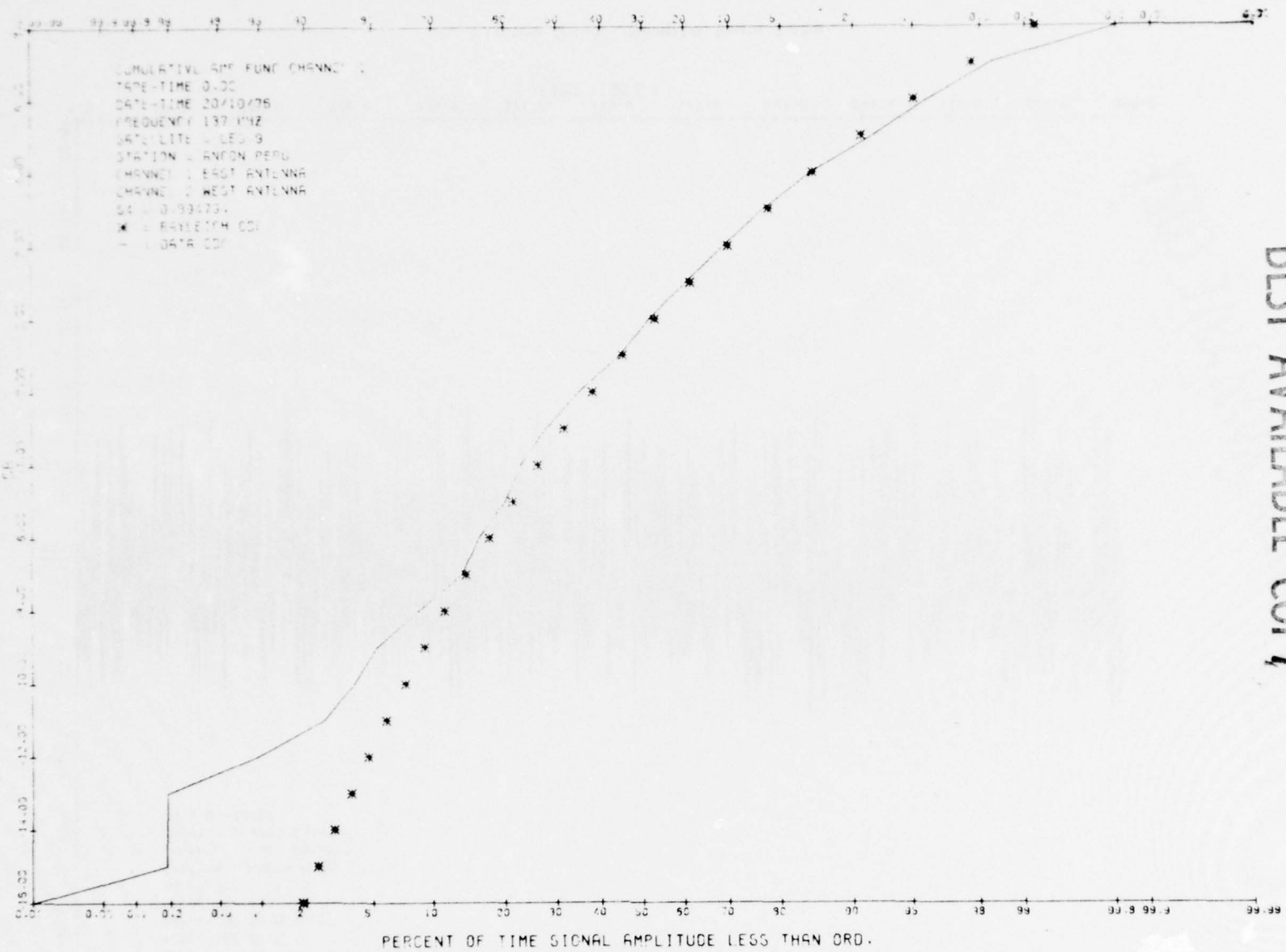

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Figure 23-2 Cumulative Amplitude Distribution

Figure 23-3 is a sample of the autocorrelation coefficients plotted with respect to the correlation interval for the first 16 seconds. Autocorrelation coefficients greater than or equal to 0.0 are printed together with their corresponding lag times. The program for calculating the coefficients first evaluates the mean of the data value $\bar{X}$ and the variance σ^2 before computing the coefficients AC.

The autocorrelation is a method of characteristizing the rate of scintillation fading. The width of the autocorrelation is inversely related to the variance of the data. Large variations at a fast rate will produce a short width in the autocorrelation function.

A third routine for this analysis calculates the crosscorrelation between the data in power of the two channels for time lags of 0 to 1 minute, with channel 1 leading for the positive time lags and channel 2 leading for the negative time lags. The subroutine uses the formula:

$$CC_j = \frac{1}{N} \sum_{I=1}^{N-J} \frac{(X_i - \bar{X})\ (Y_{i+j} - \bar{Y})}{\sqrt{\sigma_x^2\ \sigma_y^2}}$$

for the Jth crosscorrelation. ($\bar{X}$, $\bar{Y}$ are the means of the two time series; σ_x^2, σ_y^2 are the variances.) The crosscorrelations are calculated by calling the crosscorrelation routine twice, first with channel 1 in the data array, the second time with channel 2 in the array. The first value in the output array, AC, is the crosscorrelation at time lag zero; this value is plotted in the center of the graph. The other time lags are plotted to the right (positive time lags, channel 1 leading) and to the left (negative time lags, channel 2 leading).

The cross correlation function is shown in Figure 23-4 for time lags of up to 1.5 minutes with first one time series leading the other, and vice versa. The maximum crosscorrelation coefficient is printed out.

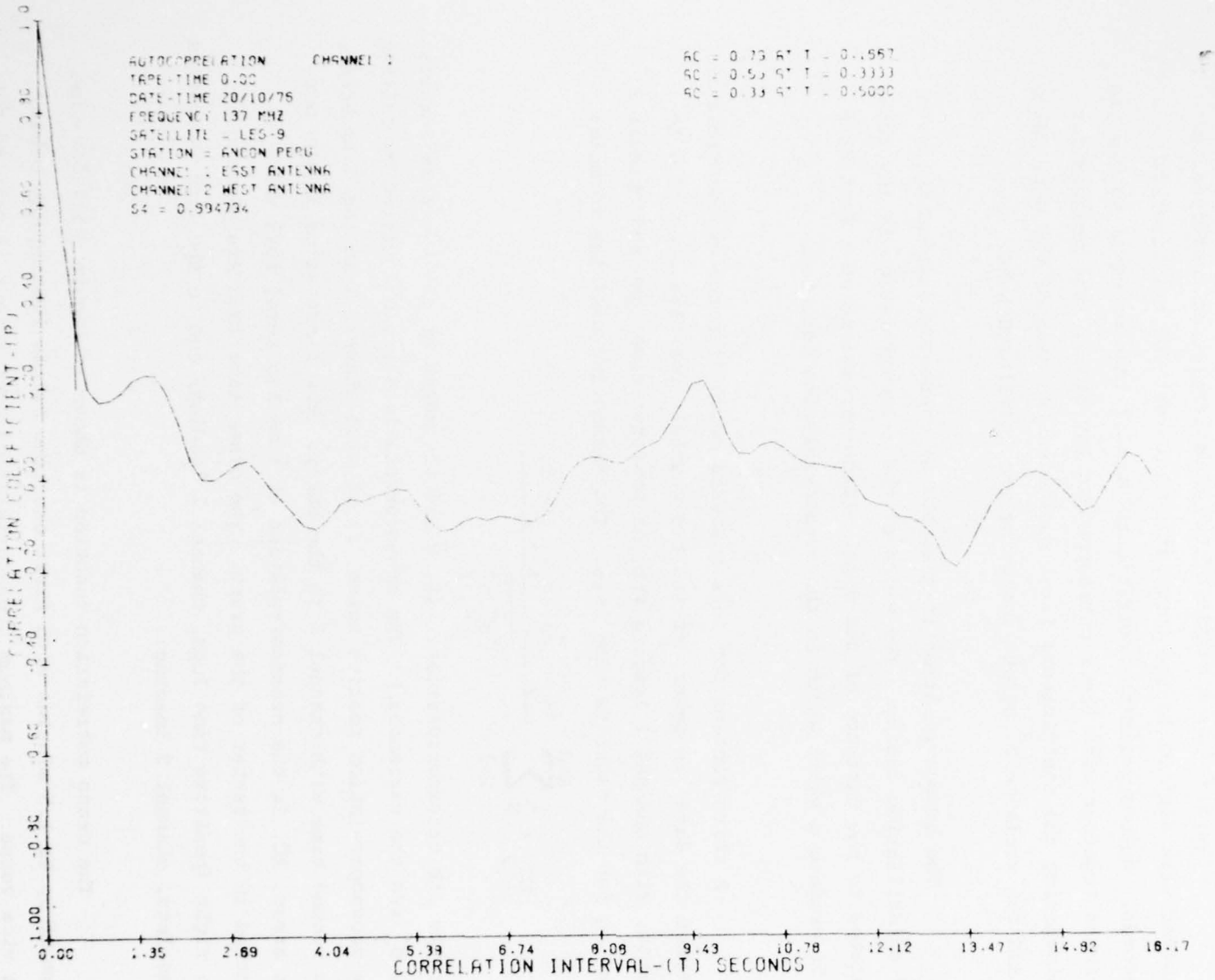

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Figure 23-3 Sample Autocorrelation Plot

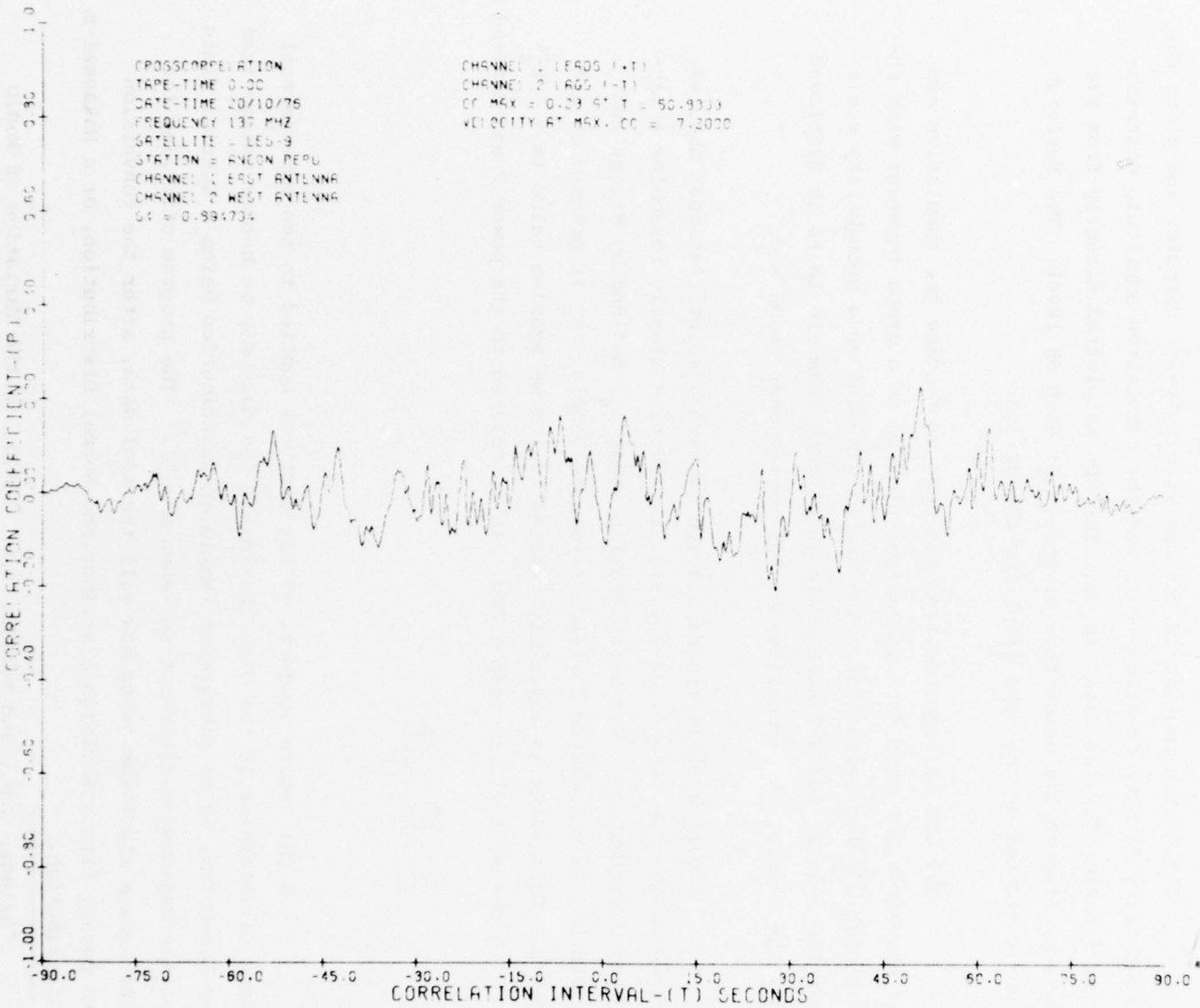

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Figure 23-4 Sample Crosscorrelation Plot

The fourth routine in the analysis software computer and plots the probability density function (PDF) and the cumulative amplitude distribution function for the data, in dB. The PDF is plotted directly from the data by finding the percentage of points at each dB level. The Rayleigh PDF is plotted on the same graph for comparison.

The CDF is computed from the data by finding the cumulative sum of the PDF's for each dB. It is then plotted on a graph together with the Rayleigh CDF for comparison. The graphs are done on a probability scale for the X-axis, and a linear scale in dB only from -16 to +8 is displayed for the Y-axis. A probability of 50% corresponds to dB = 0.

Figure 23-1 is representative of strong scintillations; and, as shown by the CDF (Figure 23-2), its distribution closely resembles a Rayleigh Distribution. The scintillation index S_4, defined by Briggs and Parkins[1], is calculated for each 15-minute sample. S_4 is printed on all plots. This value is inversely related to the Nakagami-m value ($m = 1/S_4^2$) and is the most widely used index. It is related to the power P and defined by

$$S_4^2 = \frac{\bar{P}^2 - \bar{P}^2}{\bar{P}^2}$$

A Chi-Square goodness of fit test was applied to the experimental data to determine if the distribution of the data may be better categorized as Log-Normal or as Nakagami-m (Rayleigh Distribution being a special class of the Nakagami-m distribution, when m = 1).[2] The program utilizing the Chi-Square algorithm tests how well the real data, after the conversion to power, fits a Rayleigh Distribution, Normal Distribution, or a Nakagami-m distribution.

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[1] Briggs, G.H., and Parkin, I.A. (1963), On the Variation of Radio Star and Satellite Scintillations with Zenith Angle, J. Atms. Terr. Phys., 25:pp. 330-366.

[2] Nakagami, M (1960), Statistical Methods in Radio Wave Propagation, edited by W.C. Hoffman, PP. 3-36, Pergamon, New York.

The real data is compared with a theoretical distribution function. The probability that the data represents that particular distribution is calculated. The theoretical distribution function is supplied by the user. Equi-probable cells are set up, and the number of data points which fall into each cell are counted. The expected value of each cell is compared with the actual value of each cell, and the differences are saved. The sum of the differences is used to calculate the Chi-Square statistic, which is then used to find the probability that the real data fits the theoretical distribution. This particular application uses 25 equi-probable cells, with 22 degrees of freedom. The steps in the Chi-Square test are as follows:

(1) Determine k, the number of cells

(2) Determine the hypothesized distribution, F(X)

(3) Find the values of X_i such that if the true distribution is F(X) then

$$F(X_{i+1}) - F(X_i) = \frac{1}{k}$$

where

$$X_o = -\alpha, \quad X_k = \infty$$

X_i determines the k cells

(4) Calculate the number of observation in the cells called N_i, for i = 1, ..., k

(5) Compute the Chi-Square statistic

$$\bar{X}^2 = \Sigma(N_i - n/k)^2/(n/k)$$

(6) If F(X) is the correct distribution $\bar{X}^2$ has a Chi-Square distribution with k - 1 degrees of freedom.

When F(X) has estimates rather than the actual parameter the distribution of $\bar{X}^2$ is Chi-Square distributed with K - m - 1 degrees of freedom when F(X) is the true distribution.

The results of the Chi-Square goodness of fit test are printed out, along with the mean, the median, the Nakagami-m, the moments, S_4, B_1, B_2, M_1, M_2, M_3, M_4, and the values of the CDF function.

$$M_k = \frac{\sum_i (y_i - \bar{y})^k}{n} = \text{moments}$$

$\bar{y}$ = mean of data

y_i = data points

n = number of data points

$\sqrt{B_1}$ = skewness

$$\sqrt{B_1} = \frac{M_3}{(M_2)^{3/2}}$$

B_2 = Kurtosis

$$B_2 = \frac{M_4}{(M_2)^2}$$

A fifth program calculates the power spectrum, which is a fast Fourier transform of the power levels of the input data. The output is plotted on a semi-log graph, on which the Y-axis is linear in dB values, and the X-axis is logarithmic in frequency values. The ith frequency is calculated using the formula

$$F_i = \frac{i}{2N\ (\Delta\tau)}$$

where N = number of values in the power series, and $\Delta\tau$ = sample rate in seconds. Optionally, the data series may be split into N shorter segments, for each of which the spectral computations are made separately. The N spectra are then averaged. For most of the analysis N = 1, so that there is only a single segment to accomodate an entire input series. The number of terms in that series must be a power of 2. If this is not the case, the

excess is zero-filled, up to a maximum, which in our present case is 8192 words. The equation for the power spectrum is

$$PS_i = \frac{\Delta\tau}{N} \quad (X_i^2 + X_i^2 + 1)$$

where PS_i = the ith value of the power spectrum, $\Delta\tau$ = sample rate, N = the number of points, X_i = power series value. A ten-point running average is taken on the spectral values, after which they are converted back to dB values for plotting.

Figure 23-5 is a sample of a power spectrum. Various data windows and segmentation may be applied to smooth the incoming signal in order to obtain more information for future detailed analysis. However, here neither course was taken. We chose instead to take a ten-point running mean of the power spectra values after they were computed.

The power spectrum is a useful way of characterizing the rate of scintillation fading. For strong scintillations, the power spectrum is relatively flat at low frequencies and exhibits a roll-off at higher frequencies. The cut-off frequency denotes the bandwidth of the process. This parameter is related to the inverse of the width of the autocorrelation. Autocorrelations which have relatively large widths will reflect in the power spectrum large bandwidth with no cut-off frequency or roll-off. The power spectrum will then appear to contain only one measurably slope.

There is a control card, read in at the beginning of the program, which controls the sections of the program. The first ten columns in the card are assigned to ten control words. A 0 in a column skips the corresponding part of the program; a non-zero directs action to be taken. The items controlled are as follows:

Column 1: plot data, channel 1.

2: plot data, channel 2.

3: calculate and plot autocorrelations, channel 1.

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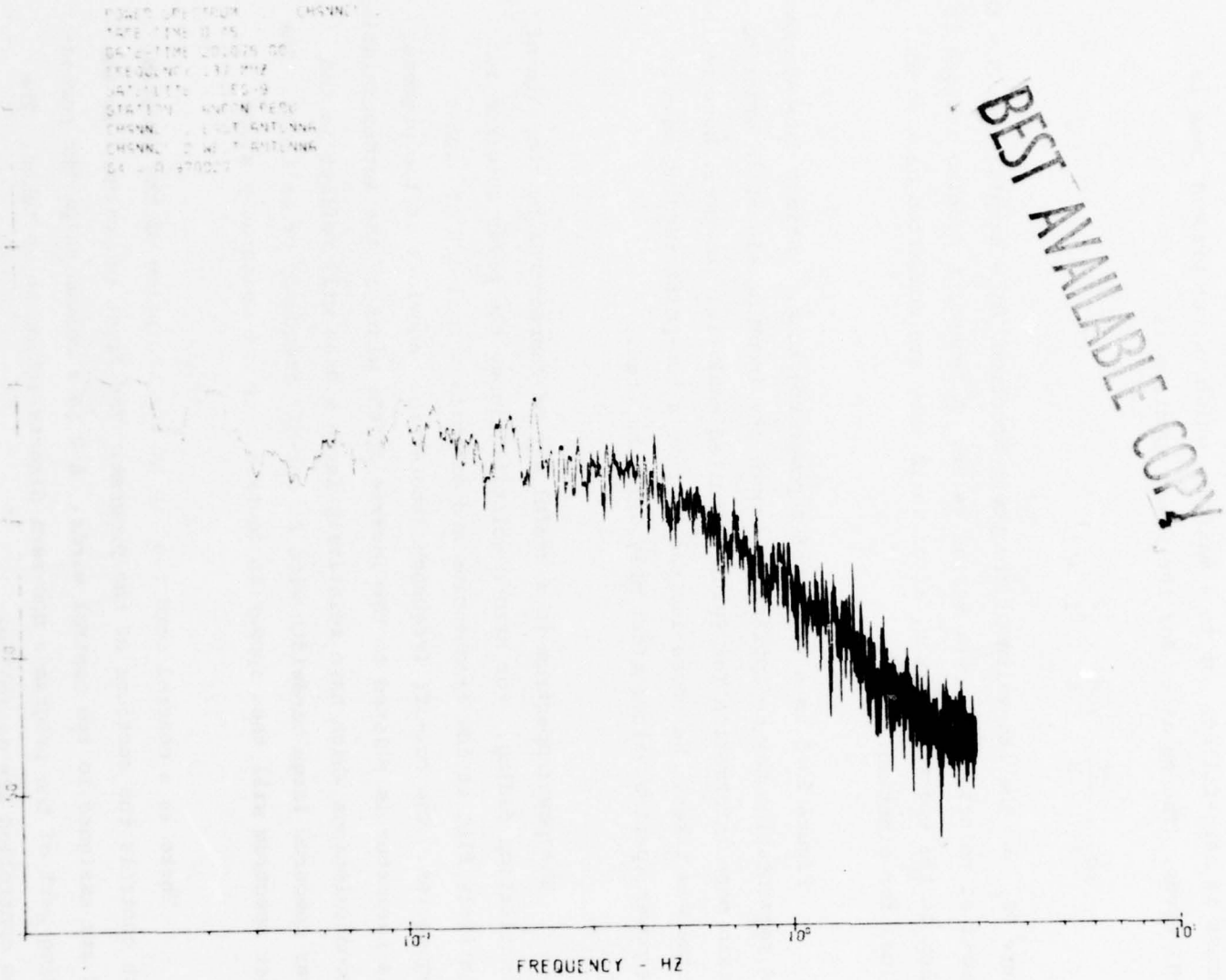

Figure 23-5 Sample Power Spectrum

4: calculate and plot autocorrelations, channel 2.

5: calculate and plot crosscorrelations.

6: calculate and plot power spectrum, channel 1.

7: calculate and plot power spectrum, channel 2.

8: calculate PDF and CDF, channel 1 and print, along with results of Chi-Square test.

9: calculate PDF and CDF, channel 2 and print, along with results of Chi-Square test.

10: plot PDF and CDF.

Presently a separate program is being used to calculate eight different values which are used to analyze the data. The values can be computed for either 1-1/2 minute segments or 15 minute segments. They are printed out at the end of the program, first for channel 1 and then for channel 2. The eight values are: the median of the data (in dB); the mean of the power; S_4; Nakagami-m; the time for which the autocorrelation first is equal to or less than 0.5; the maximum crosscorrelation; the time for which the crosscorrelation is at a maximum; and the velocity, i.e., 366 meters/time of maximum crosscorrelation. The autocorrelation and crosscorrelation are calculated from power levels. This program will be incorporated into the main program.

From the observed signal levels, the amplitude and rate characteristics of intense scintillations were analyzed. It can be seen from the distribution that the data closely resemble a Rayleigh distribution which is a special case of the Nakagami-m distribution for m = 1. The autocorrelation and power spectrum define the fading rate and give a basis for evaluation of different data. The crosscorrelation gives a means of evaluating space diversity at similar frequencies. Confidence bands are included to give credence to the reliability of the results. Also to be determined are (a) the effect a different digitized sampling rate would have on the results, and (b) the optimal time interval of analysis. Additional data exists at present and more data is being obtained. To obtain this analysis, all data will be processed; and tables of the output will be assembled along with plots for comparison of data.

24. Error Analysis of Turbulence Parameters

INITIATOR: E. MURPHY

PROBLEM NO: 4889 PROJECT NO: 6687

BACKGROUND

Seven years of rocket grenade data (winds and temperature), representing 153 measurements from four sites at different latitudes, have been collected. This data has been analyzed statistically to provide probability of occurrence models for turbulence and average value of turbulence parameters as a function of latitude, altitude, and time of year. The experimental errors are available for the wind velocity and temperature data used. Equations or expressions which use temperature and component winds and their derivatives were supplied along with the data and the experimental errors.

ANALYSIS AND RESULTS

The following equation is used to determine the Richardson number (R_i). The Richardson number is the basis for the criterion for the presence or absence of turbulence.

$$R_i = g\left[\frac{\partial T}{\partial Z} + \Gamma\right] / T\left[\frac{\partial u}{\partial z}\right]^2$$

where g = the gravitational value at the latitude - assumed to have negligible error

Γ = dry adiabatic lapse rate which is a generally accepted constant (9.8° k/km)

The remaining parameters (T, $\frac{\partial T}{\partial Z}$ and $(\frac{\partial V}{\partial Z})^2 = (\frac{\partial V_X}{\partial Z})^2 + (\frac{\partial V_Y}{\partial Z})^2$) are obtained from the grenade data using a spline fit which provides the temperature, temperature gradient ($\frac{\partial T}{\partial Z}$), and the wind component gradients ($\frac{\partial V_X}{\partial Z}$ and $\frac{\partial V_Y}{\partial Z}$) at the desired altitudes.

When $R_i \leq .25$, turbulence is considered present and turbulence parameters are calculated using the following relations.

$$\frac{W'}{|V|} = \alpha(R_i)^{1/2} + b$$

where

$$\alpha = \begin{cases} +0.15 \text{ for } R_i > 0 \\ -0.15 \text{ for } R_i < 0 \end{cases}$$

$b = 0.08$

V = wind speed

$$N = \left[\left| (g\frac{\partial T}{\partial Z} + \Gamma)/T \right| \right]^{1/2}$$

$$\varepsilon = \frac{2(W')^2 N}{3} \quad \text{rate of dissipation of KE}$$

$(W')^2$ = turbulent intensity

$$K_w = C\frac{\varepsilon}{N^2} \simeq \frac{W'^2}{N} \quad \text{turbulent diffusivity}$$

These parameters are calculated and averaged. They assume a value of zero when there is no occurrence of turbulence.

The first concern was to provide meaningful expressions for the errors in the turbulence parameters (rate of dissipation of kinetic energy, turbulent diffusivity, and turbulent intensity), and to display these results using the CALCOMP plotter. Standard deviations were calculated for the turbulence parameters, the Richardson numbers, and also for temperature and component winds. In addition, software was written to introduce maximum error into the calculations. This was done by applying the errors to the wind and the temperature data in such a way as to produce the greatest errors in a spline interpolation, and therefore in the Richardson number. Twenty-five combinations of errors were calculated.

The standard deviations and maximum errors were incorporated into plots of the turbulence parameters. A plot was made for each parameter for each latitude for each of three seasons (winter, summer, annual), with the corresponding standard deviation at ten kilometer intervals. For the plots of the Richardson number, the standard deviation was not necessarily used. Since the maximum possible error was to be displayed, the greater of the standard deviations or the experimental errors was used. Plots were also made of the worst possible case for each latitude.

After the calculation of the turbulence parameters had been done on a summer, winter and annual basis, further breakdown was done for one location. There was enough data from Wallops Island to have statistically significant results if done seasonally. The data was run for four time periods corresponding to four seasons.

Additional data was obtained in an effort to verify the results obtained for the four latitudes. Another set of data from a latitude close to that of Wallops Island was used. However, the results were not as expected. Originally, the discrepancy was attributed to the presence of high mountains near the new site which could have created disturbances. Consultation with the originator of the data revealed that two different models were used to reduce the data, one for higher altitudes and one for lower altitudes. This data was discarded and additional data requested. This sequence is reported to indicate that there have been problems in the past with the data base. Care must be taken in the interpretation of results obtained from the data available.

Another comparison was attempted with additional data, predominantly low altitude. This data was available for altitudes between twenty and sixty kilometers for two locations. One location was Wallops Island. Hence there was an overlap with existing altitude data from that site. The other location was Ascension Island which has a latitude similar to that at Natal. (Data from Natal had been previously processed and analyzed.) When these two data sets were processed, no occurrences of

turbulence were found despite the fact that some instances appeared at the low end of the high altitude data. There are two possible explanations for these results. First, and most likely, is that since this data was smoothed, the smoothing process masked or eliminated the data which would have resulted in turbulence. The second possibility is that the higher altitude data was incorrect since it was at the low end of its range. Subsequent investigation indicates that the smoothing done was minimal and that is probably did not significantly affect the data.

Additional plots were requested and generated for this task. The previously plotted turbulence parameters were put through a modified version of an existing interpolation routine to provide a smoothed least squares fit of the data. These plots also displayed the weighting factor, or number of data sets on which the point was based, next to the point. Further, plots of the wind components were made. There were several methods used in displaying the wind components.

The first set of plots showed the wind components for all experimental shots plotted together. These showed what was anticipated: namely that the east-west component exhibited a fairly constant value over all altitudes; whereas, the range of the north-south component increased with increased altitude. All latitudes showed this phenomenon, with the results from Natal being the most pronounced.

Other plots were made of the wind components. Each shot was plotted alone with a ten point running average. Then, the average was subtracted from the component and the result plotted. A program was also written to produce histograms of the wind components. This was done to determine whether the distribution of the wind follows a normal distribution. Further processing and analysis is anticipated on this task.

Many of the results and plots from this effort were presented at a NATO conference in April 1977. Additional results and plots will be published shortly.

Additional high and low altitude data for 1969-1975 has been received and is being processed. The high altitude tapes have been read and processing will be performed. The results of this initial processing will determine what further processing will be done. The preliminary reading of the low altitude data is currently underway.

25. Ionospheric Mapping

INITIATOR: C. RUSH

PROBLEM NO: 4927 PROJECT NO: 7663

BACKGROUND

The objective of this effort is to determine the accuracy of current recommended techniques for forecasting and specifying ionospheric parameters. Predicted f_oF_2 values will be compared with observed data. Measured monthly median (hourly) ionospheric parameters are available from various locations around the world. Tapes of these data have been prepared for analysis. Once the accuracy of the world-standard has been evaluated and described as a function of local time, season, solar cycle, and geographical location, it will be possible to improve upon the forecasting accuracy of the original computations by incorporating corrections based on the measured data.

This task is not completed. This following is a summary of what has been accomplished and what additional work is needed for the future analysis.

ANALYSIS AND RESULTS

Specific tasks being undertaken are:

Task 1. Sort each tape according to month (original tape arranged according to station). Retain only the values associated with the f_oF_2 values. Four tapes have been processed, and two additional tapes have been submitted for processing. During preparation of the data tapes for processing, numerous errors have been detected on the tape. Data records are missing. To provide for a "clean data tape" for the analysis program, dummy records were added.

Header records are missing. For this case the site, its coordinates, etc., are being obtained from tables supplied; and this information is being added to the data on the tape. This information, header and data records, have been added to the four tapes already sorted. The other two tapes will be supplemented with the information and processed.

Further, problems have occurred with the reading of one of the data tapes supplied. The source of the data, National Bureau of Standards, was contacted. It became apparent that the tape sent was mislabeled. NBS agreed to send another tape replacing the original one.

Task 2. Provide a listing, by month, of stations from which data are available. The four tapes mentioned previously have been listed. Data has been listed for the years, 1970, 1972, 1973, and 1974. After the preparation of the data tapes additional data will be available for 1966 and 1971.

Task 3. For each month (and appropriate sunspot number) compute the difference, for each hour, between the observed median f_0F_2 and that predicted using the coefficients contained in the modified "ITS Model" that is currently being used in the ISIS 2 analysis. Record the difference between observation and prediction, together with the number of observations that went into the computation of the median. Software has been developed to perform this task. Again four tapes have been prepared for future analysis.

Task 4. Arrange the output on a tape so that the following can easily be obtained:

a. Plots of differences for a given station-month as a function of time - 24 values for each of the 24 hours.

b. Values of differences (or differences squared) placed at the appropriate station coordinates (or geomagnetic coordinates) for each hour of local mean or universal time. This is equivalent to placing individual values of the differences at the appropriate locations on a global map.

c. RMS values of differences computed from specified grouping(s) of stations.

Figure 25-1 illustrates the geographical distribution of the stations supplying data for a particular month. This plot shows that data is available from locations around the world. (It was not intended to be accurate within each 15° x 15° block. An "X" does not indicate exact location. Rather an X indicates a site is located within the block, two X's indicate two sites within the block.) After analyzing the distribution of sites it was decided:

1. Not to perform a computer contour interpolation, at present. This is because there is no information for ocean areas.

2. To determine relationships between sites within blocks. That is, determine if differences between predicted and observed f_oF_2 for sites relatively close to each other can be modeled by using only one site.

The analysis will continue by developing software to plot on a Mercator projection at the site locations:

1. The difference between predicted and observed f_oF_2 for all sites for the hours 00, 03, 06, ... local time and

2. The difference between predicted and observed f_oF_2 for all sites for the hours 00, 03, 06, ... universal time.

A plot will be produced for each hour/month combination. Characters will be displayed to indicate a range of differences. This effort is a subtask of Task 4 described previously. Table 25-1 is representative of the data, both predicted and observed.

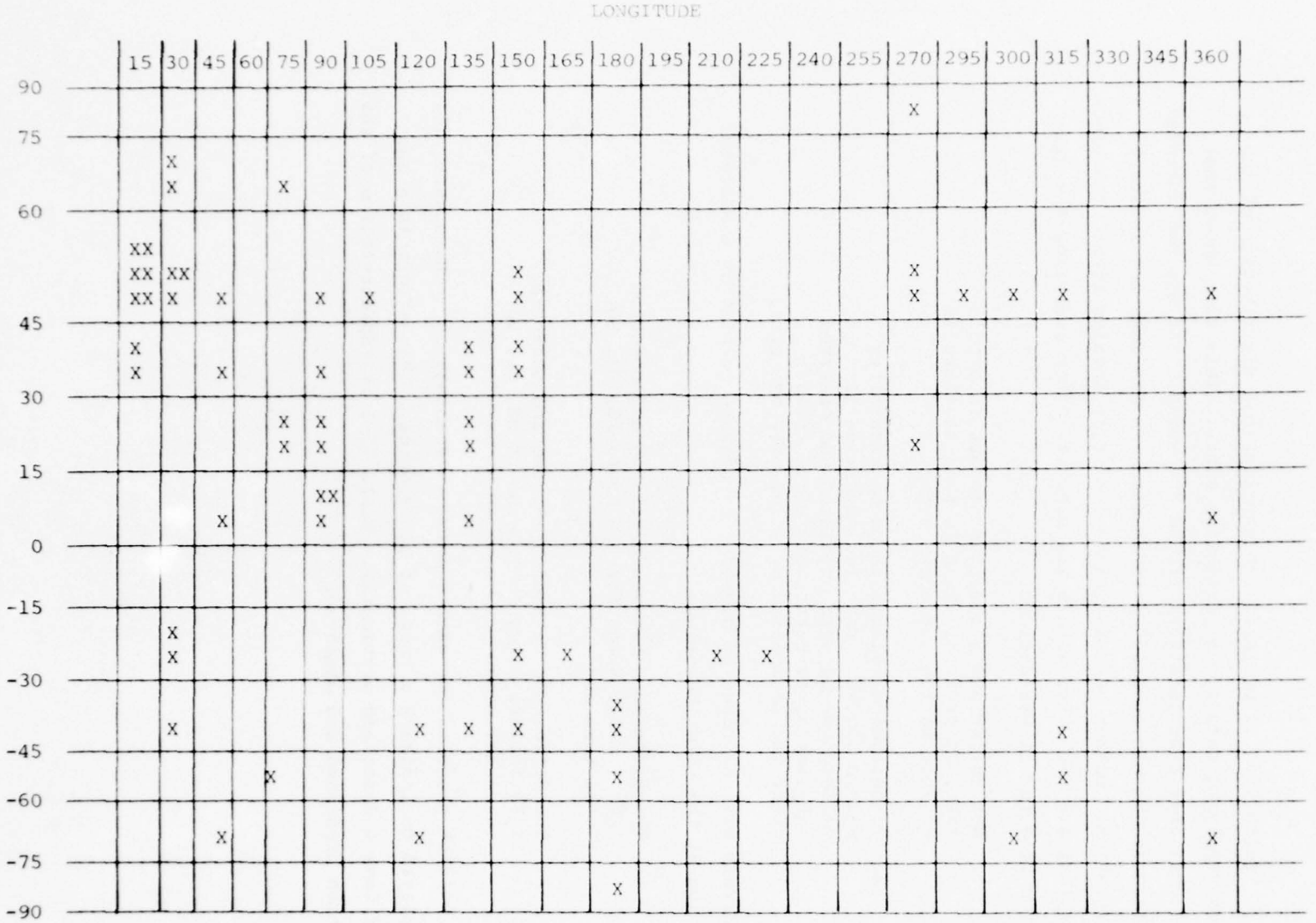

Figure 25-1 Distribution of Observing Stations

TABLE 25-1

SAMPLE f_oF_2 DATA

SITE BOULDER, COLO, DAY 350		40 N. LAT 254.70 E. LONG. SUNSPOT NUMBER 55.10	
HOUR	OBSERVED	PREDICTED	DIFFERENCE
0	2.7	2.8	-.1
1	3.0	3.1	-.1
2	3.1	3.3	-.2
3	3.3	3.3	0
4	3.2	2.9	.3
5	3.0	2.6	.4
6	3.1	2.8	.3
7	3.9	3.9	0
8	6.0	5.5	.5
9	6.7	6.9	-.2
10	6.9	7.8	-.9
11	8.3	8.2	.1
12	8.7	8.6	.1
13	8.6	8.9	-.3
14	8.2	8.7	-.5
15	7.9	8.2	-.3
16	7.2	7.3	-.1
17	5.6	6.1	-.5
18	3.9	4.8	-.9
19	3.2	3.8	-.6
20	2.6	3.2	-.6
21	2.4	2.8	-.4
22	2.3	2.6	-.3
23	2.5	2.6	-.1

26. Correlation Studies For The Prediction Of Scintillation And Total Electron Content

INITIATOR: J. AARONS

PROBLEM NO.: 4918 PROJECT NO.: 4643

BACKGROUND

ASEC has been involved with a task whose purpose is to determine if scintillation and total electron content (TEC) at a station can be predicted from the scintillation and/or TEC at another station. The aim is to find forecasting tools for AWS in problems of radar corrections and in irregularity formation. Specifically, the first subtask is to develop a series of programs to calculate correlation functions in support of scintillation studies for AFSATCOM and total electron content studies in support of ADCOM and GPS.

The material for the studies consists of series of values of scintillation indices and of total electron content values. The volume of data extends over several years and consists of measurements for many satellites and for several locations. Basically, correlation functions (auto and cross) for these 15-minute indices are required as a first approach in the analysis.

Previous studies have addressed and documented a high latitude model of scintillation excursion based on observations of the scintillations of beacons from synchronous satellites.[1] Equations have been developed to predict scintillations as a function of local time, magnetic index, solar flux, and month of the year. Other studies have shown clear seasonal maximum of the occurrence of equatorial scintillations. Diurnal

[1] "A High-Latitude Empirical Model of Scintillation Excursions: Phase I", Jules Aarons et al, 17 September 1976, AFGL-TR-0310.

occurrence of scintillation peaks before midnight for both quiet and magnetically disturbed days.[2] Based upon these studies and others, it appeared possible to predict scintillation and total electron content at a station, given knowledge of scintillation and/or TEC at another, spatially separated station. Consequently this prediction task was undertaken.

ANALYSIS AND RESULTS

The initial objective was to develop a software package to perform correlation calculations. The material for the studies consists of series of values of scintillation indices and of total electron content values. The volume of data extends over several years and consists of measurements for many satellites and for several locations. The data consist of scintillation values in dB or in scintillation index. They consist of TEC absolute values. Basically, correlation functions (auto and cross) for these 15-minute indices are required.

The following is a summary of work performed on this problem to date. Although the indices are of 15 minutes of data, further calculations may involve one hour mean indices for auto and cross correlations. Provisions for this data handling have been included in the software. It is presently possible to obtain nightly values and use these values to compute auto and crosscorrelation functions. If desired, the four highest values for the period 2200-0400 UT may be specified and used as the basis for the auto or crosscorrelation functions. It is possible to specify auto and crosscorrelation functions for one season or one month. Careful distinction is made in the data between no data and zero values. (Portions of the data supplied were supplemented with a code to identify missing data.)

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[2] "Equatorial Scintillations: A Review", Jules Aarons, 13 April 1976, AFGL-TR-76-0078.

Software has been generated to calculate auto and crosscorrelation functions. Both five-day lag and 36-hour lag plots are being produced for future analysis. Sample plots are shown in Figures 26-1, 26-2, 26-3, and 26-4. Total data, and monthly and seasonal auto and cross-correlation functions are being produced for three sites. They are Narssarssuaq, Goose Bay, and Sagamore Hill. In the calculations, the magnetic index can be quantized in steps of selectable size. Initially, two scales of granularity were used:

a) A division with Kp either in the range 0 to 3+ or in the range of 4- to 9

b) No division with respect to Kp.

Using only nightly data has produced results which show diurnal variations about midnight, which was to be expected.

One of the difficulties has been the handling of large amounts of data for multi-seasonal and total time auto and crosscorrelations. The problem has been resolved with the inclusion of an algorithm which combines means, varriances, auto covariances or cross-covariances from the individual time groups of data. For disjoint data groups, the equations used for the combinations of means, variances, auto-covariance or total cross-covariance are:

$$\underline{\text{Total Mean}}: \quad \bar{X} = \frac{\Sigma N_i \bar{X}_i}{N}$$

$\bar{X}_i$ = mean of individual group

N_i = number of occurrences in individual group

$N = \Sigma N_i$

$$\underline{\text{Total Variance}}: \quad \sigma^2 = \frac{\Sigma (N_i \sigma_i^2) + \Sigma N_i (\bar{X}_i - \bar{X})^2}{N}$$

where σ_i^2 = variance of individual group.

Total auto-covariance: $$TACV_j = \left[\sum N_i ACV_{ij} + \sum[M_i(\bar{X}_i - \bar{X})^2] + (\bar{X}_i - \bar{X})\left[(\sum(\bar{X}_i + \bar{X}_j)) - 2\bar{X}_i M_i\right]\right]/\Sigma N_i$$

where N_i = number of occurrences in group i

$\bar{X}_i$ = means of group i

$\bar{X}$ = overall mean

M_i = number of terms summed in the group i

ACVij = auto covariance for groups i, lag j

Hence the total auto correlation is determined by

$$AC_j = \frac{TACV_j}{(\sigma^2)}$$

A similar computation for the crosscorrelation becomes:

Total cross covariance:

$$TCCV_j = \left[\sum N_i CCV_{ij} + \sum\left[M_i\ (\bar{X}_i - \bar{X})\ (\bar{Y}_i - \bar{Y}\ ]\right.\right.$$
$$\left.\left. + \sum(\bar{X}_i - \bar{X}) \sum_{i=1}^{M_i} (Y_i - \bar{Y}_i) + \sum(\bar{Y}_i - \bar{Y}) \sum_{i=1}^{M_i} (X_i - \bar{X})\right]/\Sigma N_i\right.$$

for groups $Y_1, Y_2, \ldots, Y_n$ lagging groups $X_1, X_2, \ldots, X_n$

N_i = number of occurrences used to calculate cross-covariance for group Y_i lagging X_i

$\bar{X}_i$ = means of group X_i

$\bar{Y}_i$ = means of group Y_i

CCVij = cross-covariances for group i (Y_i lagging X_i), lag j

M_i = number of terms used in the calculation

$\bar{X}$ = overall mean of the X_i 's

$\bar{Y}$ = overall mean of the Y_i 's

Hence, the crosscorrelation is determined by

$$CC_{ij} = \frac{TCCV_{ij}}{[\sigma_X^2 \, \sigma_Y^2]^{1/2}}$$

σX^2 = total variance for group X

σY^2 = total variance for group Y

In addition to these algorithms, the individual group (season) auto-covariances, number of data points, means, etc., are saved for future use. Hence, this method facilitates the inclusion of additional data when it becomes available. Past results are not recalculated; rather, they are new terms or constants which are added to the equations. Overall data handling is facilitated, and computer time is saved. Modifications to the software to include data from overlapping groups have been formulated and could be included.

The first phase of the analysis software has been completed. This software has been used to produce auto and crosscorrelations based on the scintillation index at the three sites. At present, some 300 sets of autocorrelation plots and 100 sets of crosscorrelation plots have been produced for future analysis.

Future work will include the completion of the calculation of all auto and crosscorrelation functions for the TEC and crosscorrelations between TEC and scintillation index for all combinations (i.e., seasonal, nightly, yearly). Following this, will be the calculation of monthly means and the generation of correlation functions of the deviations from monthly means and the crosscorrelations for deviations at several stations. Most of the software necessary to calculate the correlation functions of the deviations from monthly means is available. Additions to existing software in use will be necessary to complete the software package. Upon completion of the correlation function calculations and analysis thereof, equations will be formulated to predict the scintillation index and total electron content at a specified geographic location given values of scintillation and/or TEC at another station.

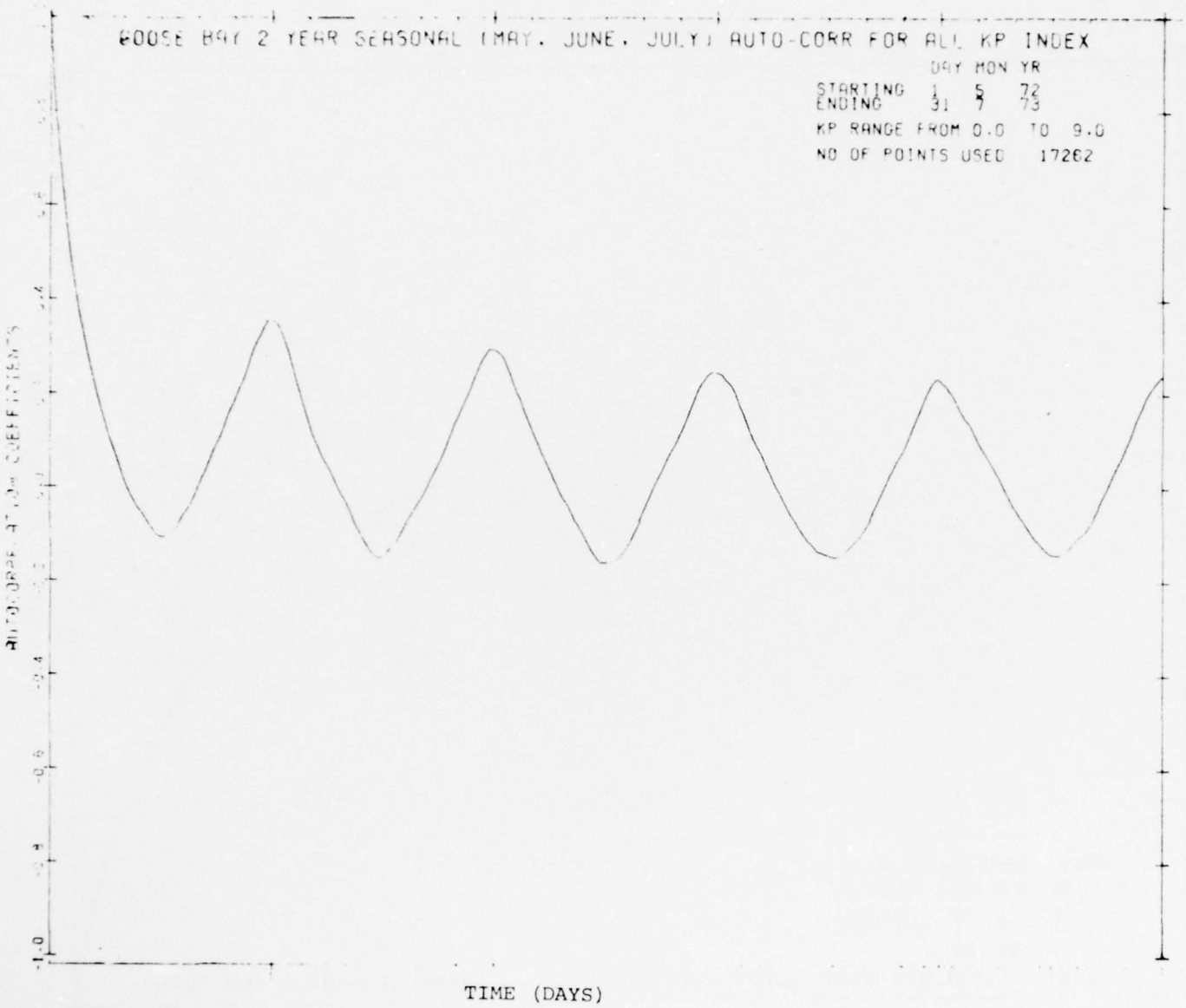

Figure 26-1 Goose Bay Autocorrelation (Days)

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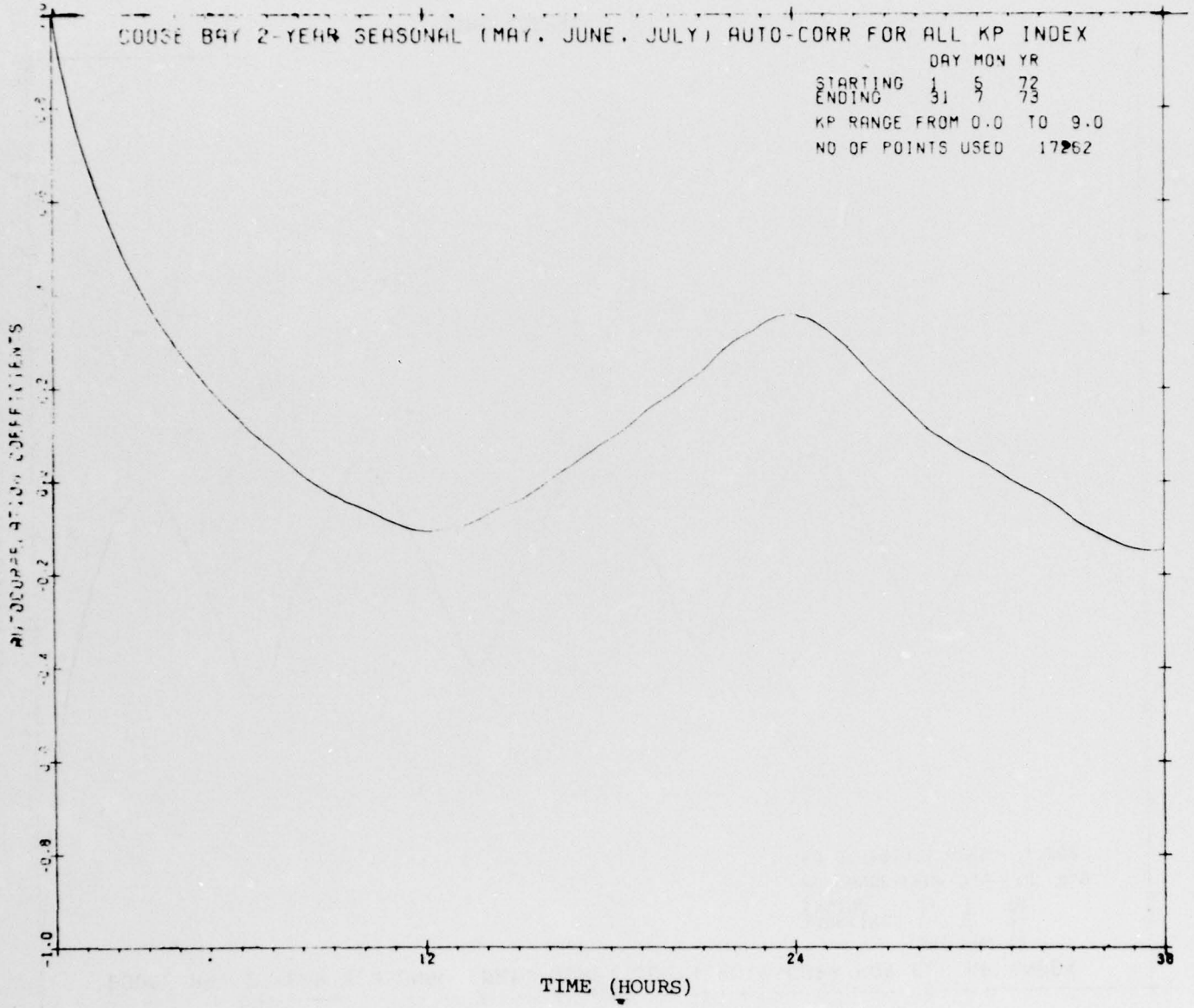

Figure 26-2 Goose Bay Autocorrelation (Hours)

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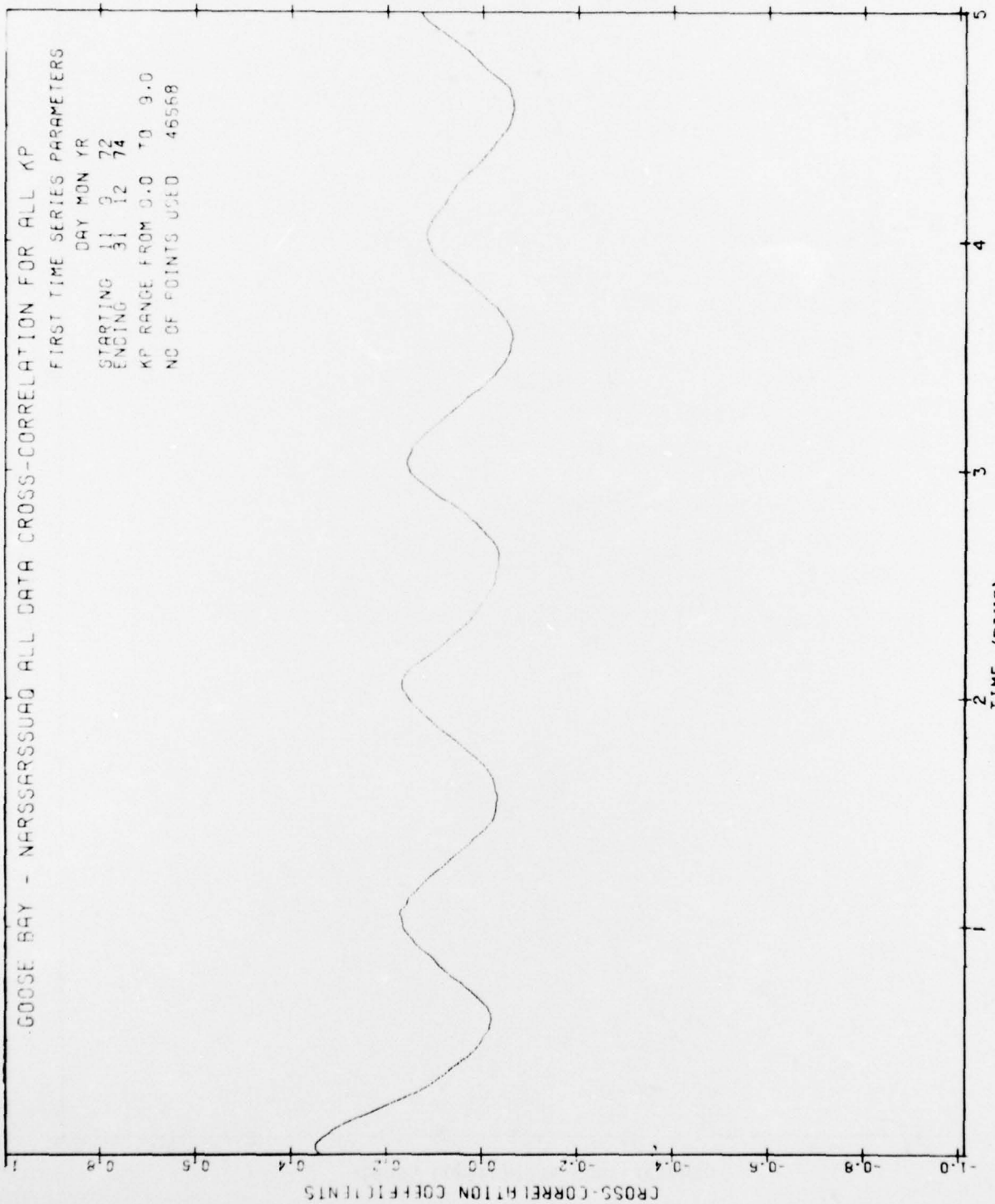

Figure 26-3 Goose Bay Narssarssuaq Crosscorrelation (Days)

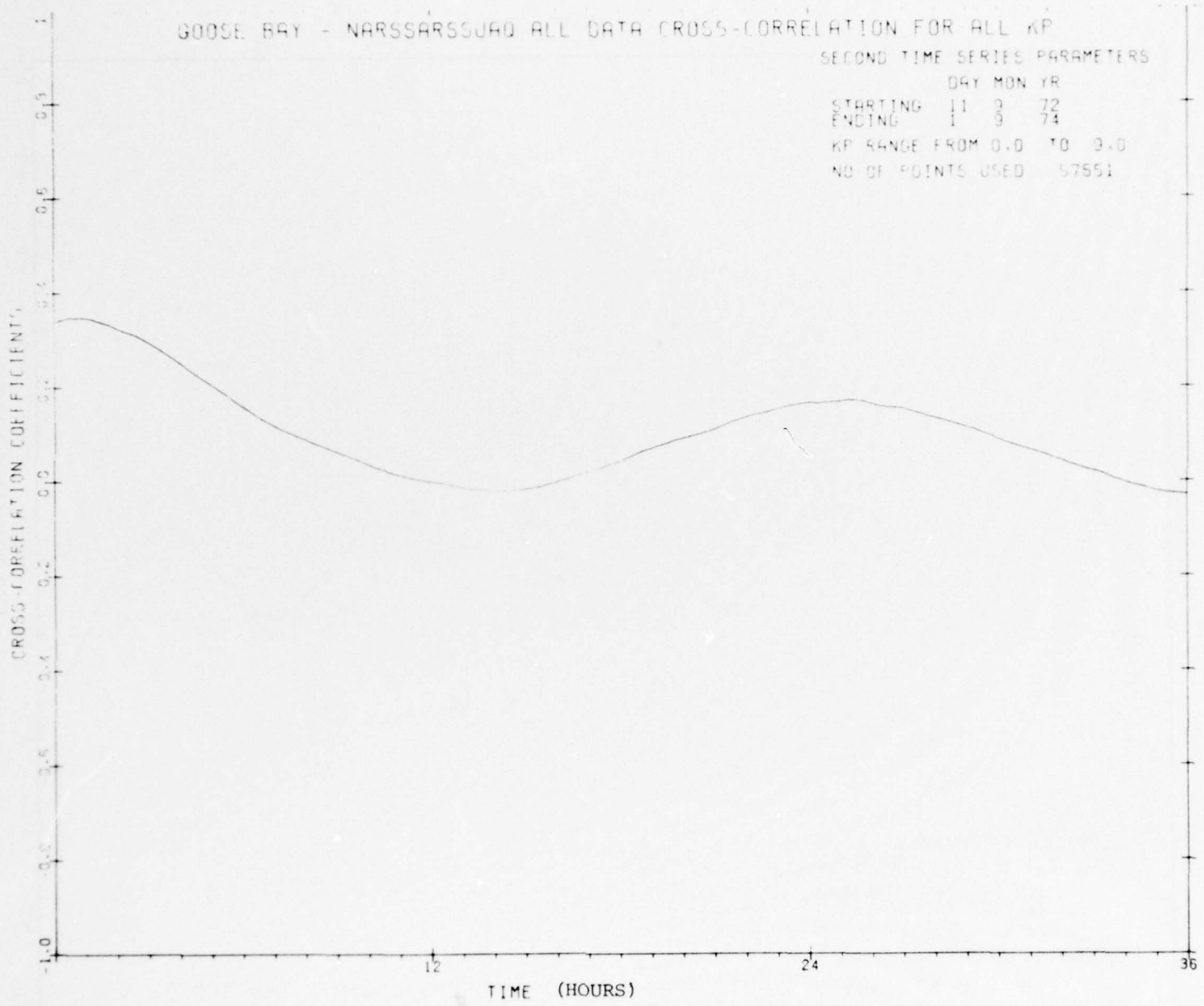

Figure 26-4 Goose Bay Narssarssuaq Crosscorrelation (Hours)

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27. Aerosol Spectroscopy

INITIATOR: F. VOLZ

PROBLEM NO.: 4928 PROJECT NO.: 7621

BACKGROUND

Particle counts are being measured by the AFGL/OPA group at Hanscom AFB. It is desired that the particle counts be obtained with respect to size over a period of time. This data is obtained utilizing a DAS-64 Dual Differential Analog Module, and values are recorded on a 9-track tape.

The particles are being counted in six different ranges. These ranges, in turn, are subdivided into 15 equal groups, referred to as bins. The particle counts are recorded at a sampling period determined by the operator. This period is between .01 seconds to 1 second. Along with the counts for the various ranges, the date, time, counting rate, and range size are stored on the tape for reference and future analysis.

Data is obtained either in automatic mode, where all ranges are sample sequentially, or manually, where a particular range may be sampled. All analysis here assumes automatic mode.

ANALYSIS AND RESULTS

The data as it appears on the tape is described in Figure 27-1. Four bits of each word represent a field. Hence it was necessary to write a program to unpack the data on the tape into CDC 6600 words containing 4 bits of information. These fields were then combined using the scale factor described in Figure 27-1 to obtain the data values.

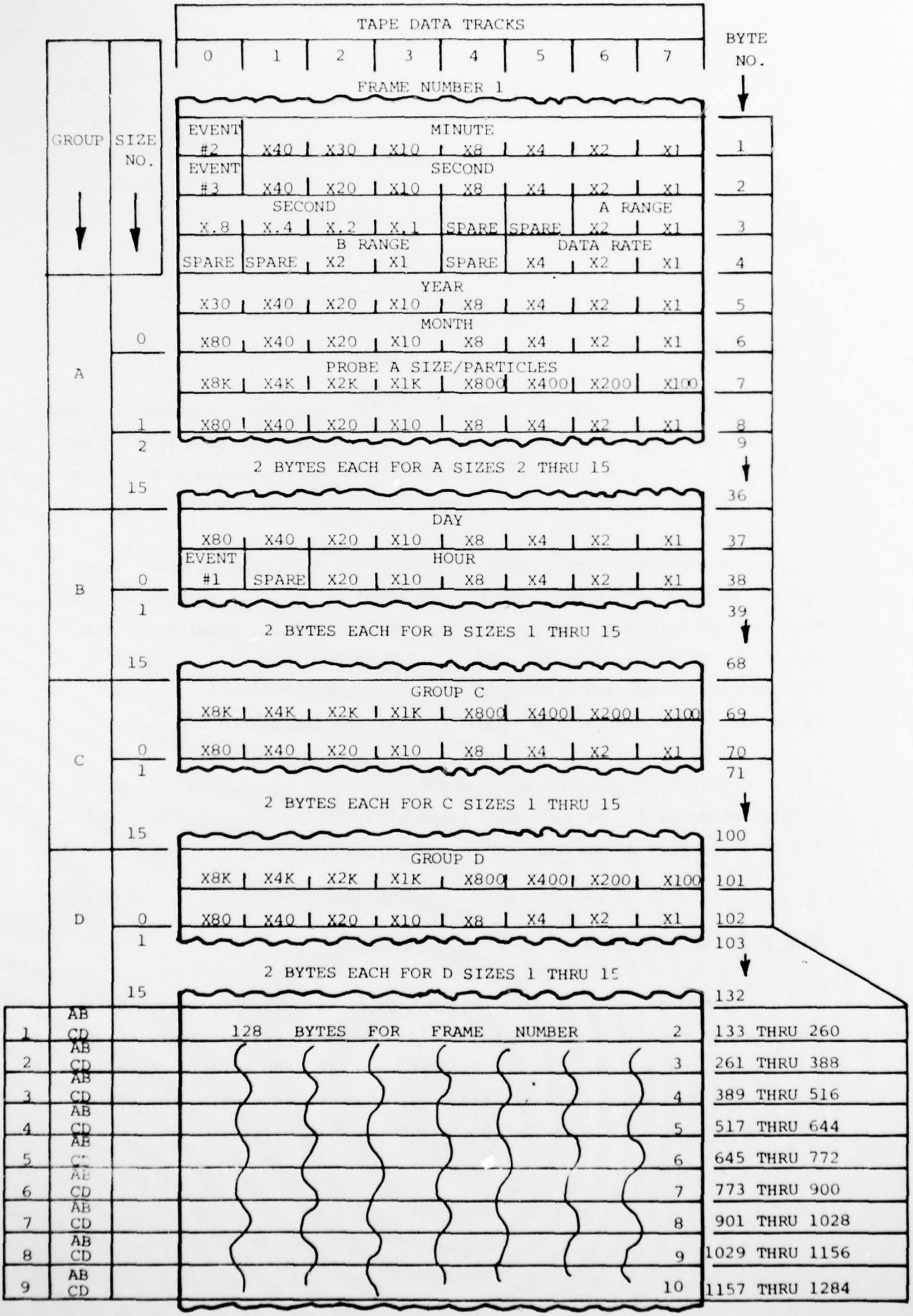

Figure 27-1 DAS-64 Tape Format

Software has been written to read a 7 inch phase encoded 9-track hexadecimal tape with aerosol count data and to rearrange and display this data. The data for log-log plots of counts versus size of bins has been normalized. In addition to providing the counts for the fifteen different size bins for each of six measuring ranges, the software performs the following operations.

1. Calculation of absolute particle concentration
2. Determination of bin size distribution
3. Definition of bin size
4. Smoothing of data to extract large statistical fluctuation
5. Printing of information (format described in Figure 27-2 and 27-3)
6. Plotting of information (Figure 27-4)
7. Provision for count data to be input via cards.

The following is a discussion of the equations used and the output obtained from the software. Particle counts C_i in a certain size bin (i = 1 to 15) of one of the 6 measuring ranges are related to absolute particle concentration dN_i by

$$dN_i = \frac{C_i}{T \cdot SVR} \quad (cm^{-3})$$

C = number of counts

T = Collection duration (seconds)

SVR = Sampling volume rate (cm^{-3} sec^{-1})

This concentration refers to the size (diameter) interval

$$dD_i = D_{i+1} - D_i \text{ or radius interval } dR_i = dD_i/2$$

In a flat size distribution, or narrow bins, the median radius R_{mi} is calculated with the equation $R_{mi} = (D_{i+1} + D_i)/4$. However, where the

bin size is wide and the size distribution steep, an effective radius may be defined as:

$$R_{ei} = [D_i + K(D_{i+1} - D_i)]/2$$

where input parameter K ($0 < K < 1$); in natural haze, $K \simeq 0.2$

$$R_m = R_e \text{ for } K = 0.5$$

The range sizes are defined below:

Range	Size in microns (μ)	Bin Size in μ (Bin #1 thru 15)
A3	0.15 to 0.3	(.01)
A2	0.2 to 0.65	(.03)
A1	0.35 to 1.1	(.05)
A0	0.6 to 3.0	(.16)
B1	0.6 to 3.0	(.16)
B0	1.0 to 20.0	(1.27)

The effective radius is calculated for Ranges A0, B1, B0, for bin sizes 1 through 6. All other ranges use the median radius.

It was desired to calculate the size distributions in terms of $dN_i/dlogr_i$.

$$dlogr_i = 0.434\ (\ell n\ R_{ei+i} - \ell n\ R_{ei})$$

$$\text{Therefore } dN_i/dlogr_i = \frac{2.3\ C_i}{(\ell n\ R_i + 1 - \ell n\ R_i) \cdot T \cdot SVR}$$

Range and size data will be different for various instruments. This information is input via data cards.

Low counts show large statistical fluctuations. During conversion to size distributions, they are smoothed as follows:

$$SC_i = (C_{i-1} + 4C_i + C_{i+1})/6$$

Present count limits for smoothing have been set for values ≤ 20.

Counts for particular range and bin sizes are summed for periods of time determined on input cards, and this is output to the printer as in Figure 27-2.

DATE TIME	RANGE	BIN	0	1	2	3	. . . 15
	3-4	Counts	8500	3000	980		
	2-4		2210				

Figure 27-2 Count Data

An option provides count data from input cards if desired.

Count listing is followed by a dN/dlogr listing. An example is given in Figure 27-3:

DATE TIME	RANGE	BIN	0	1	2	3
171830	1-4	Radius	.015	.02	.025	
		dN/dlogr	3.32 + 2	3.0 + 1		
171900	0-4	Radius	.65	.77		
		dN/dlogr	2.2 + 1			

Figure 27-3 Listing of dN/dlogr

Log - log plots of the dN/dlogR versus radius are obtained with all ranges on one plot. Each range identified by a separate symbol. The method of processing of data taken in a manual mode will be decided at a future date.

Calculations and processing have been made for sample data. Further modification to the processing software may be necessary. Smoothing of output to be displayed has been discussed. Algorithms necessary to interpolate output are available and may be incorporated. Certain anomalies have been detected in the instruments. Once these have been corrected by the vendor, interpolation may be applied to the output before plotting. This program will be used for the comparison of data obtained from NATO aerosol spectrometers. Figure 27-4 is a sample of the output plot being generated.

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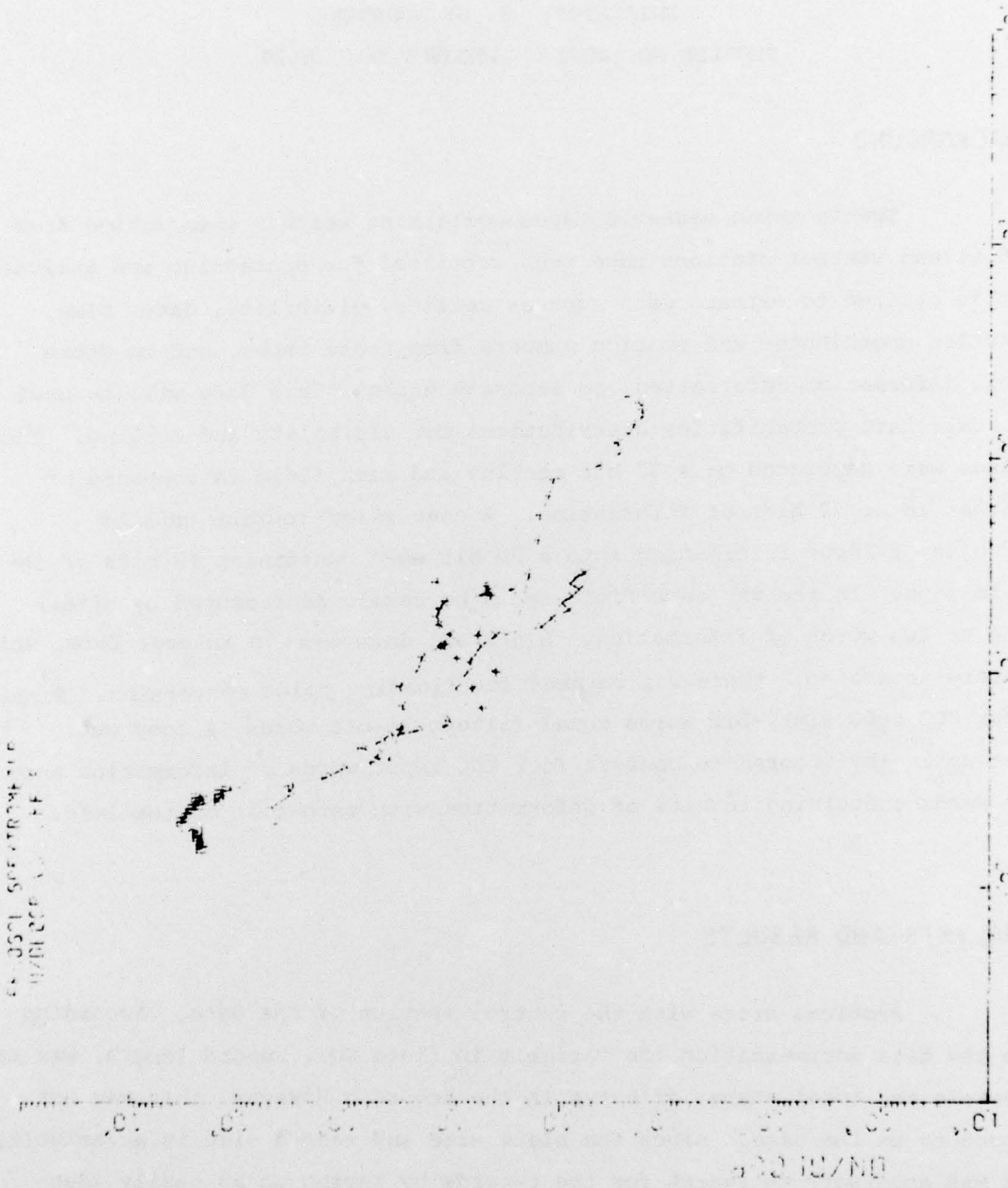

Figure 27-4 Output from Aerosol Spectrometer

28. German Surface Weather Data

INITIATOR: I. GRINGORTEN

PROBLEM NO: 4931 PROJECT NO: 8624

BACKGROUND

Twenty seven magnetic tapes containing weather information from 26 German weather stations have been submitted for processing and analysis. It is desired to extract data such as ceiling, visibility, date, time, station coordinates and station numbers from these tapes, and to store this information, reformatted, on separate tapes. This data will be used to calculate probabilities distributions for visibility and ceiling. These tapes were generated on a 32 bit machine and each field is composed of either 16 or 32 bits of information. A conversion routine unpacks 60 bits of input information into a 60 bit word containing 16 bits of information. In the way each field could be easily represented by either one or two words of information. Since all data was in integer form, unless otherwise stated, there was no need for floating point conversion. Since four CDC 6600 sixty-bit words equal fifteen 16-bit words, a loop was set up in the program to convert four CDC input words of information into 15 words containing 16 bits of information with zero-fill on the left.

ANALYSIS AND RESULTS

Problems arose with the control section of the data. According to the data documentation, the variable in field C01, record length, was to contain the total number of bytes in the record. However, this was not found to be the case. Since the block size and record size is a variable, it was necessary to search for the records by keying on an easily identifiable parameter. Since the first record of each block always had the same length, except for the "additional Data Section," which appears after the needed data, the year, month, day, hour could be obtained from the first record of each block. By searching for these parameters in the subsequent record, all records in each block could be obtained.

The latitude and longitude were converted from degrees and minutes to degrees to nearest hundredth by dividing the minutes by 60 and adding this fraction to the number of degrees. The visibility value on tape in meters was divided by 402, and if it exceeds 100, it was set to 100. The value 402 meters is the largest expected value.

Multi-file tapes were set up for the data extracted from the tapes, converted and stored in the following order.

ORDER	FIELD	DESCRIPTION	CONVERT TO	SYMBOL
1	CO6	Month	Same (2 digits)	MONTH
2	CO9	Hour	01 to 24 (2 digits)	NHOUR
3	CO4	Block-station	Numbered 1 to 26	IST
4	C12	Latitude	Degrees to nearest 100th	PLAT(IST)
5	C13	Longitude	Degrees to nearest 100th	PLONG(IST)
6	CO5	Year	Last two digits of year	IYEAR
7	CO7	Day	01 to 31	MDAY
8	M30	Ceiling	Same WMO code	IH
9	M12	Visibility (V)	v = Integer of (V/402) for V $\leq$ 40200 = 100 for V $\geq$ 40200	

The above data will be used along, additional software to perform the following:

a. Calculate the probability distributions of cloud ceiling heights ($\geq$ H) and visibility ($\geq$V) at each of the 26 stations and the equivalent normal deviates (e.n.d.) for the given heights and visibilities.

b. Calculate the correlation coefficients (c.c.) for all combinations of the e.n.d.'s of ceiling (cig) and visibility (vis) at the 26 stations.

c. Calculate the joint probability of cig and vis at each station.

d. Determine the values of the parameter, known as scale distance, for cig and for vis, in the model formula for estimating c.c.

e. Calculate the conditional probability of cig and vis and the joint probability at a point (ϕ, λ).

f. Determine the probability distribution of the minimum of cig and vis in areas of varying size.

Portions of the original 27 tapes were copied onto other in-house tapes for future reference. Additional information may be extracted at a future date.

29. Floating Point Arithmetic For CDC 6600

Floating point arithmetic in the CDC 6600 takes advantage of the ability to express a number with the general expression kB^n, where

k = coefficient

B = base number,

and

n = exponent, or power to which the base number is raised.

The base number is constant for binary-coded quantities and is not included in the general format. The 60-bit floating-point format is shown in Figure 29-1. The binary point is considered to be to the right of the coefficient, thereby providing a 48-bit integer coefficient, the equivalent of approximately 14 decimal digits. The sign of the coefficient is carried in the highest-order bit of the packed word. Negative numbers are represented in one's complement notation.

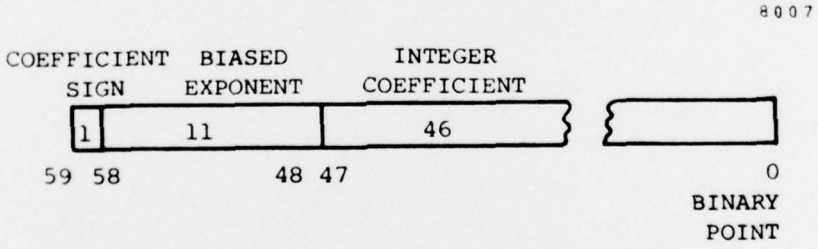

Figure 29-1 60-bit Floating Point Format

The 11-bit exponent carries a bias of 2^{10} (2000_8) when packed in the floating point word (biased exponent sometimes referred to as characteristic). The bias is removed when the word is unpacked for computation and restored when a word is packed into floating format. For complete range of permissible values see the CDC 6600 SCOPE reference manual.

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