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Soil Moisture

October 1981

GROUND REGISTRATION OF DATA FROM AN AIRBORNE MULTIFREQUENCY MICROWAVE RADIOMETER (MFMR)

John C. Richter

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16. Abstract

The Agricultural Soil Moisture Experiment was conducted near Colby, Kansas, in July and August 1978. A portion of the data collected was taken with a five-band microwave radiometer. This report documents a method of locating the radiometer footprints with respect to a ground-based coordinate system. The procedure requires that the airplane's flight parameters along with aerial photography be acquired simultaneously with the radiometer data. The software documented in this report will also read in data from the Precision Radiation Thermometer (PRT Model 5) and attach the scene temperature to the corresponding multifrequency microwave radiometer data. Listings of the programs used in the registration process are included.

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GROUND REGISTRATION OF DATA FROM AN AIRBORNE MULTIFREQUENCY MICROWAVE RADIOMETER (MFMR)

Job Order 71-323

This report describes activities of the Soil Moisture project of the AgRISTARS program.

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LOCKHEED ENGINEERING AND MANAGEMENT SERVICES COMPANY, INC.

Under Contract NAS 9-15800

For

Earth Resources Research Division
Space and Life Sciences Directorate
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS

October 1981

LEMSCO-16800

PREFACE

The Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing is a multiyear program of research, development, evaluation, and application of aerospace remote sensing for agricultural resources, which began in fiscal year 1980. This program is a cooperative effort of the U.S. Department of Agriculture, the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration (U.S. Department of Commerce), the Agency for International Development (U.S. Department of State), and the U.S. Department of the Interior.

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ACRONYMS

ASCII	American Standard Character Code for Information Interchange
ASME	Agricultural Soil Moisture Experiment
ADAS	Auxiliary Data Annotation System
CCT	computer compatible tape
EBCDIC	Extended Binary-Coded Decimal Interchange Code
JSC	Lyndon B. Johnson Space Center
MFMR	Multifrequency microwave radiometer
NASA	National Aeronautics and Space Administration
NERDAS	Navigational Earth Resources Data Annotation System
PCM	pulse-code modulated
PRT	Precision Radiation Thermometer
SAL	Sensor Analysis Laboratory
SAS	Statistical Analysis System

1. INTRODUCTION

Multifrequency microwave radiometer (MFMR) measurements were taken by the National Aeronautics and Space Administration (NASA) C-130 aircraft at 1000 and 1500 feet above ground level as part of the Agricultural Soil Moisture Experiment (ASME). This experiment was conducted near Colby, Kansas, on July 18, 20, 21, and 22, 1978, and on August 8, 9, and 11, 1978. These data are a measure of the natural microwave emission of the targets as seen by the sensor. The MFMR is a group of sensors that collect data at five frequencies: 1.42, 5.0, 18.0, 22.5, and 37.0 GHz. Location of these sensors on the aircraft is shown in figure 1-1. Each sensor collected data by viewing the ground with either a 0° or 40° incidence angle; only one incidence angle could be used at any one time. Because of mechanical incompatibility of their antennas, the 1.42 and 5.0 GHz frequencies could not be used simultaneously.

Soil samples from several layers were collected from preselected fields of approximately 40 acres on each of the 7 days of flight. These samples were weighed, oven-dried, and weighed again so that the moisture content of the layers could be calculated. The moisture contents will be used for comparison with the MFMR data.

Simultaneously with the MFMR data collection, the Precision Radiation Thermometer Model 5 (PRT-5) measured the infrared temperature of the emitting surface. Knowledge of this temperature may allow the conversion of the MFMR antenna temperatures to emissivities.

A method of converting the MFMR and PRT-5 computer compatible tape (CCT) data into disk files is outlined in this document. Each disk file will contain the date, the MFMR data, the PRT-5 temperature data, and the ground reference position of the data within the sampled field. This conversion is accomplished by four processing programs. These are listed and each program is discussed in this report.

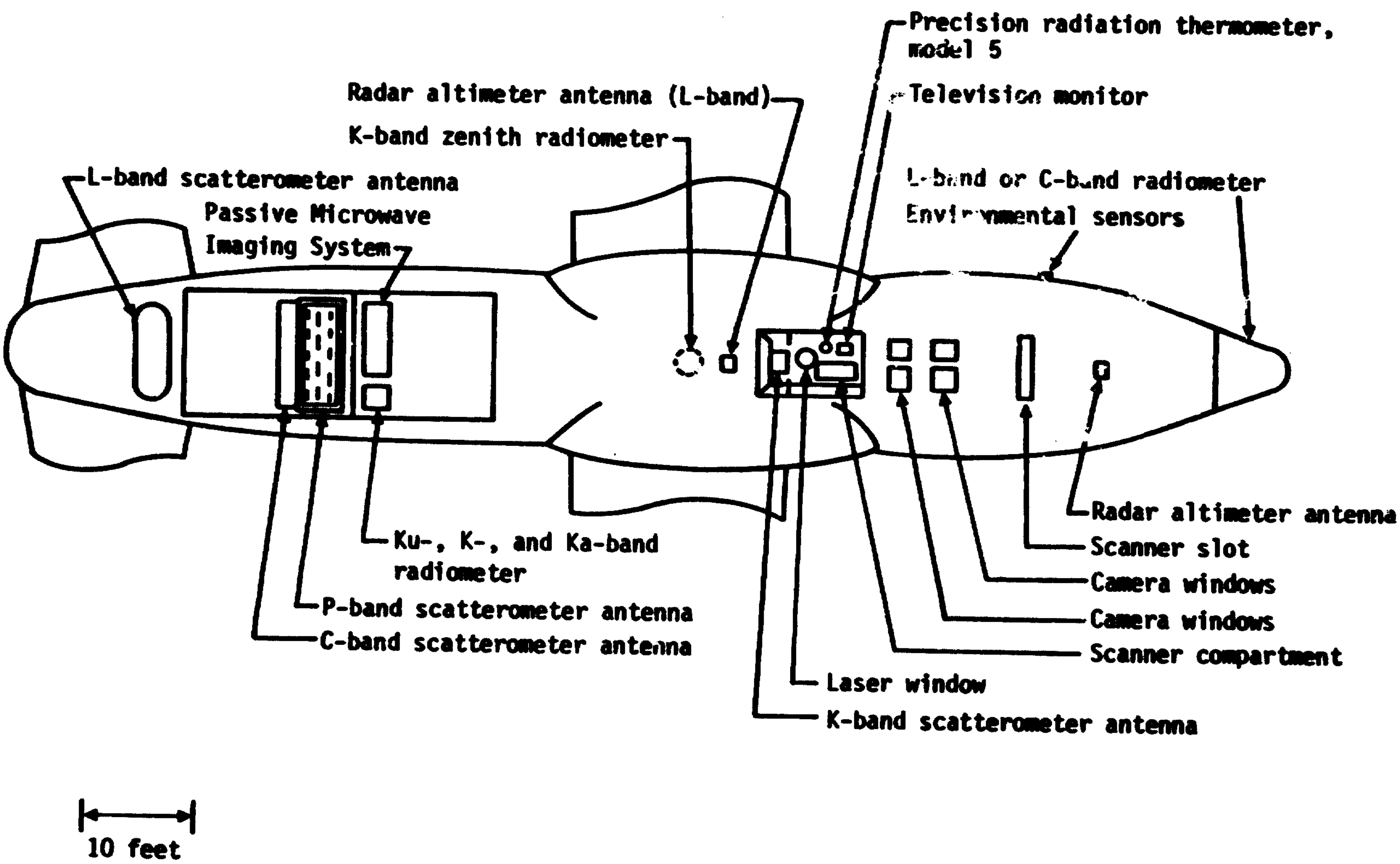

Figure 1-1.- Bottom view of the NASA C-130 aircraft.

2. REQUIRED INPUT DATA

As the aircraft flew down the flight line, the MFMR and PRT-5 data were recorded on tape in an analog format. The tapes were sent to the Sensor Analysis Laboratory (SAL) located at the Lyndon B. Johnson Space Center (JSC), Building 15. At the SAL, the analog data were digitized and recorded on tape along with the Auxiliary Data Annotation System (ADAS) data time of acquisition. Each record in the file also contains the roll, pitch, and drift angles along with the altitude, ground speed, and true heading of the aircraft. The data and flight parameters were measured approximately every 0.6 second.

A great deal of aerial photography was collected as part of the ASME. Photographs taken at an altitude of 8000 feet were used to construct controlled strip mosaics of each flight line. Additional aerial photography was acquired as the aircraft collected the MFMR data. The acquisition time and frame number of every photograph were recorded on the analog data system. This made it possible to determine the aircraft's position at the frame times. The camera positions and frame numbers were plotted on transparent overlays by the JSC Cartographic Technology Laboratory. Additional overlays were made showing the location of the sampled fields in each flight line. All overlays were made at the same scale as the controlled strip mosaics.

3. PROGRAM EXPLANATION

3.1 CONVERT PROGRAM

The MFMR data as provided by the SAL are grouped into records with a length of 160 characters. Some characters in each record are written in the American Standard Character Code for Information Interchange (ASCII) character code. The rest of the characters are in binary form. The computer used in this study is a National Advanced Systems AS/3000 which uses the Extended Binary-Coded-Decimal Interchange Code (EBCDIC) for character representation. Therefore, before the ground registration of the data can begin, the ASCII and binary characters must be converted to EBCDIC. This is accomplished by a FORTRAN program called CONVERT. A listing of the program and its execute file are given in appendix A. The program reads in the data, does the character conversion, and reformats the data to a record length of 132 characters so that a printed copy can be obtained. The data file from the SAL can contain three types of records: calibration, baseline, and data. The program CONVERT will write each to a separate file in EBCDIC representation. A sample listing of the output data file is shown in appendix A. The column titles are added for clarity but are not actually written to the data file. Note that at this point all columns have numbers in them, even if the sensor was turned off during the run. To identify the useful data, the file identification code must be referenced. Only the useful data will be placed in the file output by the final processing program.

3.2 MFMR PROGRAM

The second program used to process the MFMR and PRT-5 data is a FORTRAN program called MFMR. A listing of the program and its execute file are given in appendix A. This program reads in the reformatted and converted data file and computes the location of the aircraft's negative z-axis intersection with the ground in a scene-based coordinate system. The MFMR program refers to the camera location but, as clearly shown in figure 1-1 of section 1, the MFMR sensors have an along-track displacement from the camera. The sensor displacements and beamwidths are listed in table 3-1. To obtain the location of the sensor footprint center, the displacement must be added to the along-track displacement.

TABLE 3-1.- MFMR SENSOR SUMMARY

Sensor			Along-track displacement (ft)	Beamwidth, degrees	
Band	Frequency (GHz)	Wavelength (cm)		Half-power	Null to null
L	1.4	21.2	+25.0	16.0	40.0
C	5.0	6.0	+25.0	4.5	12.0
Ku	18.0	1.66	-42.0	5.0	14.0
K	22.0	1.36	-42.0	5.0	14.0
Ka	37.0	0.81	-42.0	4.0	12.0

Three inputs from the terminal are requested by the program. The first input, called AMISS, is the distance (in feet) of the aircraft toward the north from the southern field boundaries if the flight line runs east-west. If the flight line runs north-south, then AMISS is the distance toward the west from the eastern field boundaries. AMISS is measured at the beginning of the flight line. The second input, called YUP, is the crosstrack distance (in feet) that the aircraft's position changed between the beginning and the end of the flight line. Figure 3-1 is a diagram of a flight line and shows the distances represented by AMISS and YUP. Both inputs are measured with the overlay on the strip mosaic. The final requested input is a three-symbol numeric identifier called Code. The Codes used for the ASME MFMR data are shown in table 3-2.

TABLE 3-2.- IDENTIFICATION CODES FOR THE COLBY ASME DATA

Code	Day, 1978	Sensor	Polarization
1	199 (July 18)	13.3 GHz Scatterometer	Like
2	201 (July 20)	4.75 GHz Scatterometer	Cross
3	202 (July 21)	1.6 GHz Scatterometer	Horizontal receive
4	203 (July 22)	0.4 GHz Scatterometer	Vertical receive
5	220 (August 8)	0° L, Ku, K, Ka MFMR	Horizontal and vertical receive
6	221 (August 9)	40° L, Ku, K, Ka MFMR	
7	223 (August 11)	0° C MFMR	
8		40° C MFMR	

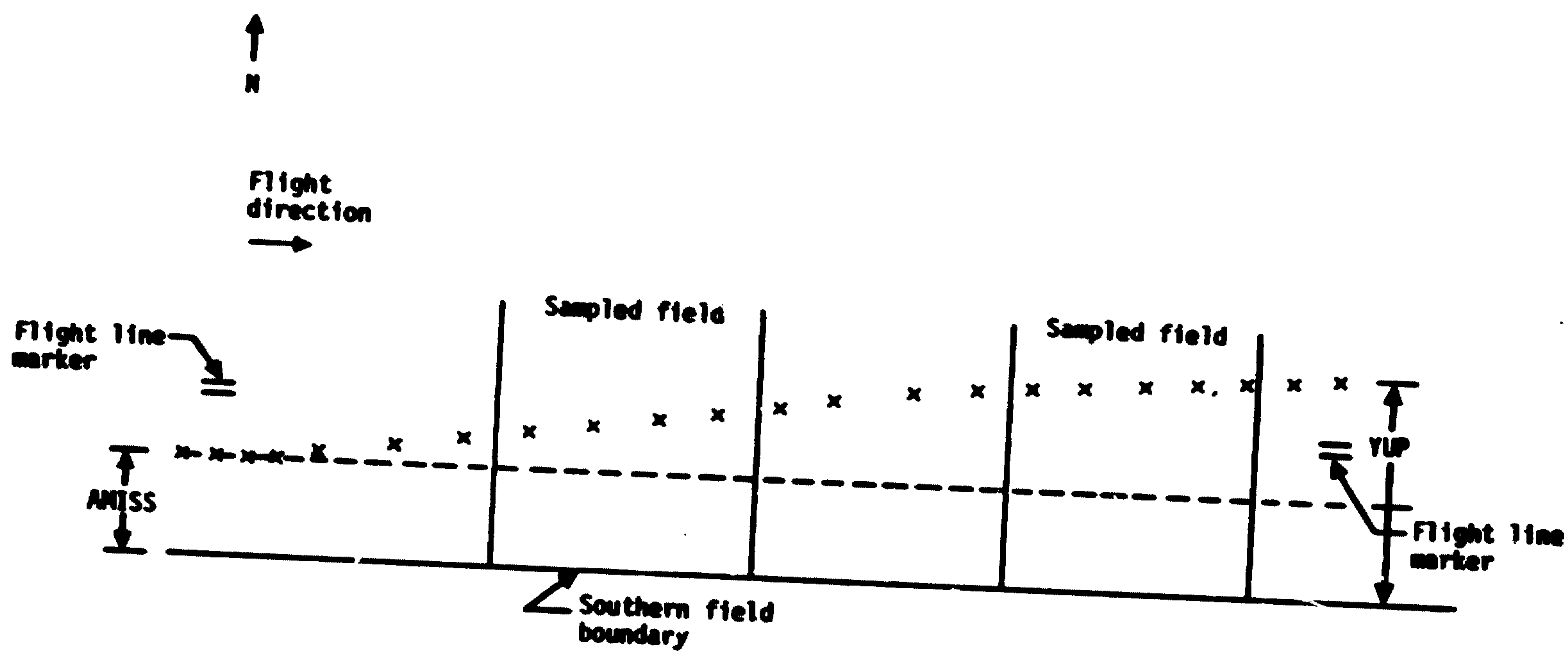

Figure 3-1.- A sample plot illustrating how and where to measure the variables AMISS and YUP.

Program MFMR creates an output file that contains the downtrack and crosstrack locations of the airplane with respect to the beginning of the flight line. This file also contains the corresponding MFMR data values for those locations and the time that the data were acquired. Time of data acquisition is no longer needed for MFMR data ground registration, but it will be used to register the PRT-5 data acquired simultaneously.

3.3 MPLOT PROGRAM

The third program, MPLOT, is a Statistical Analysis System (SAS) program which reads the file output by program MFMR and plots the aircraft's ground track along with one band of corresponding MFMR data. The plot is at the same scale as the strip mosaics. A program listing is given in appendix A, and a portion of the plot is shown in figure 3-2. At this point in the analysis, the MFMR data are referenced by the distance (in feet) downtrack and the distance from the southern or eastern field boundaries, depending upon the direction of the flight line. It is necessary to know the ground reference position of the data within the sampled fields. This is accomplished by using the overlays in conjunction with the plot. Both overlays, one with photographic position and the other with field boundaries, are placed on the plot in the following manner. First, a time is found when the aircraft's flight parameters are available and when an aerial photograph was taken. The time represented by each asterisk in the flight-path plot can be found by using the exclamation points plotted alongside. The exclamation points are time marks when the aircraft clock was at the minute or a multiple of 10 seconds after the minute. Next, the overlays are placed on the plot so that the photographic position from the overlay is on top of the asterisk representing the same time. The solid line paralleling the plot of the flight path should be even with the southern field boundaries for an east-west flight or with the eastern field boundaries for a north-south flight. Figure 3-3 is an illustration of the plot with the overlays in place. The downtrack distance (in feet) of each field's closest boundary to the beginning of the flight line is read from the plot. These distances, along with the dimensions of the corresponding fields, are written in a separate file. This file is used as an input to the next program.

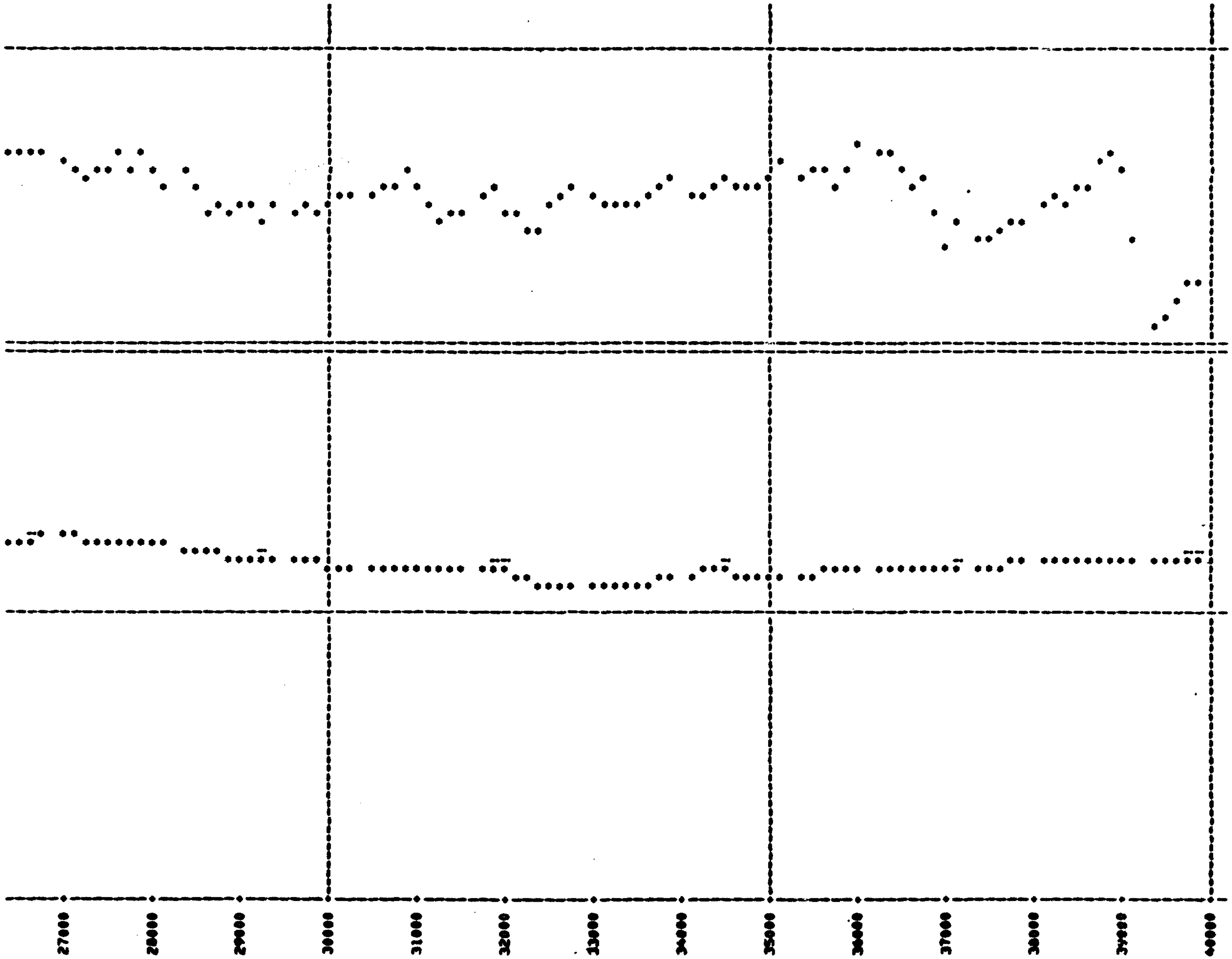

Figure 3-2.- A portion of the plot of the MPLOT program.

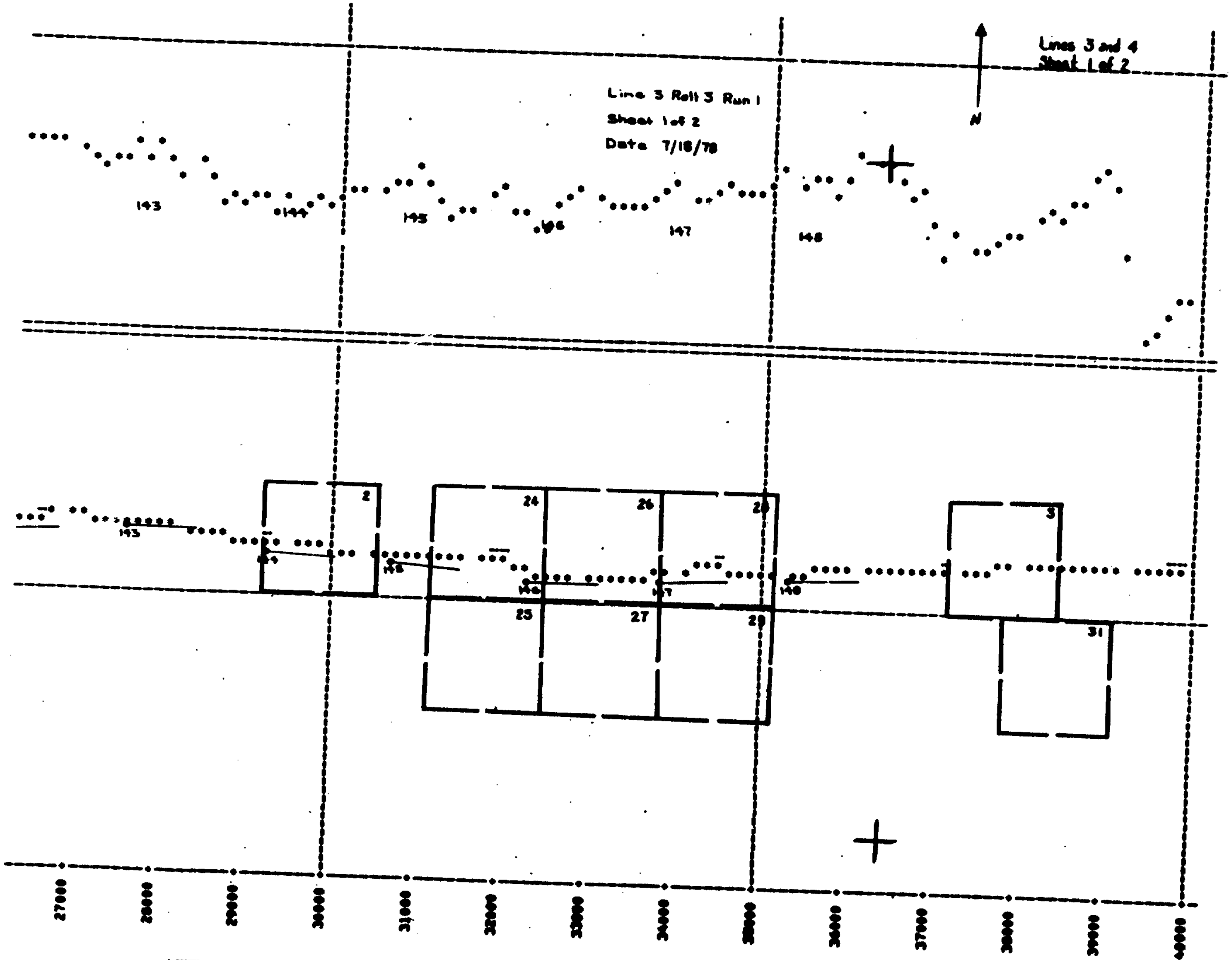

Figure 3-3.- An illustration of the plot (MPLOT program) with overlays of photographic position and field boundaries in place.

When the procedure is carried out in the manner described above, a di crepancy may become apparent. If the overlay and plot were registered at an ext eme end of the flight line, the overlay and plot positions may not match at the opposite end of the line. This is caused by a lack of sufficient accuracy in the recording of the aircraft's flight parameters. Therefore, it is recommended that the overlay and plot be registered near each sampled field before the downtrack distances are read.

3.4 MGRID PROGRAM

The final processing program, called MGRID, reads in the boundary data file, the file created by program MFMR, and the corresponding file of PRT-5 data. A listing of program MGRID and its execute file are given in appendix A. Program MGRID determines which MFMR data lie within a sampled field and calculates the location of the sensor footprints with respect to the northern and western field boundaries. The program then searches through the PRT data to find the infrared temperatures that correspond to the footprints. One output file is created for each sampled field within the flight line. The output files can then be combined in the manner which best suits the analysis technique that will be used.

APPENDIX A

PROGRAM AND DATA LISTINGS

APPENDIX A

PROGRAM AND DATA LISTINGS

The following data are presented in this appendix.

a. CONVERT FORTRAN

b. CONVERT EXEC

c. Converted and reformatted data listing (See figure A-1.)

d. MFMR FORTRAN

e. MFMR EXEC

f. MPLOT SAS

g. MGRID FORTRAN

h. MGRID EXEC

FILE: CONVERT FORTRAN A EODL / JOHNSON SPACE CENTER

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CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                             C
C   THIS PROGRAM READS IN ONE DISK FILE OF MFMR DATA.  THE    C
C   BINARY AND ASCII CHARACTER CODES ARE CONVERTED TO EBCDIC. C
C   THREE FILES ARE WRITTEN, ONE FOR EACH COLLECTION MODE:    C
C    DATA, CALIBRATION AND BASELINE.                          C
C   WRITTEN BY: JOHN C RICHTER  FEBURARY,1981                 C
C                                                             C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      LOGICAL*1 A(108)
      INTEGER*2 B(26)
      INTEGER DCHAR(95),CHX
      DATA DCHAR/64,64,64,64,64,64,64,64,64,64,64,64,64,64,64,
     164,64,64,64,64,64,64,64,64,64,64,64,64,64,64,64,64,
     290,127,123,91,108,80,125,77,93,92,78,107,96,75,97,240,241,
     3242,243,244,245,246,247,248,249,122,94,76,126,110,111,
     4124,193,194,195,196,197,198,199,200,201,209,210,211,212,
     5213,214,215,216,217,226,227,228,229,230,231,232,233,173,
     6224,189,95,96/
      DO 2 M=1,1000
      READ(8,101,END=999)(A(I),I=1,108),(B(K),K=1,26)
  101 FORMAT(108A1,26A2)
      DO 10 K=1,108
   10 A(K)=DCHAR(A(K))
      IUNIT=10
      CHX=A(108)
      IF(CHX.EQ.195)IUNIT=11
      IF(CHX.EQ.194)IUNIT=12
      WRITE(IUNIT,102)A(18),A(19),A(20),A(13),A(16),A(33),A(34),
     1A(36),A(37),A(39),A(40),A(41),A(42),A(66),A(68),A(69),A(70),
     2A(75),A(76),A(77),A(78),A(79),A(84),A(85),A(86),A(87),A(88),
     3A(91),A(92),A(93),A(94),A(95),A(97),A(98),A(99),A(100),A(101),
     4A(104),A(105),A(106),B(1),B(2),B(3),B(4),B(7),B(8),B(9),B(10),
     5B(11),(B(I),I=13,24)
  102 FORMAT(3A1,1X,A1,A1,1X,2A1,':',2A1,':',4A1,1X,4A1,1X,
     15A1,1X,5A1,1X,5A1,1X,5A1,1X,3A1,1X,I3,1X,I3,1X,I4,I3,1X,I4,I3,
     2I4,I3,1X,I4,1X,I4,I3,I4,I3,1X,I4,I3,I4,I3,1X,I4,I3,I4,I3)
    2 CONTINUE
  999 STOP
      END
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FILE: CONVERT EXEC A EODL / JOHNSON SPACE CENTER

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&CONTROL OFF
FILEDEF 5 READER (PERM
FILEDEF 6 DISK READ LISTING A (PERM
FILEDEF 7 PUNCH (PERM
FILEDEF 8 DISK &1 DATA D (PERM RECFM F LRECL 160 BLKSIZE 160
FILEDEF 10 DISK &1 EDATA D (PERM RECFM F LRECL 132 BLKSIZE 132
FILEDEF 11 DISK &1 CALDATA D (PERM RECFM F LRECL 132 BLKSIZE 132
FILEDEF 12 DISK &1 BLDATA D (PERM RECFM F LRECL 132 BLKSIZE 132
GLOBAL TXTLIB CMSLIB FORTMOD2
LOAD READ
START
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FILE: M17531    PDATA    A    EODL / JOHNSON SPACE CENTER                                   PAGE 002

199 31 18:05:03.2 1620 086.3 +05.8 +00.1 +00.5 159 500 150 3523 4 2941 122976 19   0 3340 43338 0 3351 03386 1 3763 253396 0
199 31 18:05:03.7 1620 086.0 +05.8 +00.5 +00.6 159 500 150 3523 4 2949 172960 11   0 3340 43338 0 3351 03386 1 3756 263396 0
199 31 18:05:04.3 1620 086.0 +05.8 +00.8 +00.7 160 500 150 3524 4 2926 122961 14   0 3340 53338 0 3351 03386 0 3763 263396 1
199 31 18:05:04.8 1630 085.5 +05.8 +00.6 +00.8 160 500 150 3523 4 2933 132968 22   0 3340 53338 0 3351 03386 0 3763 223396 0
199 31 18:05:05.3 1620 085.5 +06.2 +00.6 +00.9 160 500 150 3525 4 2933 152976 12   0 3334 03338 1 3351 03386 1 3763 273396 0
199 31 18:05:05.9 1620 085.5 +06.6 +00.5 +00.9 160 500 150 3523 4 2949 132984 12   0 3340 53338 1 3351 03386 0 3763 253396 0
199 31 18:05:06.4 1630 085.5 +06.6 +00.7 +00.8 160 500 150 3524 4 2949 122968 13   0 3340 43338 0 3357 53386 0 3763 233396 0
199 31 18:05:06.9 1630 086.4 +06.4 +01.1 +00.8 160 500 150 3523 4 2941 112968 19   0 3340 53338 0 3351 03386 0 3756 233396 0
199 31 18:05:07.5 1630 086.4 +06.4 +01.3 +00.7 160 500 150 3524 5 2957 192976 12   0 3340 43338 0 3351 03386 0 3763 213396 0
199 31 18:05:08.0 1630 087.1 +05.5 +01.4 +00.8 160 500 150 3523 5 2941 152976 11   0 3340 53338 0 3351 03386 1 3742 233396 0
199 31 18:05:08.5 1640 087.1 +05.5 +01.6 +00.6 160 500 150 3523 6 2941 112984 16   0 3340 53338 0 3351 03386 0 3749 193396 0
199 31 18:05:09.1 1640 086.9 +05.2 +01.7 +00.5 160 500 150 3523 4 2941 112968 16   0 3334 03338 0 3351 03386 0 3756 213403 5
199 31 18:05:09.6 1650 086.4 +05.2 +01.4 +00.2 160 500 150 3524 4 2949 122984 13   0 3340 43338 0 3351 03386 0 3763 233396 0
199 31 18:05:10.1 1640 086.4 +05.6 +01.0 +00.2 160 500 150 3523 4 2934 182976 14   0 3340 43338 0 3351 03386 1 3763 243396 0
199 31 18:05:10.7 1650 086.4 +05.6 +00.7 -00.1 160 500 150 3523 5 2941 142976 10   0 3340 43338 0 3351 03386 1 3756 243396 0
199 31 18:05:11.2 1670 086.0 +06.3 +00.2 -00.1 161 500 150 3524 4 2941 132968 11   0 3340 43338 0 3351 03386 0 3763 203396 0
199 31 18:05:11.7 1670 086.0 +06.8 -00.3 +00.2 161 500 150 3524 4 2949 102976 16   0 3340 43338 0 3351 03386 0 3763 223396 0
199 31 18:05:12.3 1660 085.7 +06.8 -00.3 +00.3 160 500 150 3523 4 2942 132969 16   0 3334 03338 0 3351 03386 0 3763 263396 0
199 31 18:05:12.8 1660 085.7 +07.0 +00.2 +00.2 160 500 150 3523 5 2933 142976 14   0 3340 53338 0 3351 03386 1 3763 233396 0
199 31 18:05:13.4 1660 085.7 +07.0 +00.8 +00.0 160 500 150 3523 4 2941 122968 12   0 3334 03338 0 3351 03386 2 3763 253396 0
199 31 18:05:13.9 1680 085.9 +07.0 +01.3 +00.0 160 500 150 3523 4 2933 122961 10   0 3334 03338 0 3351 03386 0 3763 263403 5
199 31 18:05:14.5 1670 085.9 +06.9 +02.1 -00.1 160 500 150 3523 4 2949 102976 13   0 3340 53338 0 3351 03386 0 3756 253396 0
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199 31 18:05:16.1 1640 086.4 +06.5 +01.7 -00.7 161 500 150 3523 4 2933 142984 19   0 3334 03338 0 3351 03386 1 3763 233396 0
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199 31 18:05:17.1 1640 086.1 +06.8 -00.2 -00.6 162 500 150 3523 5 2934 112984 17   0 3340 43338 0 3351 03386 1 3763 213403 5
199 31 18:05:17.7 1640 086.1 +07.1 -01.0 -00.6 162 500 150 3523 4 2949 132992 11   0 3340 43338 0 3351 03386 1 3756 223396 0

 1  2     3        4    5     6     7     8    9  10  11   12  13  14 |15| 16 |17  18 19 20| 21  22  23 |24| 25  26  27 28| 29  30
```

Column number	Explanation	Column number	Explanation
1	Calendar day number	16	C-band temperature, vertical polarization (in degrees K)
2	Line/run	17	C-band standard deviation, vertical polarization (in degrees K)
3	NERDAS time	18	Content is meaningless.
4	Aircraft altitude (in feet)	19	Ku-band temperature, horizontal polarization (in degrees K)
5	Aircraft heading (in degrees true)	20	Ku-band standard deviation, horizontal polarization (in degrees K)
6	Aircraft drift angle (in degrees) [Clockwise is positive.]	21	Ku-band temperature, vertical polarization (in degrees K)
7	Aircraft roll angle (in degrees) [Right wing down is positive.]	22	Ku-band standard deviation, vertical polarization (in degrees K)
8	Aircraft pitch angle (in degrees) [Nose up is positive.]	23	K-band temperature, horizontal polarization (in degrees K)
9	Aircraft ground speed (in knots)	24	K-band standard deviation, horizontal polarization (in degrees K)
10	Content is meaningless.	25	K-band temperature, vertical polarization (in degrees K)
11	Content is meaningless.	26	K-band standard deviation, vertical polarization (in degrees K)
12	L-band temperature (in degrees K)	27	Ka-band temperature, horizontal polarization (in degrees K)
13	L-band standard deviation (in degrees K)	28	Ka-band standard deviation, horizontal polarization (in degrees K)
14	C-band temperature, horizontal polarization (in degrees K)	29	Ka-band temperature, vertical polarization (in degrees K)
15	C-band standard deviation, horizontal polarization (in degrees K)	30	Ka-band standard deviation, vertical polarization (in degrees K)

Figure A-1.- Sample output from program CONVERT and an explanation of column values.

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FILE: MFMR FORTRAN A EODL / JOHNSON SPACE CENTER

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CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                     C
C                                                                     C
C   THIS IS THE SECOND OF FOUR PROGRAMS USED TO CONVERT THE           C
C   MFMR DATA TAPES FROM THE SENSOR ANALYSIS LAB INTO A FORMAT        C
C   THAT FACILITATES COMPARISON TO THE SOIL MOISTURE GROUND TRUTH     C
C                                                                     C
C   THE INPUT PARAMETERS FROM UNIT 10 ARE:                            C
C                                                                     C
C      ILINE     = THE NUMBER OF THE FLIGHT LINE                      C
C      IRUN      = THE NUMBER OF THE RUN                              C
C      IDAY      = CALENDAR DAY NUMBER                                C
C      IMIN      = THE NUMBER OF MINUTES ON THE AIRCRAFT CLOCK        C
C      SEC       = THE NUMBER OF SECONDS AND TENTHS ON THE CLOCK      C
C      ROLL      = THE AIRCRAFT ROLL IN DEGREES AND TENTHS            C
C                   A POSITIVE ROLL IS WHEN THE RIGHT WING IS DOWN    C
C      PITCH     = THE AIRCRAFT PITCH IN DEGREES AND TENTHS           C
C                  A POSITIVE PITCH IS WHEN THE NOSE IS UP            C
C      DRIFT     = THE AIRCRAFT DRIFT IN DEGREES AND TENTHS           C
C                  A POSITIVE DRIFT IS CLOCKWISE FROM HEADING         C
C      IALT      = THE AIRCRAFT ALTITUDE IN FEET                      C
C      ISPEED    = THE AIRCRAFT GROUND SPEED IN KNOTS                 C
C      HEAD      = THE AIRCRAFT HEADING IN DEGREES AND TENTHS         C
C      _TMP_     = THE PASSIVE MICROWAVE TEMPERATURE, THE FIRST ONE   C
C                  (OR TWO) SPACE(S) CONTAIN THE BAND IDENTIFICATION. C
C                  THE LAST SPACE CONTAINS A ONE LETTER CODE FOR      C
C                  POLARIZATION.                                      C
C      _SD_      = THE STANDARD DEVIATION OF THE TEMPERATURE. THE     C
C                  SPACES ARE DEFINED IN THE SAME WAY AS FOR THE      C
C                  TEMPERATURES.                                      C
C                                                                     C
C                                                                     C
C   THE OUTPUT PARAMETERS TO UNIT 13 ARE:                             C
C                                                                     C
C      IC1,IC2,IC3 = A THREE NUMBER CODE FOR DAY/DATA TYPE/ANGLE.     C
C      TOTX      = THE DOWNTRACK DISTANCE (IN FEET) OF THE AIRCRAFT   C
C                  FLIGHT PARAMETERS                                  C
C      TOTY      = THE DISTANCE (IN FEET) TO THE SOUTHERN/EASTERN     C
C                  FIELD BOUNDARIES FOR THE FLIGHT PARAMETERS         C
C      ITEN      = USED TO PUT TIME MARKS ON THE PLOT                 C
C      _TMP_     = SAME AS THE INPUT.                                 C
C      _SD_      = SAME AS INPUT.                                     C
C                                                                     C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      REAL TOTX(510),TOTY(510),ITEN(510),ACSEC(510),DRIFT(510)
      REAL TRACK(510),SPEED(510),YOFF(510)
      INTEGER CSDH(510),CTMPV(510),CSDV(510),KUTMPH(510)
      INTEGER KUSDH(510),KUTMPV(510),KUSDV(510),KTMPH(510),KSDH(510)
      INTEGER KTMPV(510),KSDV(510),KATMPH(510),KASDH(510),KATMPV(510)
      INTEGER KASDV(510),LTMP(510),LSD(510),CTMPH(510),ITIME(510)
C
C  THESE STATEMENTS ASK FOR AND READ INFORMATION FROM THE TERMINAL
C
      WRITE(16,161)
  161   FORMAT('INPUT AMISS AND YUP IN F3.0,F3.0')
      READ(15,151)AMISS,YUP
  151   FORMAT(F3.0,F3.0)
      WRITE(16,162)
  162   FORMAT('TYPE IN THE THREE NUMBER CODE FOR DAY/DATA TYPE/ANGLE')
      READ(15,152)IC1,IC2,IC3
  152   FORMAT(3I1)
      YUP=((YUP-AMISS)/25.4)*1000.0
      AMISS=(AMISS/25.4)*1000.0
      CHGSN=1.0
      YOLD=0.0
      ICHK=0
      HTOT=0.0
      TOTY(1)=0.0
      TOTX(1)=0.0
C
C  THESE STATEMENTS READ IN AND MANIPULATE THE  DATA
C
      IFLAG=0
      DO 1 I=1,510
        READ(10,106,END=201)IDAY,ILINE,IRUN,IMIN,SEC,IALT,HEAD,DRIFT(I),
     1    ROLL,PITCH,ISPEED,LTMP(I),LSD(I),CTMPH(I),CSDH(I),
     2    CTMPV(I),CSDV(I),KUTMPH(I),KUSDH(I),KUTMPV(I),
     3    KUSDV(I),KTMPH(I),KSDH(I),KTMPV(I),KSDV(I),KATMPH(I),KASDH(I),
```

```
     4    KATMPV(I),KASDV(I)
 106   FORMAT(I1,1X,I1,I1,4X,I2,1X,F4.1,1X,I4,1X,F5.1,1X,F5.1,
     1     1X,F5.1,1X,F5.1,1X,I3,9X,I4,I3,1X,I4,I3,I4,I3,
     2     6X,I4,I3,I4,I3,1X,I4,I3,I4,I3,1X,I4,I3,I4,I3)
       SPEED(I)=FLOAT(ISPEED)
       ALT=FLOAT(IALT)
       MIN=FLOAT(IMIN)
       ACSEC(I)=(MIN*60.0)+SEC
       DTOR=(ROLL*3.141593)/180.0
       YOFF(I)=ALT*TAN(DTOR)
       NUMBAC=I-1
       IMIN=IMIN*1000
       ISEC=IFIX(SEC*10.0)
       ITIME(I)=IMIN+ISEC
       SPEED(I)=SPEED(I)*1.6878
       IF(HEAD.LT.40.0)HEAD=HEAD+360.0
       ICTR=I-1
       IF(I.NE.1)ICHK=ITIME(I)-ITIME(ICTR)
       IF(ICHK.GT.30)IFLAG=1
       IF(ICHK.LT.0)IFLAG=2
       IF(IFLAG.EQ.1)ITIME(I)=ITIME(I)-400
       IF(IFLAG.EQ.2)ITIME(I)=ITIME(I)+60000
       IF(IFLAG.EQ.2)ACSEC(I)=ACSEC(I)+3600.0
     1 TRACK(I)=DRIFT(I)+HEAD
 201 CONTINUF
       IF(ILINE.EQ.1)CHGSN=-1.0
       IF(ILINE.EQ.4)CHGSN=-1.0
       IF(ILINE.EQ.5)CHGSN=-1.0
       YUP=YUP/((ACSEC(NUMBAC)-ACSEC(1))*SPFED(1))
       NN=NUMBAC+1
C
C  THESE STATEMENTS COMPUTE THE AVERAGE FLIGHT DIRECTION
C
       ANN=FLOAT(NN)
      DO 14 K=1,NN
  14   HTOT=HTOT+TRACK(K)
      HAVG=HTOT/ANN
C
C  THIS SECTION COMPUTES THE LOCATION OF THE AIRCRAFT
C
      DO 11 I=1,NUMBAC
        ELPTME=FLOAT(ITIME(I+1)-ITIME(I))/10.0
        IF(ELPTME.GT.40.0)ELPTME=ELPTME-40.0
        MSEC=IFIX(ELPTME)
        IF(MSEC.GT.2)ELPTME=ELPTME-MSEC
        ANGLE=(((HAVG-TRACK(I)))*3.141593)/180.0
        DISP=ELPTME*SPEED(I)
        XDISP=DISP*COS(ANGLE)
        YDISP=DISP*SIN(ANGLE)*CHGSN
        L=I+1
        IF(I.EQ.1)GO TO 12
        YDIFF=(YOFF(I)-YOFF(I-1))*CHGSN
        TOTX(L)=TOTX(L-1)+XDISP
        TOTY(L)=TOTY(L-1)+YDISP+YDIFF+(YUP*TOTX(L)-YUP*TOTX(L-1))
          GO TO 11
  12 TOTX(L)=XDISP
        TOTY(L)=YDISP+YOFF(I)+AMISS
  11 CONTINUE
C
C  THIS SECTION DETERMINES WHICH DATA IS AT 10 SECONDS
C
      DO 8 I=2,NUMBAC
        L=I-1
        ITEN(I)=0.0
        ITEMP=ITIME(I)/100
        IDIFF=ITIME(I)-(ITEMP*100)
        IF(IDIFF.LE.3)ITEN(I)=TOTY(L)+100.0
        IF(IDIFF.GT.96)ITEN(I)=TOTY(L)+100.0
   8  CONTINUE
      DO 5 K=1,NUMBAC
   5    WRITE(13,104)IC1,IC2,IC3,ILINE,IRUN,TOTX(K),TOTY(K),ITEN(K),
     1     LTMP(K),LSD(K),CTMPH(K),CSDH(K),CTMPV(K),CSDV(K),KUTMPH(K),
     2     KUSDH(K),KUTMPV(K),KUSDV(K),KTMPH(K),KSDH(K),KTMPV(K),KSDV(K),
     3     KATMPH(K),KASDH(K),KATMPV(K),KASDV(K),ITIME(K)
 104    FORMAT(3I1,1X,I1,'/',I1,1X,F5.0,1X,F5.0,1X,F5.0,2X,I4,1X,
     1     I3,2X,I4,1X,I3,1X,I4,1X,I3,2X,I4,1X,I3,1X,I4,1X,I3,2X,
     2     I4,1X,I3,1X,I4,1X,I3,2X,I4,1X,I3,1X,I4,1X,I3,3X,I6)
      STOP
      END
```

```
FILE: MEMR      EXEC      A    EODL / JOHNSON SPACE CENTER

REMOTE " TO HOUSTON
SPOOL E NOHOLD
GLOBAL TXTLIB CMSLIB FORTMOD2
FILEDEF 5 READER (PERM
FILEDEF 6 PRINTER (PERM
FILEDEF 7 PUNCH (PERM
FILEDEF 10 DISK 61 EDATA A (PERM RECFM F LRECL 132 BLKSIZE 132
FILEDEF 13 DISK 61 YMEMR A (PERM RECFM F LRECL 132 BLKSIZE 132
FILEDEF 15 TERMINAL (PERM
FILEDEF 16 TERMINAL (PERM
LOAD MEMR
START
```

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OF POOR QUALITY

FILE: MPLOT   SAS   A   EODL / JOHNSON SPACE CENTER

```
CMS FILEDEF FILE1 DISK MEMR1 YMEMR A1;
DATA  PART1 PART2;
   INFILE FILE1;
   INPUT @9 X 6.0 @16 Y 5.0 @22 YTIC 5.0 @39 YI ;
   AA=((YI/10.0)-270.0)/3.0;
   IF YTIC = 0.0 THEN YTIC=.;
   Y2=AA*300.0+3000.0;
   DROP AA;
   IF X LE 40000 THEN OUTPUT PART1;
   IF X GE 20000 THEN OUTPUT PART2;
PROC PLOT DATA=PART1;
   PLOT X*Y='*' X*YTIC='!' X*Y2='*'/OVERLAY
      HAXIS= -3000 TO 9000 BY 1000
      VAXIS= 0 TO 40000 BY 1000
      HSPACE= 10 VSPACE= 8
   HREF=0 3000 3150 6500
   VREF=0 TO 40000 BY 5000
   VPOS=350 ;
PROC PLOT DATA=PART2;
   PLOT X*Y='*' X*YTIC='!' X*Y2='*'/OVERLAY
      HAXIS=-3000 TO 9000 BY 1000
      VAXIS=20000 TO 62000 BY 1000
      HSPACE=10 VSPACE=8
   HREF=0 3000 3150 6500
   VREF=20000 TO 62000 BY 5000
   VPOS=350 ;
```

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FILE: MGRIO   FORTRAN D   EODL / JOHNSON SPACE CENTER

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                 C
C    THIS PROGRAM IS THE FOURTH OF FOUR PROGRAMS USED TO PROCESS  C
C    THE COLBY ASME RADIOMETER DATA.  THIS PROGRAM SEPERATES THE  C
C    DATA INTO FILES FOR EACH SAMPLED FIELD ALONG THE FLIGHT LINE. C
C    ALONG WITH THE MFMR TEMPERATURES THE CORRESPONDING PRT-5     C
C    TEMPERATURES ARE WRITTEN IN EACH FILE.                       C
C                                                                 C
C    THE INPUTS FROM UNIT 2 ARE:                                  C
C     IMIN    = THE NUMBER OF MINUTES PAST THE HOUR ON THE        C
C               NERDAS CLOCK,                                     C
C     SEC     = THE NUMBER OF SECONDS PAST THE MINUTE ON THE      C
C               NERDAS CLOCK                                      C
C     PTEMP   = THE ARRAY CONTAINING THE PRT-5 TEMPERATURES.      C
C     IRANGE  = THE TEMPERATURE RANGE SETTING ON THE PRT-5        C
C     TAT     = THE ARRAY CONTAINING THE TOTAL AIR TEMPERATURE    C
C               AS MEASURED AT THE AIRCRAFT                       C
C                                                                 C
C    THE INPUT VARIABLES FRON UNIT 9 ARE:                         C
C     IC1,                                                        C
C     IC2,IC3= SEE TABLE IN TEXT FOR EXPLANATION                  C
C     ILINE   = THE FLIGHT LINE NUMBER                            C
C     IRUN    = THE NUMBER OF THE RUN                             C
C     MFMRX   = THE DOWNTRACK DISTANCE (IN FEET) OF THE DATA      C
C     MFMRY   = THE DISTANCE TO THE SOUTHERN/EASTERN FIELD        C
C               BOUNDARIES                                        C
C     IMFMR   = THE ARRAY CONTAINING THE RADIOMETER DATA          C
C                                                                 C
C    THE INPUTS FROM UNIT 10 ARE:                                 C
C                                                                 C
C     IFLD    = AN ARRAY CONTAINING THE NUMBERS OF THE SAMPLED    C
C               FIELDS IN THE FLIGHT LINE                         C
C     START   = THE DOWNTRACK DISTANCES OF THE FIELDS IN THE LINE C
C     XWIDE   = THE LENGTH OF THE FIELDS (ALONGTRACK)             C
C     YWIDE   = THE WIDTH OF THE FIELDS (CROSSTRACK)              C
C                                                                 C
C    THE OUTPUT VARIABLES ARE:                                    C
C                                                                 C
C     IC1,IC2,IC3,IFLD,ILINE,IRUN= SEE   ABOVE                    C
C     X       = NUMBER OF FEET FROM NORTHERN FIELD BOUNDARY       C
C     Y       = NUMBER OF FEET FROM THE WESTERN FIELD BOUNDARY    C
C     MFMR    = THE ARRAY OF THE RADIOMETER DATA                  C
C                                                                 C
C     THE WRITE STATEMENT USED IS DEPENDENT UPON THE              C
C     DATA TYPE.  MECHANICAL LIMITATIONS PREVENTS L-BAND AND      C
C     C-BAND FROM BEING ACQUIRED SIMULTANEOUSLY.  FOR THE COLBY   C
C     EXPERIMENT, THE KU, K AND KA BAND SENSORS WERE TURNED ON    C
C     WHENEVER THE L-BAND WAS ON.  THE C-BAND SENSOR WAS OPERATED C
C     BY ITSELF.                                                  C
C                                                                 C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      INTEGER*2 IFLD(15),IMFMR(510,18),MFMR(15,18),A(75,132),X(20),Y(20)
      REAL START(15),XWIDE(15),YWIDE(15),APRT(15),ATAT(15)
      INTEGER MFMRY(510),KTIME(15),MFMRX(510),ITIME(510),PTIME(400)
      INTEGER MMFMR(15)
      COMMON A
      REAL PTEMP(400),TAT(400)
C
C  READ THE INPUT FILES
C
      READ(9,100)IC1,IC2,IC3,ILINE,IRUN,MFMRX(1),MFMRY(1),
     6  (IMFMR(1,N),N=1,18),ITIME(1)
100   FORMAT(3I1,1X,I1,1X,I1,1X,I5,1X,I5,9X,I4,1X,
     1     I3,2X,I4,1X,I3,1X,I4,1X,I3,2X,I4,1X,I3,1X,I4,1X,I3,2X,
     2     I4,1X,I3,1X,I4,1X,I3,2X,I4,1X,I3,1X,I4,1X,I3,3X,I6)
      DO 1 M=2,510
        READ(9,101,END=11)MFMRX(M),MFMRY(M),(IMFMR(M,N),N=1,18),ITIME(M)
101       FORMAT(8X,I5,1X,I5,,9X,I4,1X,
     1       I3,2X,I4,1X,I3,1X,I4,1X,I3,2X,I4,1X,I3,1X,I4,1X,I3,2X,
     2       I4,1X,I3,1X,I4,1X,I3,2X,I4,1X,I3,1X,I4,1X,I3,3X,I6)
1       NUMB=M
11    CONTINUE
      DO 2 N=1,15
        READ(10,102,END=12)IFLD(N),START(N),XWIDE(N),YWIDE(N)
102       FORMAT(I2,1X,F7.1,1X,F6.1,1X,F6.1)
2     NFLDS=N
12    DO 400 MK=1,400
      READ(2,404,END=401)IMIN,SEC,PTEMP(MK),IRANGE,TAT(MK)
404   FORMAT(20X,I2,1X,F4.1,53X,F5.2,14X,A1,9X,F5.2)
```

FILE: MGRID FORTRAN D EODL / JOHNSON SPACE CENTER

```
      PTIME(MK)=(IMIN*1000)+IFIX(SEC*10.0)
      IF(MK.EQ.1)GO TO 400
      KCHK=PTIME(MK)-PTIME(MK-1)
      IF(KCHK.GT.30)PTIME(MK)=PTIME(MK)-400
      IF(KCHK.LT.0)PTIME(MK)=PTIME(MK)+60000
  400 CONTINUE
C
C  M IS THE COUNTER FOR INPUT FILE 10
C
  401 M=1
C
C  THIS SECTION LOOKS FOR THE BOUNDARIES IN THE DATA
C
      DO 3 K=1,NUMB
         IF(MFMRX(K).LT.START(M))GO TO 3
         L=K+1
         END=START(M)+XWIDE(M)
      DO 4 N=1,20
         IF(MFMRX(L).GT.END)GO TO 44
    4  L=L+1
   44 L=L-1
      ARANGE=MFMRX(L)-MFMRX(K)
C
C  THIS SECTION SETS UP THE FIELD DIMENSIONS
C
      NPTS=L-K+1
      ISTART=1
      BTWN=0.0
      XW=XWIDE(M)
      YW=YWIDE(M)
      IF(ILINE.EQ.1)XW=0.0
      IF(ILINE.EQ.4)XW=0.0
      IF(ILINE.GE.6)YW=0.0
      IF(ILINE.GT.4)GO TO 45
C
C  THIS SECTION IS FOR LATITUDINAL FLIGHT LINES
C
      EDGE=(XWIDE(M)-ARANGE)/2.0
      DO 5 N=1,NPTS
         NUM=L-N+1
         X(N)=IFIX(ABS(XW-(EDGE+BTWN)))
         Y(N)=IFIX(YWIDE(M)-MFMRY(NUM))
         KTIME(N)=ITIME(NUM)
      DO 6 NN=1,18
    6    MFMR(N,NN)=IMFMR(NUM,NN)
       KTR=L-N
       BTWN=MFMRX(L)-MFMRX(KTR)
    5 CONTINUE
      CALL PRTS(NPTS,ISTART,APRT,ATAT,KTIME,PTIME,PTEMP,TAT)
        GO TO 55
C
C  THIS SECTION IS FOR LONGITUDINAL FLIGHT LINES
C
   45  EDGE=(YWIDE(M)-ARANGE)/2.0
      DO 7 N=1,NPTS
         NUM=L-N+1
         X(N)=IFIX(XW-MFMRY(NUM))
         Y(N)=IFIX(ABS(YW-(EDGE+BTWN)))
         KTIME(N)=ITIME(NUM)
      DO 8 NN=1,18
    8    MFMR(N,NN)=IMFMR(NUM,NN)
       KTR=L-N
       BTWN=MFMRX(L)-MFMRX(KTR)
    7 CONTINUE
      CALL PRTS(NPTS,ISTART,APRT,ATAT,KTIME,PTIME,PTEMP,TAT)
C
C  PREPARE TO WRITE THE OUTPUT FILES
C
   55 IUNIT=10+M
C
C  WRITE OU. THE FIELDS COMPUTED IN THIS PROGRAM
C
         IF(IC2.GE.7)GO TO 333
      DO 22 KK=1,NPTS
      MMFMR(KK)=MFMR(KK,1)
   22    WRITE(IUNIT,111)IC1,IC2,IC3,IFLD(M),ILINE,IRUN,X(KK),Y(KK),
     6 MFMR(KK,1),MFMR(KK,2),(MFMR(KK,MN),MN=7,18),APRT(KK),ATAT(KK)
  111     FORMAT(3I1,1X,I2,1X,I1,I1,1X,I4,1X,I4,7(1X,I4,I3),1X,2F6.2)
      GO TO 28
```

```
  333 CONTINUE
      DO 26 KK=1,NPTS
      MMFMR(KK)=MFMR(KK,3)
   26   WRITE(IUNIT,112)IC1,IC2,IC3,IFLD(M),ILINE,IRUN,X(KK),Y(KK),
     1     (MFMR(KK,NM),NM=3,6),APRT(KK),ATAT(KK)
  112   FORMAT(3I1,1X,I2,1X,I1,I1,1X,I4,1X,I4,2(1X,I4,I3),1X,2F6.2)
   28 CONTINUE
        IF(M.EQ.NFLDS)GO TO 33
      M=M+1
      ILYR=3
      MFLD=IFLD(M)
    3 CONTINUE
   33 CONTINUE
      STOP
      END
C
C  THIS SUBROUTINE MATCHES THE PRT-5 DATA WITH THE
C    CORRESPONDING MFMR DATA
C
      SUBROUTINE PRTS(NPTS,ISTART,APRT,ATAT,KTIME,PTIME,PRT,TAT)
      REAL APRT(15),ATAT(15)
      INTEGER PTIME(400),KTIME(15)
      REAL PRT(400),TAT(400)
      KMIN=100000
      KMAX=0
      DO 9 MI=1,NPTS
      IF(KTIME(MI).LT.KMIN)KMIN=KTIME(MI)
    9 IF(KTIME(MI).GT.KMAX)KMAX=KTIME(MI)
      DO 1 I=ISTART,400
      IF(KMIN.GT.PTIME(I))GO TO 1
      LF=I-1
      IS=I
      GO TO 2
    1 CONTINUE
    2 ISTART=IS
      DO 3 M=LF,400
      IF(KMAX.GT.PTIME(M))GO TO 3
      LL=M
      GO TO 4
    3 CONTINUE
    4 DO 6 I=1,NPTS
      DO 5 N=LF,LL
      IF(KTIME(I).GT.PTIME(N))GO TO 5
      M=N-1
      IDIFF=PTIME(N)-PTIME(M)
      KDIFF=KTIME(I)-PTIME(M)
      DIFF1=KDIFF*1.0
      DIFF2=IDIFF*1.0
      RATIO=DIFF1/DIFF2
      DELPRT=PRT(N)-PRT(M)
      DELTAT=TAT(N)-TAT(M)
      APRT(I)=DELPRT*RATIO+PRT(M)
      ATAT(I)=DELTAT*RATIO+TAT(M)
      GO TO 6
    5 CONTINUE
    6 CONTINUE
      RETURN
      END
```