Environment Canada Imaging Cover Page

Report N.:

TEC-860

SKP Box Number: 672572429

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DATA PROCESSING PROCEDURES FOR
THE BARRINGER CORRELATION
SPECTROMETER (COSPEC)

by

R.M. HOFF, A.J. GALLANT and M.M. MILLÁN

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Published under the authority of
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Publication autorisée par
le sous-ministre adjoint

FISHERIES AND ENVIRONMENT CANADA
ATMOSPHERIC ENVIRONMENT SERVICE
4905 Dufferin Street
Downsview, Ontario

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R.M. Hoff, A.J. Gallant and M.M. Millán

ABSTRACT

Use of a Barringer Correlation Spectrometer (COSPEC) at
the Atmospheric Environment Service research facilities in
Toronto has led to the development of a data-processing method-
ology for the acquisition of plume dispersion data from remote-
sensing instruments. The techniques described in this report are
applicable to the use of COSPECs and other mobile sensing equip-
ment. The computer codes, written in the BASIC language, are
documented along with a user's guide for those interested in
employing these techniques.

PROCEDURES DE TRAITEMENT DES DONNÉES APPLICABLES AU SPECTROMÈTRE DE CORRELATION BARRINGER (COSPEC)

par

R.M. Hoff, A.J. Gallant et M.M. Millán

RÉSUMÉ

L'Utilisation du spectromètre de corrélation Barringer
(COSPEC) dans les laboratoires du Service de l'Environnement
atmosphérique, à Toronto, a entraîné l'élaboration de procédures
de traitement de l'information pour l'acquisition de données sur
la dispersion des panaches de fumée au moyen d'appareils de
télédétection. Les techniques décrites dans le présent rapport
s'appliquent aux spectromètres de corrélation et aux appareils de
détection mobiles en général. Le rapport expose le code machine,
écrit en langage BASIC, et présente un guide de l'utilisateur à
l'intention des personnes qui seraient intéressées à employer ces
techniques.

DATA PROCESSING PROCEDURES FOR THE BARRINGER CORRELATION SPECTROMETER (COSPEC)

by

R.M. Hoff, A.J. Gallant and M.M. Millán

(manuscript received February 8, 1978)

1.   Introduction

The use of the Barringer Correlation Spectrometer (COSPEC) for obtaining sulphur dioxide plume dispersion statistics and mass fluxes has been well documented in recent years (Millán et al., 1976a, b, c; Hoff et al., 1976). Although the methodology used to obtain these parameters has been presented in the description of at least three field programs (Millán et al., 1976a, b; Hoff et al., 1976), the data-reduction procedure has not been fully documented.

This report will serve as a user's guide to the COSPEC processing programs and will provide a background to the statistical relevance of the parameters calculated. It should be noted that the methodology is also applicable to plume dispersion data measured by other ground-based sensors, such as the Sign-X, as long as the user is aware of the limitations of interpreting dispersion statistics obtained by means of a point monitor.

2.   Background

Instrumental descriptions of the COSPEC are available from the authors and will not be discussed here. Briefly, the COSPEC measures the total overhead concentration-pathlength product of SO_2 in units of ppm-m or $\mu g/m^2$ and is thus a vertically integrating sensor. Mathematically the signal, S, recorded in volts is:

$$S = C\int_0^\infty \chi(x, y, z, t)\, dz \qquad (1)$$

where C is a constant of proportionality, determined by the use of built-in calibration cells, χ is the concentration of SO_2 and z is the vertical axis. Figure 1 shows schematically a cut or transect of an idealized plume and the corresponding resultant COSPEC signal.

The concentration profile can be analyzed to obtain the standard deviations of its width and position. It appears to be a common misconception that dispersion coefficients such as the standard deviations in the vertical, σ_z, and horizontal, σ_y, apply only to Gaussian profile

plumes. Mathematically, one finds that a distribution is completely defined if all its moments are known. A normal distribution (Gaussian) may be completely defined by its first and second moments (i.e. the centre of gravity, COG, and standard deviation). However, any distribution may be quite accurately described by a small number of lower order moments and, in principle these could be used to give information on the components which generate the distribution (i.e. the wind field, etc.).

Since the COSPEC is a vertically integrating sensor, all information about the vertical distribution of SO_2 is lost. This, however, insures that the standard deviation in the horizontal and the COG are representative of the entire plume. This result is not generally true for a single traverse made with a point monitor, since plume information at points off the line of traverse are not sampled.

By examining our cut of Figure 1, we see that the sheet of SO_2 concentration χ (y,z) at a constant downwind distance, x, and time, t, measured by the COSPEC can give the y-coordinate of the COG of the plume:

$$Y_{COG} = \frac{\int_{-\infty}^{\infty} \int_{0}^{\infty} \chi (y, z) \, y \, dy \, dz}{\int_{-\infty}^{\infty} \int_{0}^{\infty} \chi (y,z) \, dy \, dz} . \tag{2}$$

From equation (1), one sees that the vertically integrating property of the COSPEC essentially performs the integration over z so that:

$$Y_{COG} = \frac{\int_{0}^{\infty} S(y) y \, dy}{\int_{0}^{\infty} S(y) \, dy} . \tag{3}$$

This points up a distinct disadvantage of point monitors, for although they cut the plume at a set height z as the COSPEC does, they cannot perform the integration over z. Thus statistics obtained from a single car or aircraft traverse with a point monitor, such as a Sign-X, must be interpreted with care since the COG and all higher moments obtained are not true moments of plume cross-section but only of the single cut. Several cuts at different heights will be needed with a point monitor to obtain true plume dispersion statistics.

Higher moments of the horizontal distribution can thus be easily calculated:

$$\mu_n = \frac{\int_{0}^{\infty} S(y) (y - Y_{COG})^n \, dy}{\int_{0}^{\infty} S(y) \, dy} . \tag{4}$$

The standard deviation is given by:

$$\sigma y = \sqrt{\mu_2} \tag{5}$$

which specifies the width of the distribution. The skewness of the distribution is given by:

$$S_y = \mu_3 / \sigma_y^3 \tag{6}$$

which is positive for a distribution skewed towards negative values.

The Kurtosis is:

$$K_y = \mu_4 / \sigma_y^4 \tag{7}$$

which describes the peakedness of the distribution. A normal (or Gaussian) distribution would have a kurtosis of 3.0 and would be more peaked for values greater than 3.0.

Finally one may approximate the total mass crossing the plane of transect by:

$$\text{Flux} = C \left(\int_0^\infty S(y) \, dy \right) \bar{u} \tag{8}$$

where C is a constant (for converting to relevant units) and $\bar{u}$ is the average wind speed across the plane of transect. There are, however, limitations under wind shear conditions when this formulation is not valid.

The idealized transect of Figure 1 almost never occurs when one is using a ground-based COSPEC to conduct the traverse. One is constrained to the road network so that the transect is no longer orthogonal to the plume axis nor is it a straight traverse. One may, however, still calculate the centre of gravity of the distribution over the traverse by means of the following equations:

$$X_{COG} = \frac{\int_0^\infty S(x, y) \, x dx}{\oint_0^\infty S(x, y) \, dxdy} \tag{9}$$

and

$$Y_{COG} = \frac{\int^\infty S(x, y) \, y dy}{\oint_0^\infty S(x, y) \, dydx} \tag{10}$$

where $\oint$ denotes a path integral.

Once this centre of gravity has been defined in space and the axis of the plume determined, the traverse may be projected onto an orthogonal plane to determine the plume statistics. Near the stack, the "plume axis" may be well defined by the line from the stack to the centre of gravity. If such information is available, one may more precisely draw the centre-line of the plume back to a COG previously determined from a traverse nearer the stack (Millan et al., 1976b). The geometry regarding this projection will be given in full in the program description.

We have, to this point, only formulated the background to the data-processing problem. The following sections describe the data-reduction procedure and programs. The data reduction at the Atmospheric Environment Service (AES) is done using Hewlett-Packard 9830A calculators and related peripherals. The reader is not provided below with cross-references to other systems or data-reduction techniques. This is not parochialism. A data-reduction system must be designed and thought through right from the field-unit sensor to the printed output. If the reader wishes to pattern a data-reduction procedure along the lines presented in this report, he would be well advised to follow the conceptual flow of the processes rather than the details.

3.   Data Collection and Digitization

The AES processing procedure involves reduction of analog strip-chart records to digital magnetic cassette storage. Analog charts may be either in a timed or elapsed distance mode.

In the timed mode, the chart record is played out at constant speed, so that if the speed of the vehicle is not constant, the record is not a faithful reproduction of the plume in space. This is overcome by using event marks to record the distance traversed by the vehicle. Mileage counters can be obtained from Hartwig Instruments, Toronto, Ontario and are graduated to produce marks on the side of the strip chart corresponding to intervals of 0.1 and 0.01 mile. The authors do not wish to endorse these counters or any others, but can provide manufacturers' names for reference to existing devices. An example of a chart record is shown in Figure 2.

A traverse usually consists of a calibration sequence using the internal SO_2 cells at the start of each record. By convention (we will see why this is important later) the start point of any traverse is the left-most point in space if one were to view the traverse from the stack (i.e. the azimuth with respect to true North of the start point is always less than that of the end point). When traverses are run back and forth along a road under the plume alternate traverses will be reversed from this convention. Chart records reading from left-to-right which spatially do not follow the convention are termed "inverted". If the observed data are to be averaged over a suitable time period, all traverses which are to be averaged must have the same spatial start point. This is not just a constraint, it is also a good data-collection technique, since it discourages "plume chasing".

In the elapsed distance mode (for example, using an ARQT SPED counter connected to the wheel hub odometer) chart records are played out synchronously with elapsed distance thus making event marks (other than start and end points) unnecessary. The authors' system employs a Hewlett-Packard 9861A Digitizer and the data are stored on cassette tapes in an HP 9865A Cassette Memory Unit for subsequent processing.

In this and the following sections the reader is encouraged to refer to the appendices which contain a user's guide to each data-processing program as well as computer listings of the routines. The first program the user will need is a COSPEC digitizer routine. Depending on the mode for recording the data the user has two routines that may be chosen:

(1)   the COSPEC Digitization (Asynchronous) Routine (Appendix A) is designed to digitize chart records taken in the event marker mode described above.

(2)   The alternate routine (COSPEC Digitization Routine (for SPED data); Appendix B) is designed for charts recorded in an elapsed distance mode.

4.   Map Digitization Routine

Assuming that the digitization of the COSPEC data is complete, the next step is to create a set of map files so that the processing program can determine the spatial orientation of each of the traverses taken. This program (Appendix C) requires use of topographic or road maps or, if properly scaled, aerial photographs of the research area. These maps should be sufficiently large to include a fair number of data points (the grid used is 0.05 inch in the program). Each traverse should not, however, cover more than 12 inches on the map (because of file size restrictions). The authors have found that 1:250,000 to 1:25,000 is a useful range of map scales for field use.

5.   COSPEC Processor

The COSPEC data-processing routines are linked in four sub-routines (Appendix D). The program flow is shown in Figure 3. The original digitized data are averaged over a suitable time period, usually $\frac{1}{2}$ or 1 hour depending on the standards criteria prevalent in the province where the data are observed. The average profile data are stored and then, after the proper map file has been referenced, are processed to give the distance of the centre-of-gravity of the profile from the stack y (in metres). The bearing of the COG from the stack is also produced and can be used to define the normal to the projection plane. This procedure can be modified by finding the bearing to a nearer COG (if one is available). In this way shearing plumes which are examined simultaneously by more than one COSPEC may be more properly tracked.

The program then calculates the actual crosswind distances of the projected profiles and respaces and interpolates the data so that compression or expansion on projection is eliminated. The profile thus created from the average profile is the Eulerian or ground-referenced average.

The Eulerian average is processed to give its COG relative to the true COG of the average profile (this should be near zero, if the projection does not severely compress the data; see Millan, 1976c). The plume statistics are then output to the printer, the Eulerian average stored and the same process repeated on each of the original data profiles.

Once this procedure is complete, the program forms the Lagrangian (or plume-referenced) average profile. This is accomplished by superimposing COG's for the individual profiles and then averaging. Statistics are then output for the Lagrangian average.

A few words of explanation concerning how certain techniques are carried out in the program may be helpful to the user. All data files are 768 point arrays. Because array length is limited to 256 word rows, data are stored in a 3 x 256 array, along with two string variables for data and traverse information stored in COMMON locations. Much of the COSPEC PROCESSOR deals with juggling these arrays and will not be explained here. It is useful to note that the length of this program and its run time can be significantly improved by using a machine which is not subject to these array limitations.

The map file which has been digitized contains a 2 x N member array (N $\leqslant$ 256) in which the first row contains the x coordinate (in metres) relative to the stack for each data point digitized and the second, the y coordinate. Since these data points do not correspond to the COSPEC data digitization grid the map file must be respaced. This is carried out in the second linked program of the processor. Referring to Figure 4, it may be seen that that x and y coordinates of the data points on the proper grid may be interpolated from the map file. The relevant equations for these points are:

$$x = T(1,N) + (D1-D\emptyset) * \sin (\theta)$$

$$y = T(2,N) + (D1-D\emptyset) * \cos (\theta)$$

where θ =   azimuth bearing (from true North) of the road segment digitized between point N and N + 1;

          $D\emptyset$ =   distance from start of traverse to start of road segment N;

          D1   =   distance along road segment N.

The program runs several series of tests to ensure that $D\emptyset$ does not exceed total traverse length, that θ is in the proper quadrant, and that D1 does not exceed the coordinate value for the start of the next digitized road segment.

The coordinates x, y and θ are stored in Files 8, 9, 10, respectively, of the processor cassette, as memory limitations force use of the full core. These files are read in the third linked subprogram which calculates the true crosswind distances. The COG of the average plume is now easily calculated by equations (9) and (10), since the x and y values are now stored in the same array element configuration as that of the signal array. The integrals in this program are calculated by a rectangular approximation, since dual stepwise summation via Simpson's method is extremely tedious because of the awkward array structure. The y grid spacing is sufficiently narrow that the rectangular approximation should be adequate.

Once the COG of the profile is known the average profile and the individual profiles must be projected onto the crosswind plane. If the coordinates of the COG are defined as X7, Y7 and the bearing to the stack (or previous COG) is given by T2, simple geometry shows that the crosswind distance of any point I in our array (Figure 5) is:

$$D = [(T(1, I) - X7)^2 + (T(2, I) - Y7)^2]^{\frac{1}{2}} * \sin (T4)$$

where T(1,I) and T(2,I) are the x, y coordinates of data point I, and T4 is given by:

$$T4 = T3 - T2$$

where T3 is the bearing of point I.

It should be clear to the reader that the crosswind distances so calculated will never be properly spaced unless the original traverse is straight. Even then the grid spacing will differ from the original spacing by a factor which is the cosine of the projection angle. Therefore the array of crosswind distances must again be respaced to match the original grid size, which is done in subprogram III. This procedure is essentially the same as for the map respacing except that now the actual data must be interpolated to obtain their correct values. The interpolation variables are drawn in Figure 6. A listing of a computer-output run using the HP 9830A "PRINT-ALL" feature is shown in Figure 7. Heavy underlines indicate operator input.

Completion of the processor program may be followed by the processing of additional half-hourly or hourly averages. Alternatively, the user may wish to obtain hard copy plots of the data (Appendix E) in one of the three plotting modes available. In the "SPACE" mode, the raw data are plotted versus elapsed distance along the road traverse (Figure 8). In the "EULERIAN" mode, the profiles are plotted with respect to the average centre of gravity in the projected plane (Figure 9). A final form of presentation is shown in Figure 10 for the "LAGRANGIAN" mode in which all centres-of-gravity are aligned at the origin, labelled "COG".

6.	Conclusion

This paper has detailed the technical procedures used by the AES to process data observed by COSPEC and other ground-based sensors. The theory of the data-analysis scheme has been presented along with listings of the programs used and a user's guide.

7.	Acknowledgements

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2.   M.M. Millán, A.J. Gallant, H. E. Turner, Atmospheric Environment 10, 499 (1976a).

3.   M. M. Millán, R. M. Hoff, A. J. Gallant, Presentation 76-26.4, Air Pollution Control Association 69th Annual Meeting, Portland, Ore. (June 27, 1976b).

4.   M. M. Millán, Atmospheric Environment 10, 655 (1976c).

APPENDICES

The following appendices include a users' guide to the AES COSPEC data-processing procedure and also listings of the BASIC routines. These listings were made on an impact printer for clarity. The reader should note, however, that the number zero is represented by "0" rather than the "∅" found in the normal HP printed output; also, all capitalization refers to input and output statements as they appear in the calculator display of the printout.

APPENDIX A

COSPEC DIGITIZATION ROUTINE (ASYNCHRONOUS)

Source File: Processor Cassette File 1

For use in digitizing chart data taken in timed mode with external event markers to indicate the distance traversed.

Procedure

1.   Mark the data cassette with 22 files of 1575 words each. Command structure is: MARK #5,22,1575. ERROR 58 should result during the writing of file 21; rewind the tape to start. Files 0-20 are available for use.

2.   Turn on 9861A and align chart record with platen. Set "origin" (0) at bottom of chart.

3.   Several internal program parameters must be adjusted for the chart-recording variations possible.

        The variable K is the number of miles (metres, kilometres) in the traverse. If the event marker triggers every 0.1 miles, line 660 should read $N = INT (K/0.1)$. Change this line to obtain different event rates. N should always be the number of event marks on the record.

        The program interpolates values between event marks, since 160.7 m (0.1 miles) is too coarse a grid size. Line 100 gives the final digitization interval D7 which is 160.7/5 = 32.1 m for the existing program. If K or D7 must be changed the loop in 730 must also be changed to produce the proper fractional stepping between event marks.

        C9 (line 110) is the value of the calibration cell in ppm-m or $\mu g/m^2$.

4.   Run program (LOAD 2, RUN).

5.   "INPUT LST: DAY/MONTH/YEAR" - Enter traverse data and time (not current date) in given format. Example: "1027: 16/10/76" (quotes may be omitted).

6.   "TOTAL MILEAGE READING" - enter mileage.

7.   "IS TRACE INVERTED" - enter "YES" or "NO" (quotes optional).

8.   "READY FOR CAL-CONTINUOUS ON" - Switch to "continuous" after positioning the digitizer cursor at the reading for calibration signal. The digitizer will beep when each data point is read averaging 40 points over 0.8 inch of chart record.

9.   "CAL OFF" - follow a procedure similar to (8) for the baseline reading.

10.   Program responds with output of the calibration scaling and the baseline already digitized. If compensation for baseline drift is desired, reset baseline by entering the distance (inches) of the new baseline above the edge of the chart. The calibration remains valid.

11.   "SET TO SINGLE" - push "S" on cursor within 10 seconds (if you haven't already done so). It is good practice to always press SINGLE on the cursor after a CONTINUOUS run is taken. This prevents the program from running away from the operator inadvertently at some other point in the program.

12.   "ENTER LEAD EDGES, END PT. ON SNGL" - for each event mark, enter a single pulse, digitizing always from the start point to the end point as per the convention.

13.   "SWITCH TO CONTINUOUS AND DIGITIZE SIGNAL" - self-explanatory, but note that the 9861A always acknowledges the receipt of a valid data point with a beep. If a significant distance along the record is travelled without a beep, retrace the curve until the proper point is found.

14.   "C.M. FILE FOR STORAGE" - enter an available file number on the data cassette in external cassette memory.

15.   Program complete - follow same procedure for all traverses on chart records.

```
10  COM D$[13],T$[50],SS[3,256]
20  REM COSPEC DIGITIZATION ROUTINE (ASYNCHRONOUS) MOD 2
30  DIM Y[40],Z[40],RS[3,256],Q$[3]
40  DISP "INPUT LST:DAY/MONTH/YR";
50  INPUT D$
60  DISP "INPUT START-END LOCATIONS";
70  INPUT T$
80  DISP "TOTAL MILEAGE READING";
90  INPUT K
100 D7=160.7/5
110 C9=5300
120 M1=1
130 M2=4
140 DISP "IS TRACE INVERTED";
150 INPUT Q$
160 IF Q$#"YES" THEN 190
170 I3=-1
180 GOTO 200
190 I3=+1
200 DISP "READY FOR CAL, CONTINUOUS ON";
210 WAIT 10000
220 FOR I=1 TO 40
230 IF I>1 THEN 270
240 ENTER (9,*)X0,Y[I]
250 WRITE (9,*)
260 GOTO 310
270 ENTER (9,*)X,Y[I]
280 IF X#X0+0.02 THEN 270
290 WRITE (9,*)
300 X0=X
310 NEXT I
320 DISP "CAL OFF"
330 WAIT 10000
340 FOR I=1 TO 40
350 IF I>1 THEN 390
360 ENTER (9,*)X0,Z[I]
370 WRITE (9,*)
380 GOTO 430
390 ENTER (9,*)X,Z[I]
400 IF X#X0+0.02 THEN 390
410 WRITE (9,*)
420 X0=X
430 NEXT I
440 S1=S2=0
450 FOR I=1 TO 40
460 S1=S1+Y[I]
470 S2=S2+Z[I]
480 NEXT I
490 C1=S1/40
500 C2=S2/40
510 S9=C9/(C1-C2)
520 PRINT
530 PRINT "FLIGHT: ";D$;" :CAL. IS ";S9;" PPMM/IN"
```

```
540  PRINT "BASELINE IS ";C2;"INCHES"
550  PRINT
560  PRINT
570  DISP S9;C2
580  WAIT 10000
590  DISP "BASELINE OK";
600  INPUT Q$
610  IF Q$#"NO" THEN 660
620  DISP "BASELINE = ";
630  INPUT C2
640  DISP "SET TO SINGLE!"
650  WAIT 10000
660  N=INT(K/0.1)
670  DISP "ENTER LEAD EDGES,END PT. ON SNGL"
680  WAIT 4000
690  X0=I9=0
700  J7=1
710  FOR J=1 TO N+1
720  ENTER (9,*)X,Y
730  FOR K=0.2 TO 1 STEP 0.2
740  I9=I9+1
750  IF I9 <= 256 THEN 780
760  I9=1
770  J7=J7+1
780  R[J7,I9]=(X-X0)*K+X0
790  NEXT K
800  X0=X
810  NEXT J
820  N9=J7*256+I9
830  DISP "SWITCH TO CONT. AND DIGITIZE SIG";
840  WAIT 5000
850  O7=-0.04
860  FOR J1=1 TO J7
870  IF J1<J7 THEN 900
880  I8=I9
890  GOTO 910
900  I8=256
910  FOR I=1 TO I8
920  ENTER (9,*)X,Y
930  IF (X-R[J1,I]-O7)>0.005 THEN 920
940  IF (X-R[J1,I]-O7)<-0.005 THEN 920
950  WRITE (9,*)
960  S[J1,I]=(Y-C2)*S9
970  NEXT I
980  NEXT J1
990  FOR J=J7 TO 3
1000 IF J=J7 THEN 1030
1010 I8=1
1020 GOTO 1040
1030 I8=I9+1
1040 FOR I=I8 TO 256
1050 S[J,I]=0
1060 NEXT I
1070 NEXT J
```

```
1080  S[3,255]=J7
1090  S[3,256]=I9
1100  SCALE -3600*M1,15000*M1,-400*M2,1000*M2
1110  XAXIS -200*M2,1000*M1,0,14000*M1
1120  YAXIS 0,100*M2,-200*M2,800*M2
1130  LABEL (*,1.5,1.7,0,18/25)
1140  FOR J=0 TO 14000*M1 STEP 2000*M1
1150  PLOT J,-200*M2,1
1160  CPLOT -3.3,-1.3
1170  LABEL (*)J
1180  NEXT J
1190  PLOT 6000*M1,-300*M2,1
1200  LABEL (*,2,1.5,0,18/25)"METRES"
1210  FOR J=-200*M2 TO 800*M2 STEP 200*M2
1220  PLOT 0,J,1
1230  LABEL (*,1.5,1.7,0,18/25)
1240  CPLOT -5.3,-0.3
1250  LABEL (*,1.5,1.7,0,18/25)J
1260  NEXT J
1270  PLOT -1800*M1,200*M2,1
1280  LABEL (*,2,1.5,PI/2,18/25)"SIGNAL(PPMM)"
1290  LABEL (*,2,1.7,0,18/25)
1300  PLOT 6000*M1,750*M2,1
1310  LABEL (*)D$
1320  LABEL (*)T$
1330  FOR J=1 TO J7
1340  IF J<J7 THEN 1370
1350  I8=I9
1360  GOTO 1380
1370  I8=256
1380  FOR I=1 TO I8
1390  PLOT ((J-1)*256+I)*D7,S[J,I]
1400  NEXT I
1410  NEXT J
1420  DISP "C.M. FILE FOR STORAGE";
1430  INPUT F9
1440  STORE  DATA #5,F9
1450  END
```

APPENDIX B

COSPEC DIGITIZATION ROUTINE (FOR SPED DATA)

Source File: Processor Cassette File 2

For use in digitizing chart data taken in elapsed distance mode.

Procedure

The procedure for this program is the same as for that of Appendix A. However delete steps #6, 11 and 12. Note that the digitization interval in this program is <u>not</u> the traverse distance measured in metres (unlike the other routines), but rather is the actual chart record distance expressed in inches. For example, if 22.3 cm of chart paper equals 2 mi on the road, use a 20-m digitization interval such that (recalling that 2.54 cm = 1 inch and 1 mi = 1609 m):

$$D7 = \frac{20 \text{ m}}{2 \times 1609 \text{ m}} \quad \text{x} \quad 22.3 \text{ cm} \quad \text{x} \quad \frac{1}{2.54} \text{ in/cm} \quad = \quad 0.0545 \text{ in.}$$

which is the case in the listing. This parameter should be modified for each case.

```
10 COM D$[13],T$[50],S$[3,256]
20 REM COSPEC DIGITIZATION ROUTINE (FOR SPED DATA) MOD 1
30 DIM Y[40],Z[40],Q$[3]
40 DISP "INPUT LST:DAY/MONTH/YR";
50 INPUT D$
60 DISP "INPUT START-END LOCATIONS";
70 INPUT T$
80 DISP "ENTER START POINT";
90 WAIT 3000
100 ENTER (9,*)X0,Y
110 WRITE (9,*)
120 DISP "ENTER END POINT";
130 WAIT 3000
140 ENTER (9,*)X9,Y
150 WRITE (9,*)
160 MAT S=ZER
170 D7=0.05455
180 C9=5000
190 DISP "IS TRACE INVERTED";
200 INPUT Q$
210 IF Q$#"YES" THEN 240
220 I3=-1
230 GOTO 250
240 I3=+1
250 DISP "READY FOR CAL, CONTINUOUS ON";
260 WAIT 10000
270 FOR I=1 TO 40
280 IF I>1 THEN 320
290 ENTER (9,*)X3,Y[I]
300 WRITE (9,*)
310 GOTO 360
320 ENTER (9,*)X,Y[I]
330 IF X#X3+0.02 THEN 320
340 WRITE (9,*)
350 X3=X
360 NEXT I
370 DISP "CAL OFF"
380 WAIT 10000
390 FOR I=1 TO 40
400 IF I>1 THEN 440
410 ENTER (9,*)X3,Z[I]
420 WRITE (9,*)
430 GOTO 480
440 ENTER (9,*)X,Z[I]
450 IF X#X3+0.02 THEN 440
460 WRITE (9,*)
470 X3=X
480 NEXT I
490 S1=S2=0
500 FOR I=1 TO 40
510 S1=S1+Y[I]
520 S2=S2+Z[I]
530 NEXT I
540 C1=S1/40
```

```
550  C2=S2/40
560  S9=C9/(C1-C2)
570  PRINT
580  PRINT "FLIGHT: ";D$;" :CAL. IS ";S9;" PPMM/IN"
590  PRINT "BASELINE IS ";C2;"INCHES"
600  PRINT
610  PRINT
620  DISP S9;C2
630  WAIT 10000
640  DISP "BASELINE OK";
650  INPUT Q$
660  IF Q$#"NO" THEN 690
670  DISP "BASELINE = ";
680  INPUT C2
690  I=J=1
700  X1=X0
710  DISP "SWITCH TO CONT. AND DIGITIZE";
720  WAIT 5000
730  ENTER (9,*)X,Y
740  IF ABS(X1-X0)>ABS(X9-X0) THEN 860
750  IF X-X1>0.005 THEN 730
760  IF X-X1<-0.005 THEN 730
770  WRITE (9,*)
780  S[J,I]=(Y-C2)*S9
790  X1=X1+D7*I3
800  IF I=256 THEN 830
810  I=I+1
820  GOTO 730
830  I=1
840  J=J+1
850  GOTO 730
860  S[3,255]=J
870  S[3,256]=I
880  DISP "C.M. FILE FOR STORAGE";
890  INPUT F9
900  STORE  DATA #5,F9
910  END
```

APPENDIX C

MAP DIGITIZATION ROUTINE

Source File: Processor Cassette File 3

For use in digitizing map files for input to the COSPEC processor. This program digitizes directly from <u>aligned</u> topographic maps (see text).

Procedure

1.   Place the map on the platen so that North is aligned with the y-axis of the platen. This can be done quite accurately by following steps (a) to (c):

    (a)   enter into memory the routine

```
2000 ENTER (9, *) X0, Y0
2010 WRITE (9, *)
2020 ENTER (9, *) X1, Y1
2030 WRITE (9, *)
2040 DISP X1-X0, Y1-Y0
2050 WAIT 5000
2060 GO TO 2000
2070 END
```

    (b)   Push single point mode switch on cursor.

    (c)   Along a N-S grid line, digitize two points one at the bottom of the platen, the other at the top.

    (d)   Refer to the display and try to minimize the first reading. This should be obtainable within 0.02 inches over the length of the platen.

    (e)   Tape down map and check result again. If satisfied terminate this routine and continue with next step.

2.   A cassette must be marked to contain all the map files for the traverses. With a new data cassette labelled "MAP FILES", type MARK #5, 32, 1030. ERROR 58 will occur in writing file 31 and 31 files are available for storing the maps.

3.   Press LOAD 3.

4.   Only one parameter is map dependent, e.g. the map scaling on line 100 reads:

$$100 \ C0 \ = \ 0.0254*50000$$

which is only valid for 1:50000 maps. Change if not applicable.

5.   Enter, RUN EXECUTE.

6.   "SET ORIGIN AT STACK" - locate stack on map and press "0" on cursor (which must be in single mode).

7.   "INPUT START-END PTS: PROPER WAY" - if desired, type 3-digit code numbers (e.g. 133, 147) to identify the traverse positions, as a convenient way of keeping track of stations used during the field project. This will also label the map files.

8.   "ENTER START POINT, S" – this is again the start point defined by the previous convention, i.e. the left-most point of the traverse as viewed from the stack.

9.   "ENTER END POINT, E" – (see 8) record <u>precisely</u> the end point on the map.

10.   "SWITCH TO CONTINUOUS" – The program will now process data points starting at the start point, and upon every translation of 0.05 inch in either the x or y directions. Note that if the translation is made rapidly the digitizer may miss the 0.05 inch criterion and the procedure will have to be backtracked.

<u>WARNING</u>: Because of this method of checking for cursor translation, fast cursor movement may cause errors. The program tests for 0.05 inch translation <u>either</u> in the x <u>or</u> y direction. A fast movement between readings may cause the cursor to cross a test point.
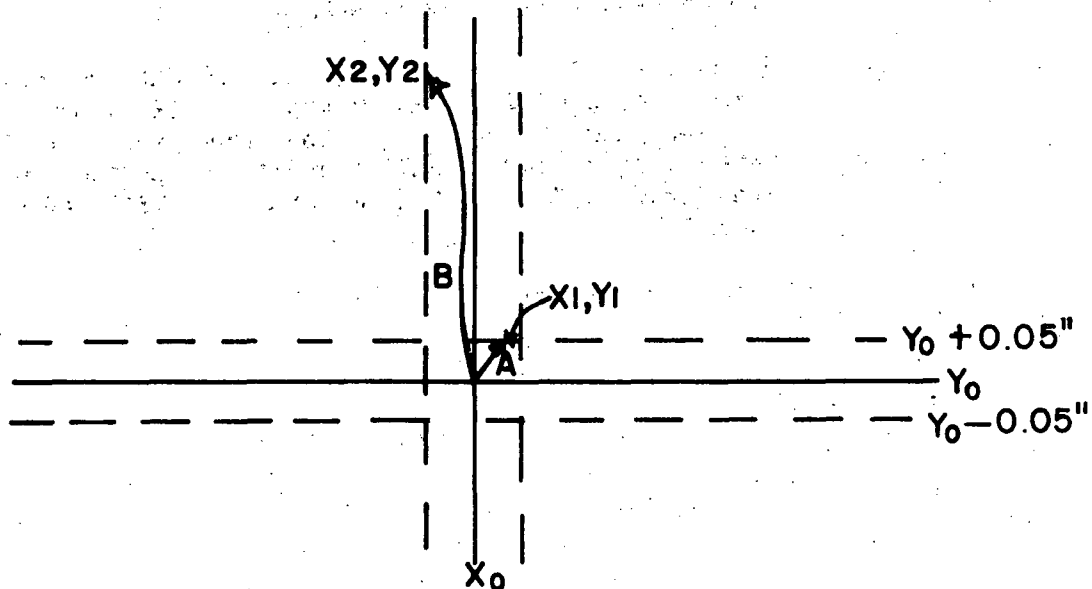
From the diagram above, if x_0 and y_0 are the coordinates of the point previously digitized, cursor movement along path A will cause the coordinates of x_1 and y_1 to be correctly digitized. If, however, rapid cursor movement (along path B, say) bypasses the line y_0 + 0.05 inch, the point x_2, y_2 could conceivably be digitized by a small horizontal translation after a large vertical one. The objective is to digitize the map fairly slowly and diligently. If there is a possibility that this error may have occurred, see step 13, below.

11.   Upon reaching the end point <u>exactly</u>, the red cursor light will stop blinking and stay lit. This emphasises the requirement expressed in step 9 for accurately recording the end point on the map for reference.

12.   "FILE FOR STORAGE" - enter the file number of the map profile.

13.   There are several checks on the validity of the digitization. Set up a piece of paper on the plotter so that "LOWER LEFT" and "UPPER RIGHT" form a square grid (6" x 6", for example). Press CONT 540. The map should be plotted correctly. To locate the stack, press CONT 600. Each grid mark represents two kilometres.

If the possibility exists that the traverse is not correct, the following array elements may be useful for checking:

(a)   Press T (1, 1), EXECUTE - start point number will be returned.

(b)   Press T (2, 1), EXECUTE - end point number will be returned.

(c)   Press T (1, 2), EXECUTE - total distance of the traverse (in metres) will be returned.

(d)   Press T (2, 2), EXECUTE - number of data points digitized will be returned. If this number is 256 it may be suspected that the traverse is too long for the file size. Either use a small scale map or change the internal program grid to 0.1 inch (use care! C∅ WILL HAVE TO BE RE-DEFINED).

The data are now ready to be processed.

```
10 REM MAP DIGITIZATION ROUTINE
20 DIM TS[2,256],DS,SS,IS,ES
30 DISP "SET ORIGIN AT STACK"
40 WAIT 4000
50 DISP "INPUT START-END PTS: PROPER WAY";
60 INPUT S,E
70 RAD
80 DISP "ENTER START POINT, S"
90 WAIT 6000
100 C0=0.0254*50000
110 ENTER (9,*)X0,Y0
120 T[1,3]=C0*X0
130 T[2,3]=C0*Y0
140 DISP "ENTER END POINT, E"
150 WAIT 6000
160 ENTER (9,*)X9,Y9
170 DISP "SWITCH TO CONTINUOUS"
180 WAIT 5000
190 Y1=Y0
200 X1=X0
210 ENTER (9,*)X,Y
220 IF X#X0 THEN 210
230 IF Y#Y0 THEN 210
240 WRITE (9,*)
250 FOR I=4 TO 256
260 ENTER (9,*)X,Y
270 IF X#X9 THEN 290
280 IF Y=Y9 THEN 370
290 IF (ABS(X-X1))=0.05 THEN 310
300 IF (ABS(Y-Y1))#0.05 THEN 260
310 WRITE (9,*)
320 T[1,I]=C0*X
330 T[2,I]=C0*Y
340 X1=X
350 Y1=Y
360 NEXT I
370 T[1,I]=C0*X
380 T[2,I]=C0*Y
390 D=0
400 FOR J=4 TO I
410 D=D+SQR((T[1,J]-T[1,J-1])↑2+(T[2,J]-T[2,J-1])↑2)
420 NEXT J
430 T[1,1]=S
440 T[2,1]=E
450 T[1,2]=D
460 T[2,2]=I
470 FOR I2=I+1 TO 256
480 T[1,I2]=T[2,I2]=0
490 NEXT I2
500 DISP "FILE FOR STORAGE";
510 INPUT F
520 STORE   DATA F,T
530 END
```

```
540  SCALE -10000,10000,-10000,10000
550  FOR I=3 TO T[2,2]
560  PLOT T[1,I],T[2,I]
570  NEXT I
580  PEN
590  END
600  XAXIS 0,2000,-8000,8000
610  YAXIS 0,2000,-8000,8000
620  END
```

APPENDIX D

COSPEC PROCESSOR

Source Files: Processor Cassette Files 4 - 7

For use in processing previously digitized COSPEC traverse data to obtain centres-of-gravity and Eulerian and Lagrangian statistics.

Procedure

To run the COSPEC PROCESSOR, the following files are necessary:

(a)   Data cassette with original transects.
(b)   Map files.
(c)   Write files: These should again be marked via MARK #5, 22, 1575 and left in the cassette memory.

The PROCESSOR program will need no modifications internally and is largely self-explanatory. The listing of a computer-run output (during PRINT-ALL) is shown in Figure 7. Heavy underlining indicates programmer input. The following comments may be helpful:

1.   Enter, LOAD 4, RUN, EXECUTE.

2.   "MOUNT DATA TAPES IN CALC" - CALC refers to calculator cassette slot; C. M., to external cassette memory.

3.   "ALL FILES ON ONE CASSETTE" - YES or NO response required. If NO, then every time a data file is to be read, the calculator will prompt the operator to check that the proper file and cassette is in the slot. Programmer care will save much reprocessing here. Note: When dealing with a series involving file 20 on any cassette, be sure to rewind cassette after file 20 is read, since some cassettes (depending on tape length) may not have a file 21 header to rewind. A fatal error will result if a cassette is read to end of tape under program control.

4.   After AVERAGE COG statistics are printed, the question is asked "BREAKING OK OR TO PAST COG?" - enter YES to use calculated bearing and stack as origin. Only use NO for multiple COSPEC operation when traverses must be averaged from the stack out, i.e. near field before middle field before far field.

5.   The program will do some reading and writing on the PROCESSOR cassette. This is normal.

6.   "INPUT THRESHOLD PPM" - since no distribution contains negative weights, the noise signal on the baseline must be subtracted off. In general, an eyeball estimate of the noise level in ppm-m is adequate to trim off unwanted weighting of the plume by background.

7.   "ALL OUTPUT FILES ON ONE TAPE" - as in (3) above if more than one cassette has been used for output, the computer will prompt operator to make changes in the Cassette Memory Unit.

If the operator has seen all these interactive questions in the program, the Lagrangian averaging stage has been reached. After answering the prompt about where the data file for the Lagrangian average should be put, the program ends with "⊢".

```
10  COM D$[13],T$[50],SS[3,256]
20  REM COSPEC DATA PROCESSING(I)
30  REM CREATION OF AVERAGE FILE
40  DIM FI[20],GI[20],WS[3,256],TS[3,256],DS[3,256],Q$[3],P$[3]
50  DEG
60  DISP "INPUT DIGIT. INTERVAL IN METRES";
70  INPUT D7
80  DISP "HOW MANY FILES TO AVERAGE";
90  INPUT N1
100 FOR I=1 TO N1
110 DISP "TRAVERSE # ";I;" ON FILE ";
120 INPUT F[I]
130 NEXT I
140 DISP "MOUNT DATA TAPES IN CALC.";
150 INPUT Q$
160 MAT W=ZER
170 DISP "ALL FILES ON ONE CASSETTE";
180 INPUT Q$
190 FOR I=1 TO N1
200 IF Q$="YES" THEN 230
210 DISP "TAPE OK FOR FILE ";F[I];
220 INPUT P$
230 LOAD  DATA F[I]
240 J8=S[3,255]
250 I8=S[3,256]
260 S[3,255]=S[3,256]=0
270 MAT S=(1/N1)*S
280 MAT W=W+S
290 NEXT I
300 MAT S=W
310 S[3,255]=J8
320 S[3,256]=I8
330 DISP "C.M. FILE FOR STORAGE OF AVERAGE";
340 INPUT F9
350 D$=D$[6,13]
360 T$[LEN(T$)]="- GROUND POSITION AVERAGE"
370 STORE  DATA #5,F9
380 DISP " MAP STORED ON FILE ";
390 INPUT F8
400 DISP "LOAD MAP FILE INTO CALC. SLOT";
410 INPUT P$
420 LOAD  DATA F8,T
430 DISP "LOAD PROCESSOR IN CALC.";
440 INPUT P$
450 LINK 5
```

```
10 REM COSPEC DATA PROCESSING (II)
20 REM MAP RESPACING AND STORAGE; CALCULATION OF AVERAGE COG
30 D0=D1=D2=X7=Y7=0
40 N7=3
50 MAT S=ZER
60 FOR J=1 TO J8
70 IF J=J8 THEN 100
80 I7=256
90 GOTO 110
100 I7=I8
110 FOR I=1 TO I7
120 GOSUB 660
130 S[3,I]=T9
140 S[2,I]=Y
150 S[1,I]=X
160 NEXT I
170 STORE  DATA 7+J,S
180 NEXT J
190 X=Y=S1=0
200 FOR J=1 TO J8
210 LOAD   DATA 7+J,T
220 IF J=J8 THEN 250
230 I7=256
240 GOTO 260
250 I7=I8
260 FOR I=1 TO I7
270 X=X+T[1,I]*W[J,I]
280 Y=Y+T[2,I]*W[J,I]
290 S1=S1+W[J,I]
300 NEXT I
310 NEXT J
320 X2=X/S1
330 Y2=Y/S1
340 IF Y2#0 THEN 400
350 IF X2>0 THEN 380
360 T2=270
370 GOTO 510
380 T2=90
390 GOTO 510
400 Z2=ABS(X2/Y2)
410 IF X2<0 THEN 470
420 IF Y2<0 THEN 450
430 T2=ATN(Z2)
440 GOTO 510
450 T2=180-ATN(Z2)
460 GOTO 510
470 IF Y2<0 THEN 500
480 T2=360-ATN(Z2)
490 GOTO 510
500 T2=ATN(Z2)+180
510 PRINT
520 PRINT " AVERAGE COG:"
530 PRINT " X = ";X2;" ;   Y = ";Y2
540 PRINT "BEARING OF AVE.COG( TRUE N) = ";T2;" DEGREES"
```

```
550   PRINT
560   IF X7#0 THEN 650
570   DISP "BEARING OK OR TO PAST COG ";
580   INPUT P$
590   IF P$="YES" THEN 650
600   DISP "INPUT COORDS. IN M. OF PAST COG";
610   INPUT X7,Y7
620   X2=X2-X7
630   Y2=Y2-Y7
640   GOTO 340
650   LINK 6
660   REM SUBROUTINE FOR X,Y GROUND POSITIONS
670   D1=D1+D7
680   D2=SQR((T[1,N7+1]-T[1,N7])↑2+(T[2,N7+1]-T[2,N7])↑2)+D0
690   IF D2>T[1,2] THEN 770
700   IF D1<D2 THEN 740
710   N7=N7+1
720   D0=D2
730   GOTO 680
740   X5=T[1,N7+1]-T[1,N7]
750   Y5=T[2,N7+1]-T[2,N7]
760   GOTO 800
770   X5=T[1,T[2,2]]-T[1,T[2,2]-1]
780   Y5=T[2,T[2,2]]-T[2,T[2,2]-1]
790   D0=T[1,2]
800   IF Y5#0 THEN 860
810   IF X5>0 THEN 840
820   T9=270
830   GOTO 970
840   T9=90
850   GOTO 970
860   Z5=ABS(X5/Y5)
870   IF X5<0 THEN 930
880   IF Y5<0 THEN 910
890   T9=ATN(Z5)
900   GOTO 970
910   T9=180-ATN(Z5)
920   GOTO 970
930   IF Y5<0 THEN 960
940   T9=360-ATN(Z5)
950   GOTO 970
960   T9=180+ATN(Z5)
970   X=T[1,N7]+(D1-D0)*SIN(T9)
980   Y=T[2,N7]+(D1-D0)*COS(T9)
990   RETURN
```

```
10 REM COSPEC DATA PROCESSING (iii)
20 REM CALCULATION OF CROSSWIND DISTANCES
30 N7=3
40 D1=0
50 D0=D1=D2=0
60 FOR J=1 TO J8
70 LOAD DATA 7+J,T
80 IF J=J8 THEN 110
90 I7=256
100 GOTO 120
110 I7=I8
120 FOR I=1 TO I7
130 IF T[2,I]-Y7#0 THEN 190
140 IF T[1,I]-X7>0 THEN 170
150 T3=270
160 GOTO 300
170 T3=90
180 GOTO 300
190 Z=ABS((T[1,I]-X7)/(T[2,I]-Y7))
200 IF T[1,I]-X7<0 THEN 260
210 IF T[2,I]-Y7<0 THEN 240
220 T3=ATN(Z)
230 GOTO 300
240 T3=180-ATN(Z)
250 GOTO 300
260 IF T[2,I]-Y7<0 THEN 290
270 T3=360-ATN(Z)
280 GOTO 300
290 T3=180+ATN(Z)
300 T4=T3-T2
310 D[J,I]=SQR((T[1,I]-X7)↑2+(T[2,I]-Y7)↑2)*SIN(T4)
320 NEXT I
330 NEXT J
340 REM RESPACING AND INTERPOLATION ROUTINE
350 I5=0
360 J5=1
370 J4=1
380 I4=2
390 FOR D9=-383*D7 TO 384*D7 STEP D7
400 I5=I5+1
410 IF I5#257 THEN 440
420 I5=1
430 J5=J5+1
440 IF D9>D[J8,I8] THEN 470
450 IF D9<D[1,1] THEN 470
460 GOTO 490
470 S[J5,I5]=0
480 GOTO 640
490 IF D9 <= D[J4,I4] THEN 560
500 IF I4=256 THEN 530
510 I4=I4+1
520 GOTO 490
530 I4=1
540 J4=J4+1
```

```
550  GOTO 490
560  IF I4=1 THEN 600
570  D8=D[J4,I4]-D[J4,I4-1]
580  S8=W[J4,I4]-W[J4,I4-1]
590  GOTO 620
600  D8=D[J4,1]-D[J4-1,256]
610  S8=W[J4,1]-W[J4-1,256]
620  C9=(D[J4,I4]-D9)/D8
630  S[J5,I5]=W[J4,I4]-C9*S8
640  NEXT D9
650  K4=0
660  REM COG OF PROFILE AND SIGMA Y
670  S1=S2=S3=S4=X1=0
680  D9=-384*D7
690  DISP "INPUT THRESHOLD PPM";
700  INPUT B8
710  FOR J=1 TO 3
720  FOR I=1 TO 256
730  D9=D9+D7
740  IF S[J,I]<B8 THEN 800
750  X1=X1+D9*S[J,I]
760  S1=S1+S[J,I]
770  S2=S2+S[J,I]*D9↑2
780  S3=S3+S[J,I]*D9↑3
790  S4=S4+S[J,I]*D9↑4
800  NEXT I
810  NEXT J
820  X6=X1/S1
830  S5=SQR(S2/S1-X6↑2)
840  S6=((S3-3*X6*S2)/S1+2*X6↑3)/S5↑3
850  S7=((S4-4*X6*S3+6*X6↑2*S2)/S1-3*X6↑4)/S5↑4
860  PRINT " COG OF EULERIAN IS ";X6;" METRES FROM AVERAGE COG"
870  PRINT "BEARING (TRUE NORTH) OF EUL. COG = ";T2+ATN(X6/SQR(X2↑2+Y2↑2));" D
880  S[3,256]=X6
890  PRINT
900  PRINT "SIGMA Y = ";S5;" METRES"
910  PRINT "MOMENTAL SKEWNESS = ";S6
920  PRINT "KURTOSIS = ";S7
930  PRINT "AREA = ";S1*D7;" PPM-M↑2"
940  PRINT
950  PRINT
960  T$=" EULERIAN AVERAGE PROFILE"
970  DISP "C.M. FILE FOR EULERIAN PROFILE";
980  INPUT F9
990  STORE  DATA #5,F9
1000 LINK 7
```

```
10  REM COSPEC DATA PROCESSING (IV)
20  DISP "DATA FILES IN CALC. SLOT";
30  INPUT P$
40  K4=K4+1
50  IF Q$="YES" THEN 80
60  DISP "FILE OK FOR FILE";F[K4];
70  INPUT P$
80  LOAD  DATA F[K4]
90  MAT W=S
100 W[3,255]=W[3,256]=S[3,255]=S[3,256]=0
110 REM INDIVIDUAL RESPACING AND INTERPOLATION ROUTINE
120 I5=0
130 J5=1
140 J4=1
150 I4=2
160 FOR D9=-383*D7 TO 384*D7 STEP D7
170 I5=I5+1
180 IF I5#257 THEN 210
190 I5=1
200 J5=J5+1
210 IF D9>D[J8,I8] THEN 240
220 IF D9<D[1,1] THEN 240
230 GOTO 260
240 S[J5,I5]=0
250 GOTO 410
260 IF D9 <= D[J4,I4] THEN 330
270 IF I4=256 THEN 300
280 I4=I4+1
290 GOTO 260
300 I4=1
310 J4=J4+1
320 GOTO 260
330 IF I4=1 THEN 370
340 D8=D[J4,I4]-D[J4,I4-1]
350 S8=W[J4,I4]-W[J4,I4-1]
360 GOTO 390
370 D8=D[J4,1]-D[J4-1,256]
380 S8=W[J4,1]-W[J4-1,256]
390 C9=(D[J4,I4]-D9)/D8
400 S[J5,I5]=W[J4,I4]-C9*S8
410 NEXT D9
420 REM COG OF PROFILE AND SIGMA Y
430 S1=S2=S3=S4=X1=0
440 D9=-384*D7
450 FOR J=1 TO 3
460 FOR I=1 TO 256
470 D9=D9+D7
480 IF S[J,I]<B8 THEN 540
490 X1=X1+D9*S[J,I]
500 S1=S1+S[J,I]
510 S2=S2+S[J,I]*D9↑2
520 S3=S3+S[J,I]*D9↑3
530 S4=S4+S[J,I]*D9↑4
540 NEXT I
```

```
550 NEXT J
560 X6=X1/S1
570 S5=SQR(S2/S1-X6↑2)
580 S6=((S3-3*X6*S2)/S1+2*X6↑3)/S5↑3
590 S7=((S4-4*X6*S3+6*X6↑2*S2)/S1-3*X6↑4)/S5↑4
600 PRINT " COG OF PROFILE AT ";D$;" IS ";X6;" METRES"
610 PRINT "BEARING(T.N.) OF COG IS ";T2+ATN(X6/SQR(X2↑2+Y2↑2));" DEGREES"
620 S[3,256]=X6
630 PRINT
640 PRINT "SIGMA Y = ";S5;" METRES"
650 PRINT "MOMENTAL SKEWNESS = ";S6
660 PRINT "KURTOSIS = ";S7
670 PRINT "AREA = ";S1*D7;" PPM-M↑2"
680 PRINT
690 PRINT
700 T$=" PROJECTED INDIVIDUAL PROFILE"
710 DISP "C.M. FILE FOR PROFILE t=";D$;
720 INPUT G[K4]
730 STORE   DATA #5,G[K4]
740 IF K4=N1 THEN 760
750 GOTO 40
760 REM LAGRANGIAN AVERAGING
770 DISP "ALL OUTPUT FILES ON ONE TAPE";
780 INPUT P$
790 MAT W=ZER
800 FOR I2=1 TO N1
810 IF P$="YES" THEN 840
820 DISP "C.M. OK FOR FILE ";G[I2];
830 INPUT Q$
840 LOAD   DATA #5,G[I2]
850 C0=S[3,256]/D7
860 S[3,256]=0
870 IF C0-INT(C0) >= 0.5 THEN 900
880 C0=INT(C0)
890 GOTO 910
900 C0=INT(C0)+1
910 FOR J=1 TO 3
920 FOR I=1 TO 256
930 I1=I+C0
940 IF I1>0 THEN 990
950 IF J=1 THEN 1050
960 J1=J-1
970 I1=256+I1
980 GOTO 1040
990 IF I1<257 THEN 1030
1000 J1=J+1
1010 I1=I1-256
1020 IF J1>3 THEN 1050
1025 GOTO 1040
1030 J1=J
1040 W[J,I]=S[J1,I1]+W[J,I]
1050 NEXT I
1060 NEXT J
1070 NEXT I2
1080 MAT S=(1/N1)*W
```

```
1090 D2=-384*D7
1100 S1=S2=S3=S4=S5=0
1110 FOR J=1 TO 3
1120 FOR I=1 TO 256
1130 D2=D2+D7
1140 IF S[J,I]<B8 THEN 1200
1150 S5=S5+D2*S[J,I]
1160 S2=S2+D2↑2*S[J,I]
1170 S3=S3+D2↑3*S[J,I]
1180 S4=S4+D2↑4*S[J,I]
1190 S1=S1+S[J,I]
1200 NEXT I
1210 NEXT J
1220 PRINT
1230 PRINT "LAGRANGIAN AVERAGE"
1240 PRINT
1250 PRINT "SIGMA Y = ";SQR(S2/S1);" METRES"
1260 PRINT "MOMENTAL SKEWNESS = ";(S3/S2)/SQR(S2/S1)
1270 PRINT "KURTOSIS = ";S1*S4/S2↑2
1280 PRINT "AREA=";S1*D7;" PPM-M↑2"
1290 S[3,256]=0
1300 D$=D$[6,13]
1310 T$="LAGRANGIAN AVERAGE"
1320 DISP "FILE TO STORE LAGR. AV. ";
1330 INPUT F9
1340 STORE  DATA #5,F9
1350 END
```

APPENDIX   E

PLOTTING ROUTINE

Source File: Processor Cassette File   11

For use in obtaining output plots of processed data in publishable format.

Procedure

Having gotten to this point, the user will want hard copy output of his profiles. There are obtained from the program on File 11. As in the first two programs there are a few internal parameters which require modification under certain conditions.

As written, the program plots distances in the horizontal on a scale in multiples of 10000 m. This is controlled by the variable M1 in line 160. To plot a 1000 m crosswind distance, put M1 = 0.1 etc. The vertical axis is scaled in multiples of 800 ppm-m which is controlled by the variable M2 in Line 170. The height of the lettering is controlled by the variable M in Line 180 (set here for plotting 3 - 6 plots per page). To9 plot fewer graphs per page make M larger (i.e. 1.0). To plot more, make M smaller (0.5, say).

The label on the y-axis is "SO_2 (*1000 PPM-M)". For COSPEC's with low concentration masks, the user may wish to delete the (*1000 PPM-M) in Lines 320 and 850 and change the "J5/1000" in lines 550 and 1130 to J5.

If the user wishes to plot multiple traverses on a single page it is recommended that the page be mounted vertical with lower left and upper right verniers set in about 1 cm. For horizontal orientation of a page, line 190 should be changed to read R∅ = 8.5/11.

In general, the procedure is to plot several traverses which make up a type of average, whether spatial (from the original traverses), Lagrangian or Eulerian, and then to plot the average itself at the bottom. This is achieved by entering the file number of the average as the last in the series of files to be plotted, remembering that the average must be counted in the total number of files to be plotted.

The program attempts to minimize ploter movement and therefore the files are read in reverse order (i.e. bottom-up). This will not be noticed if all files are on one cassette. But if, for example, original data profiles on files 0, 1, 2, 3, 4 of the DATA cassette are to be plotted, along with the average ground profile on file 0 of the WRITE cassette, the operator should be aware that when the program prompts with "TAPE IN C. M. OK FOR FILE∅?" for the first file it will be asking for the average file on the "WRITE" tape. It will then prompt in the order 4, 3, 2, 1, and ∅ on the DATA tape. In cases involving Lagrangian or Eulerian averages, this confusion in multiple numbering rarely (if ever) occurs.

The program itself should be self-explanatory to the now-experienced user. The first query of "SPACE (2), LAG (1), EUL. (∅)" will require entry of the number in parentheses for the type of average to be plotted: i.e. original data plus average (2), Lagrangian (1) or Eulerian (∅).

```
10 COM D$[13],T$[50],SS[3,256]
20 DIM FI[20],G[20],Q$[3],P$[3]
30 DISP "SPACE(2),LAG.(1),OR EUL.(0) PLOT";
40 INPUT Q1
50 DISP "HOW MANY PROFILES";
60 INPUT N1
70 DISP "INPUT DIG. INTERVAL";
80 INPUT D7
90 DISP "ALL FILES ON ONE CASSETTE";
100 INPUT P$
110 FOR I=1 TO N1
120 DISP "PROFILE ";I;" ON FILE ";
130 INPUT F[I]
140 NEXT I
150 S9=0
160 M1=0.01
170 M2=1
180 M=0.75
190 R0=11/8.5
200 IF Q1#2 THEN 630
210 SCALE -3000*M1,11000*M1,-200*M2*N1,1100*M2*N1
220 XAXIS 0,1000*M1,0,10000*M1
230 LABEL (*,1.5*M,1.7,0,R0)
240 FOR J=0 TO 10000*M1 STEP 2000*M1
250 PLOT J,0,1
260 CPLOT -3.3,-1.3
270 LABEL (*)J
280 NEXT J
290 PLOT 4500*M1,-100*M2*N1,1
300 LABEL (*,2*M,1.7,0,R0)"METRES"
310 PLOT -1200*M1,350*M2*N1,1
320 LABEL (*,2*M,1.7,PI/2,R0)"SO2 (* 1000 PPM-M)"
330 LABEL (*,2*M,1.7,0,R0)
340 OFFSET 0,200*M2
350 I6=0
360 FOR I=N1 TO 1 STEP -1
370 I6=I6+1
380 DISP "TAPE IN C.M. OK FOR FILE ";F[I];
390 INPUT Q$
400 LOAD DATA #5,F[I]
410 FOR J5=1 TO S[3,255]
420 IF J5=S[3,255] THEN 450
430 I7=256
440 GOTO 460
450 I7=S[3,256]
460 FOR I5=1 TO I7
470 PLOT ((J5-1)*256+I5)*D7,S[J5,I5]
480 NEXT I5
490 NEXT J5
500 YAXIS 0,100*M2,-200*M2,800*M2
510 FOR J5=0 TO 800*M2 STEP 200*M2
520 LABEL (*,1.5*M,1.7,0,R0)
530 PLOT 0,J5,1
540 CPLOT -4.3,-0.3
```

```
550  LABEL  (*)J5/1000
560  NEXT J5
570  PLOT 6500*M1,650*M2,1
580  LABEL  (*)D$
590  OFFSET 0,1000*M2*I6+200*M2
600  XAXIS -200*M2,1000*M1,0,10000*M1
610  NEXT I
620  GOTO 1240
630  DISP "DATA HAVE STORED COG'S";
640  INPUT Q$
650  IF Q$#"YES" THEN 680
660  S9=1
670  GOTO 720
680  FOR I=1 TO N1
690  DISP "INPUT COG OF PROFILE";I;
700  INPUT G[I]
710  NEXT I
720  SCALE -8000*M1,6000*M1,-200*M2*N1,1100*M2*N1
730  XAXIS 0,1000*M1,-5000*M1,5000*M1
740  LABEL  (*,1.5*M,1.7,0,R0)
750  FOR J=-5000*M1 TO 5000*M1 STEP 2000*M1
760  PLOT J,0,1
770  CPLOT -3.3,-1.3
780  LABEL  (*)J
790  NEXT J
800  IF Q1=0 THEN 840
810  PLOT 0,0,1
820  CPLOT -1.3,-1.3
830  LABEL  (*,1.5*M,1.7,0,R0)"COG"
840  PLOT -6000*M1,350*M2*N1,1
850  LABEL  (*,2*M,1.7,PI/2,R0)"SO2 (*1000 PPM-M)"
860  LABEL  (*)
870  OFFSET 0,200*M2
880  I6=0
890  FOR I=N1 TO 1 STEP -1
900  I6=I6+1
910  IF P$="YES" THEN 940
920  DISP "TAPE IN C.M. OK FOR FILE ";F[I];
930  INPUT Q
940  LOAD   DATA #5,F[I]
950  IF S9=0 THEN 980
960  G[I]=S[3,256]
970  S[3,256]=0
980  D1=-384*D7
990  FOR J5=1 TO 3
1000 FOR I5=1 TO 256
1010 D1=D1+D7
1020 IF (D1-G[I]*Q1)<-5000*M1 THEN 1050
1030 IF (D1-G[I]*Q1)>5000*M1 THEN 1070
1040 PLOT D1-G[I]*Q1,S[J5,I5]
1050 NEXT I5
1060 NEXT J5
1070 PEN
1080 YAXIS -5000*M1,100*M2,-200*M2,800*M2
```

```
1090  FOR J5=0 TO 800*M2 STEP 200*M2
1100  PLOT -5000*M1,J5,1
1110  LABEL (*,1.5*M,1.7,0,R0)
1120  CPLOT -5.3,-0.3
1130  LABEL (*)J5/1000
1140  NEXT J5
1150  PLOT +1000*M1,650*M2,1
1160  LABEL (*)D$
1170  IF Q1#0 THEN 1210
1180  PLOT G[I],0
1190  PLOT G[I],100*M2
1200  PEN
1210  OFFSET 0,1000*M2*I6+200*M2
1220  XAXIS -200*M2,1000*M1,-5000*M1,5000*M1
1230  NEXT I
1240  END
```
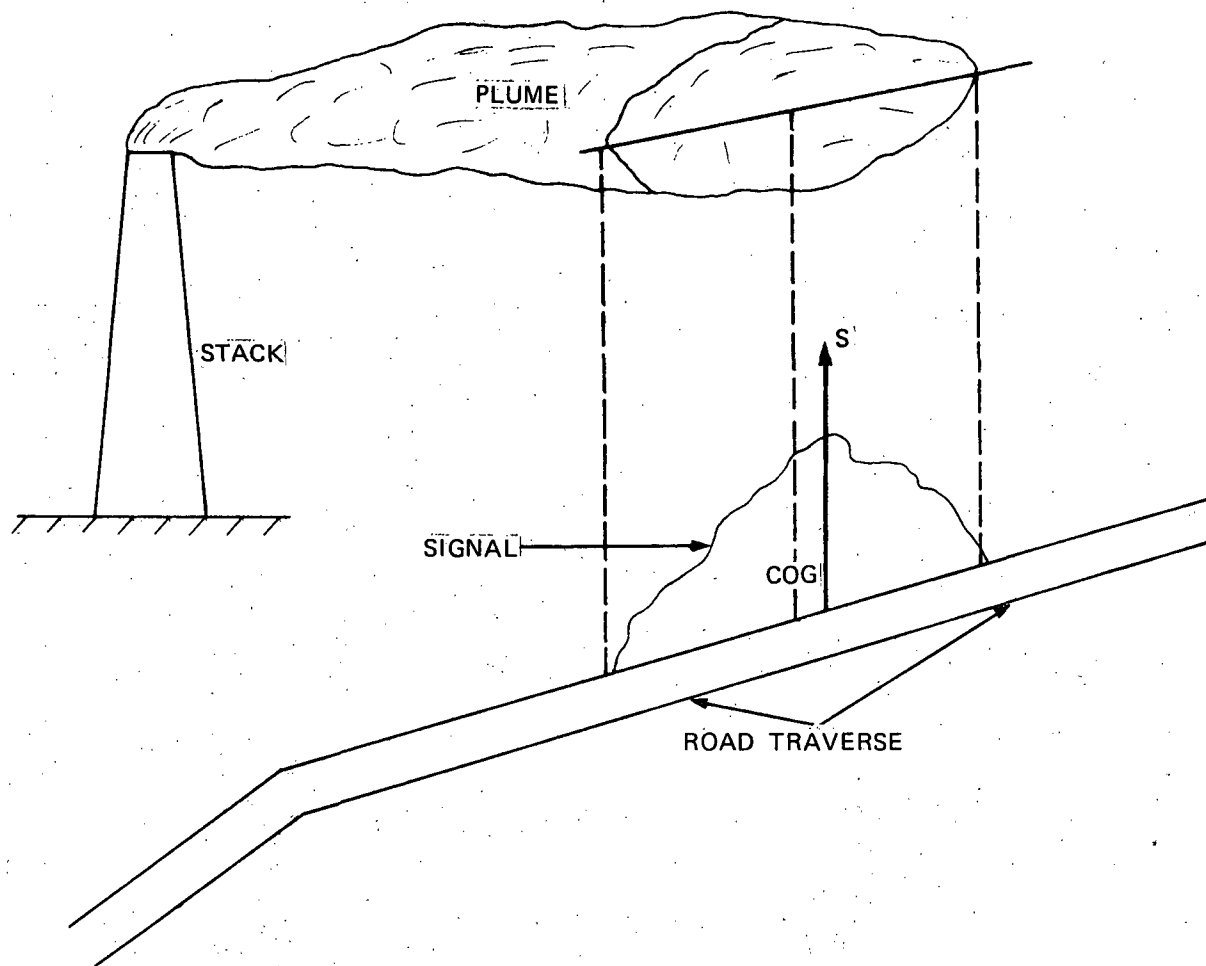
Figure 1

Schematic diagram of the vertically integrated COSPEC response
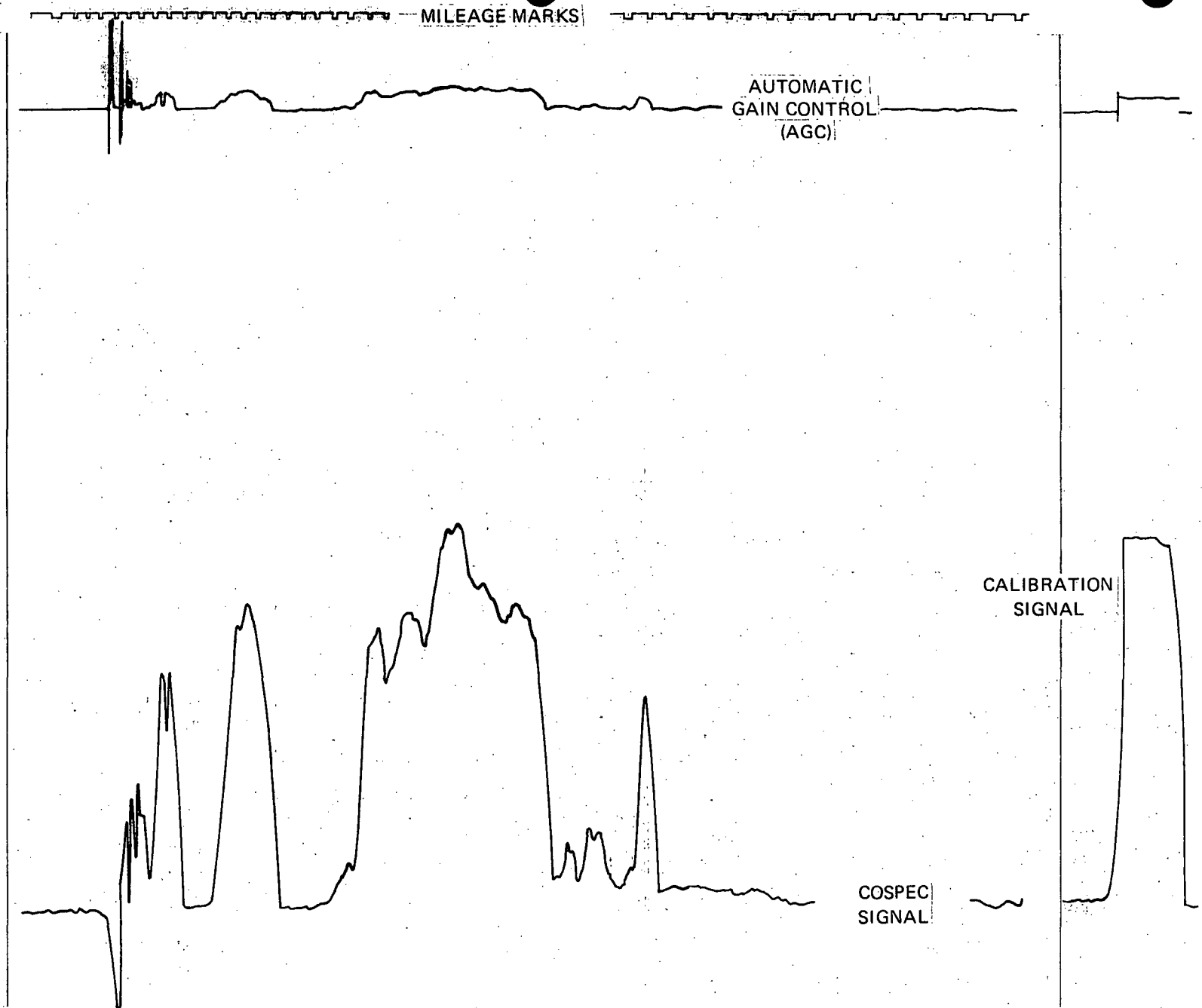
Figure 2

COSPEC chart record with mileage markers at the top
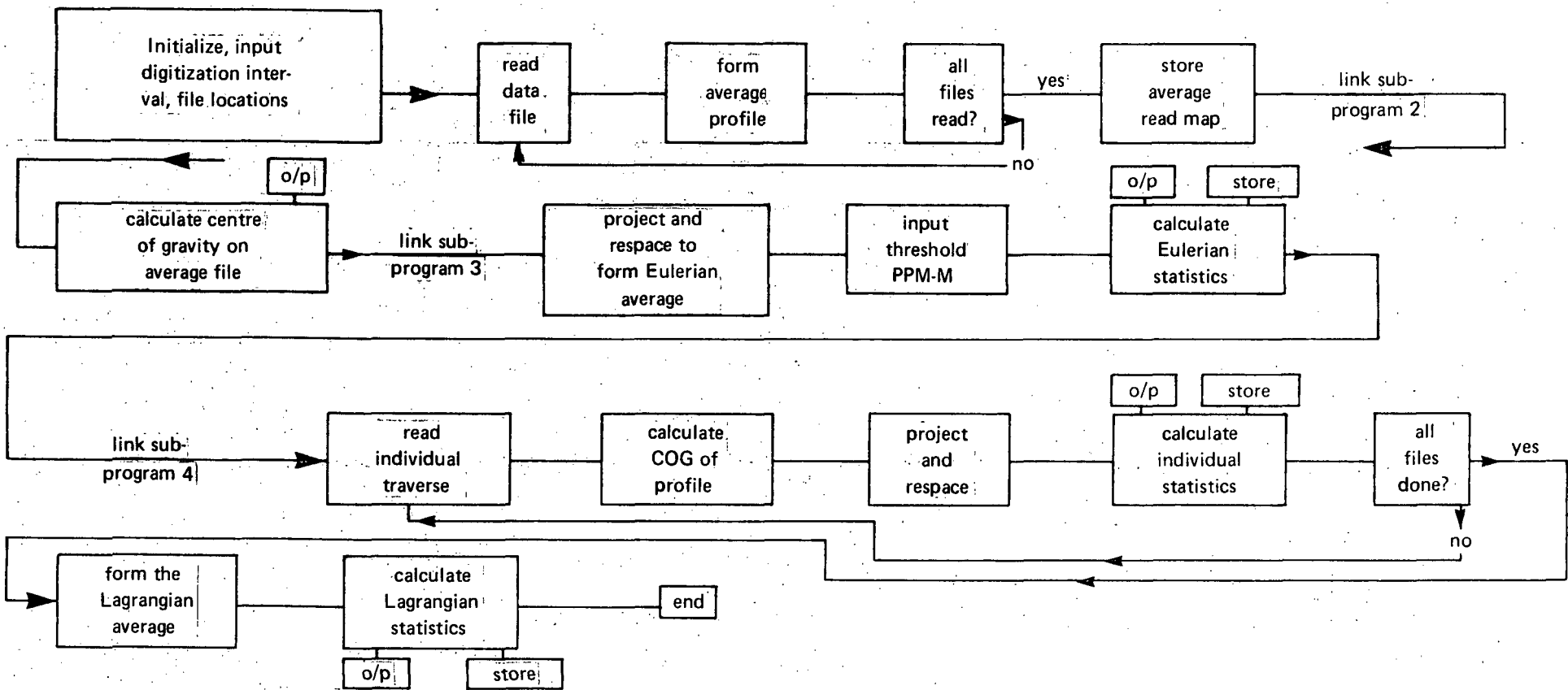
Figure   3

Program flow of COSPEC processor

$(T(1,N),T(2,N))$ — end point of traverse
$(N \leq 256)$

original
2x256
map file
$(T(1,6),T(2,6))$

final respaced (3X)3X256 map
file stored in files 8,9,10
of processor cassette.

$(T(1,5),T(2,5))$

$T(1,N)=X_n$
$T(2,N)=Y_n$
$T(3,N)=\theta_{n,n-1}$

$(T(1,4),T(2,4))$

proper digitization
grid

$(T(1,3),T(2,3))$ — start point of
traverse

n

$n-1$

$\theta_{n,n-1}$
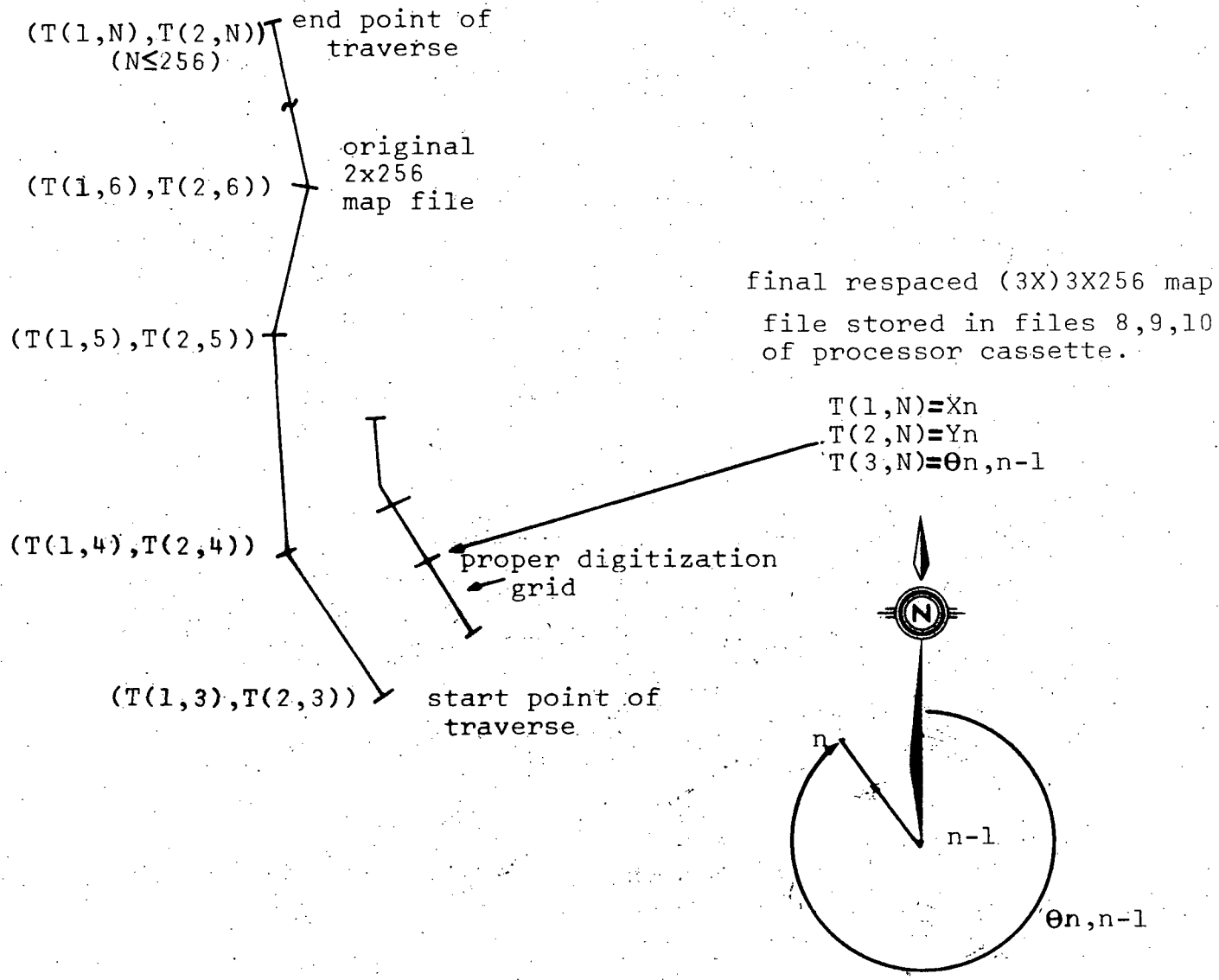
Figure 4

Map-respacing geometry

stack
(0,0)

T2   T3

D

$(T(1,I)\ ,\ T(2,I))$

COG
(X7,Y7)

D>0

plume
bearing

D<0

"effec-
tive
plane"

road
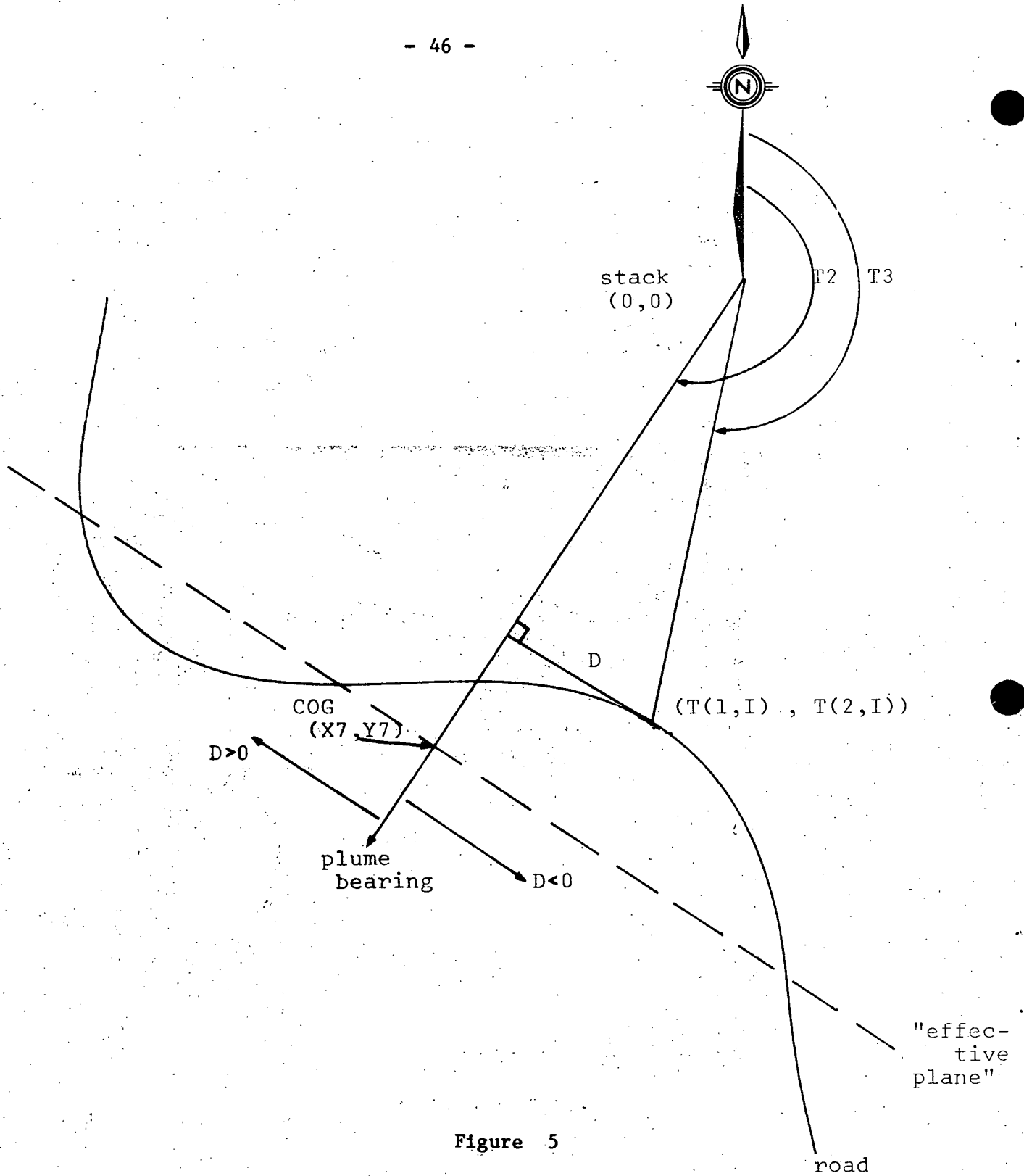
Figure 5

Crosswind-distance geometry
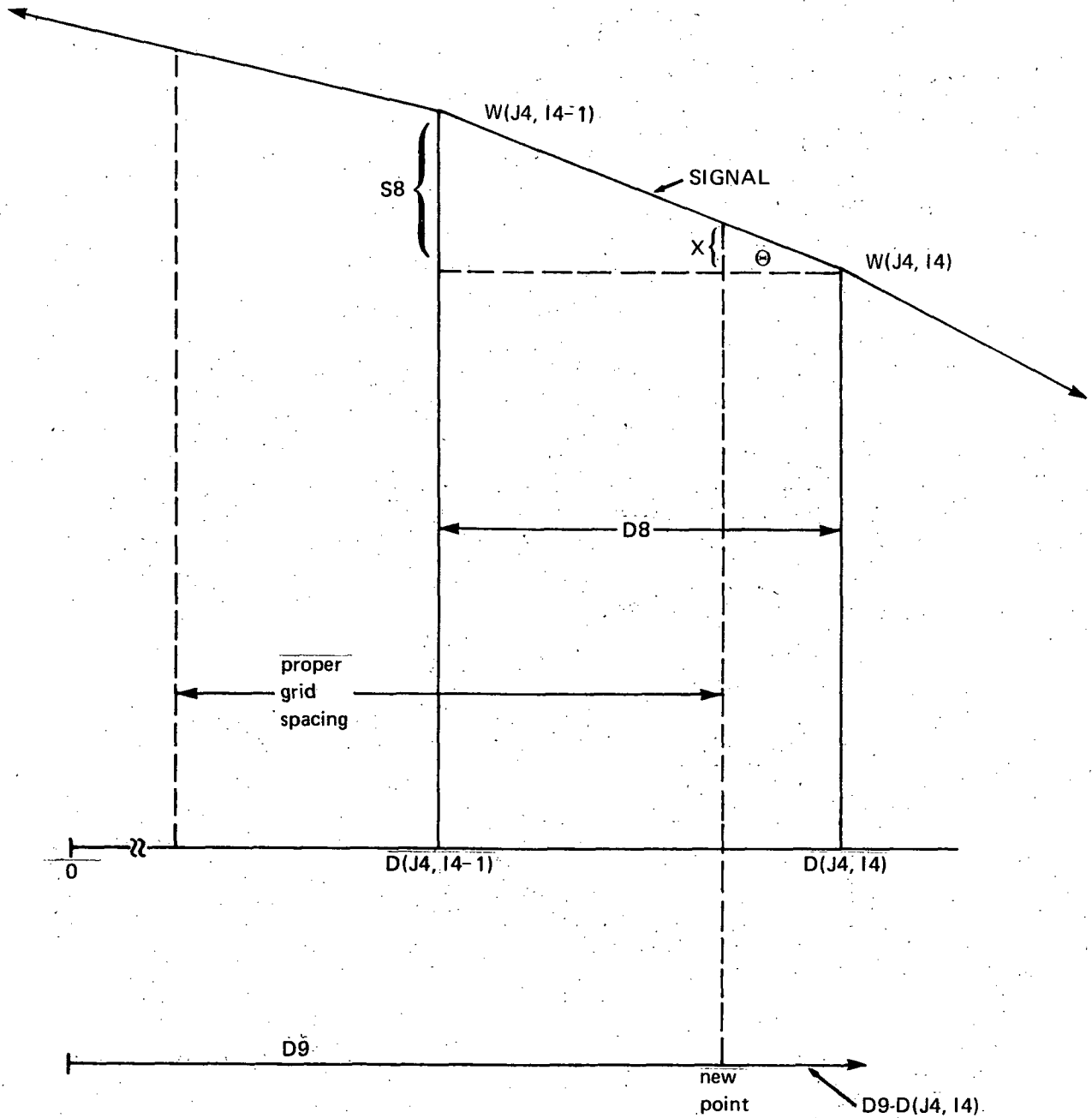
$$\tan \Theta = S8/D8 > 0 \text{ if } S8 > 0$$

$$X = (D9-D(J4,I4)\tan \Theta$$

$$= S8 \times (D9-D(J4,I4)/D8 \equiv S8 \times C9$$

$$\text{signal} = X \ W(J4,I4)$$

Figure 6

Crosswind respacing

```
LOAD  4
RUN
INPUT DIGIT. INTERVAL IN METRES? 11.9
HOW MANY FILES TO AVERAGE?  4
TRAVERSE # 1    ON FILE?  2
TRAVERSE # 2    ON FILE?  3
TRAVERSE # 3    ON FILE?  4
TRAVERSE # 4    ON FILE?  5
MOUNT DATA TAPES IN CALC.? 1*
ALL FILES ON ONE CASSETTE? YES
C.M. FILE FOR STORAGE OF AVERAGE?  10
MAP STORED ON FILE?  13
LOAD MAP FILE INTO CALC. SLOT?  1*
LOAD PROCESSOR IN CALC.?  1*


AVERAGE COG:
X = -555.0760199;  Y =  -3724.228409
BEARING OF AVE. COG (TRUE N)  = 188.4772206 DEGREES


BEARING OK OR TO PAST COG?  YES
INPUT THRESHOLD PPM?  25
COG OF EULERIAN IS  156.9173730  METRES FROM AVERAGE COG
BEARING (TRUE NORTH) OF EUL. COG  =  190.8635761 DEG

SIGMA  Y  =  459.6183018 METRES
MOMENTAL SKEWNESS  = -0.126727343
KURTOSIS  =  205687.0994  PPM-M ↑ 2


C.M. FILE FOR EULERIAN PROFILE?  11
DATA FILES IN CALC. SLOT?  1*
COG OF PROFILE AT 0951:13/03/76 IS 231.6449516 METRES
BEARING (T. N.) OF COG IS 191.9976140 DEGREES


SIGMA  Y  =  392.3966973  METRES
MOMENTAL SKEWNESS  =  -0.658325455
KURTOSIS  =  2.782261094
AREA  =  217986.3575  PPM-M ↑ 2
```

---

* These values are in response to a calculator prompt and need
   only be digital input.

FIGURE 7

Computer output for the "PRINT-ALL" feature

C.M. FILE FOR PROFILE t = 0951:13/03/76? 12
COG OF PROFILE AT 0957:/13/03/76 IS 336.0424645 METRES
BEARING (T.N.) OF COG IS 193.5771064 DEGREES

SIGMA Y = 522.3987414 METRES
MOMENTAL SKEWNESS = -0.476547480
KURTOSIS = 2.269596943
AREA = 287492.8176 PPM-M$\uparrow$2

C.M. FILE FOR PROFILE t = 0957:13/03/76? 13
COG OF PROFILE AT 1008:13/03/76 IS -24.95368276 METRES
BEARING (T.N.) OF COG IS 188.0975179 DEGREES

SIGMA Y = 338.3698451 METRES
MOMENTAL SKEWNESS = 0.435299063
KURTOSIS = 2.560940817
AREA = 142826.7619 PPM-M$\uparrow$2

C.M. FILE FOR PROFILE t = 1008:13/03/76? 14
COG OF PROFILE AT 1015:13/03/76 IS -36.41202038 METRES
BEARING (T.N.) OF COG IS 187.9231736 DEGREES

SIGMA Y = 506.8402564 METRES
MOMENTAL SKEWNESS = 1.331172999
KURTOSIS = 8.951048579
AREA = 182129.9879 PPM-M$\uparrow$2

C.M. FILE FOR PROFILE t = 1015:13/03/76? 15
ALL OUTPUT FILES ON ONE TAPE? YES

LAGRANGIAN AVERAGE

SIGMA Y = 563.2920802 METRES
MOMENTAL SKEWNESS = 3.617264986
KURTOSIS = 28.27382066
AREA = 203144.8119 PPM-M$\uparrow$2
FILE TO STORE LAGR. AV.? 16
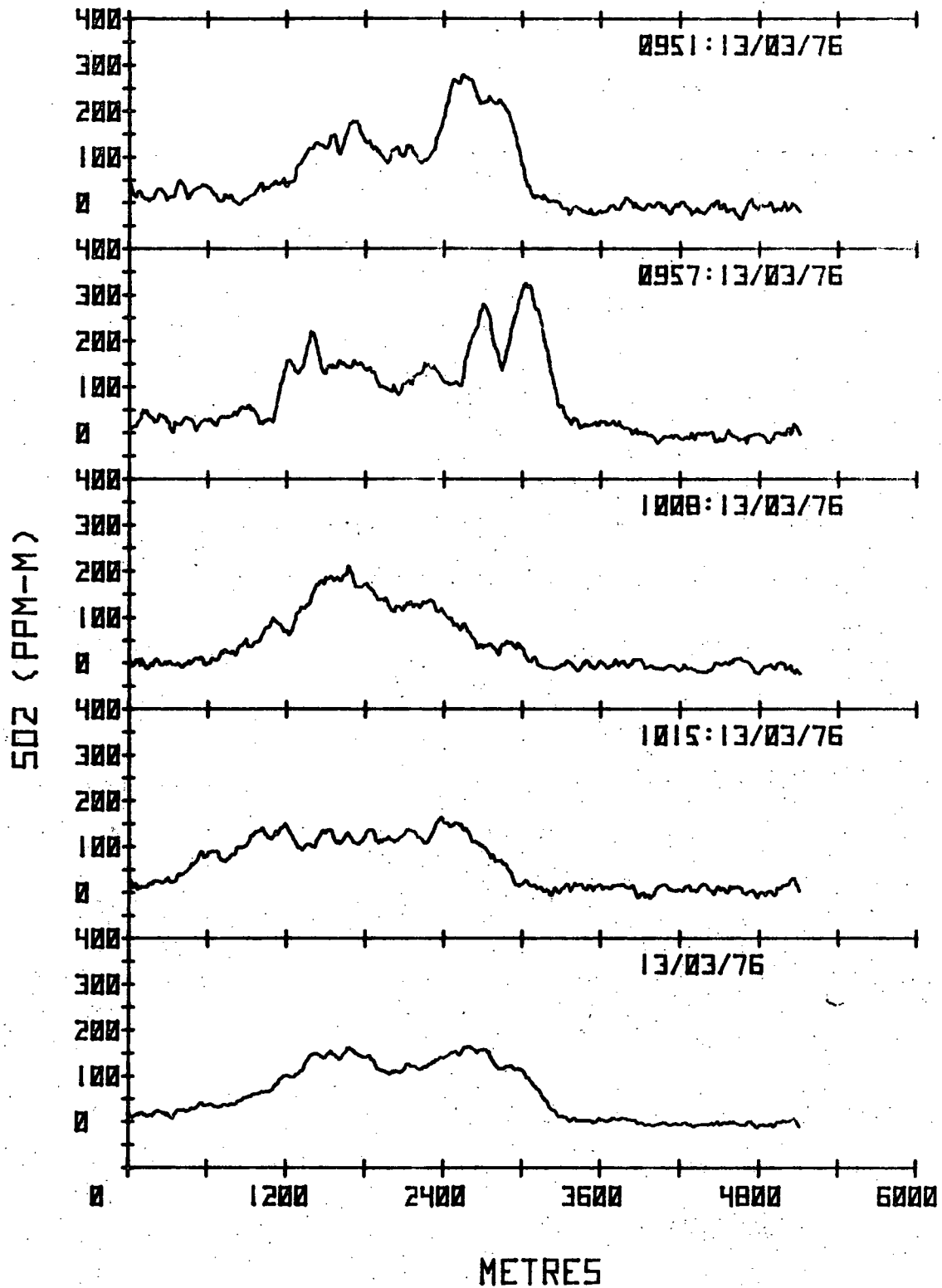
FIGURE 7

Figure 8

SPACE plot of profiles and their average
(bottom profile)
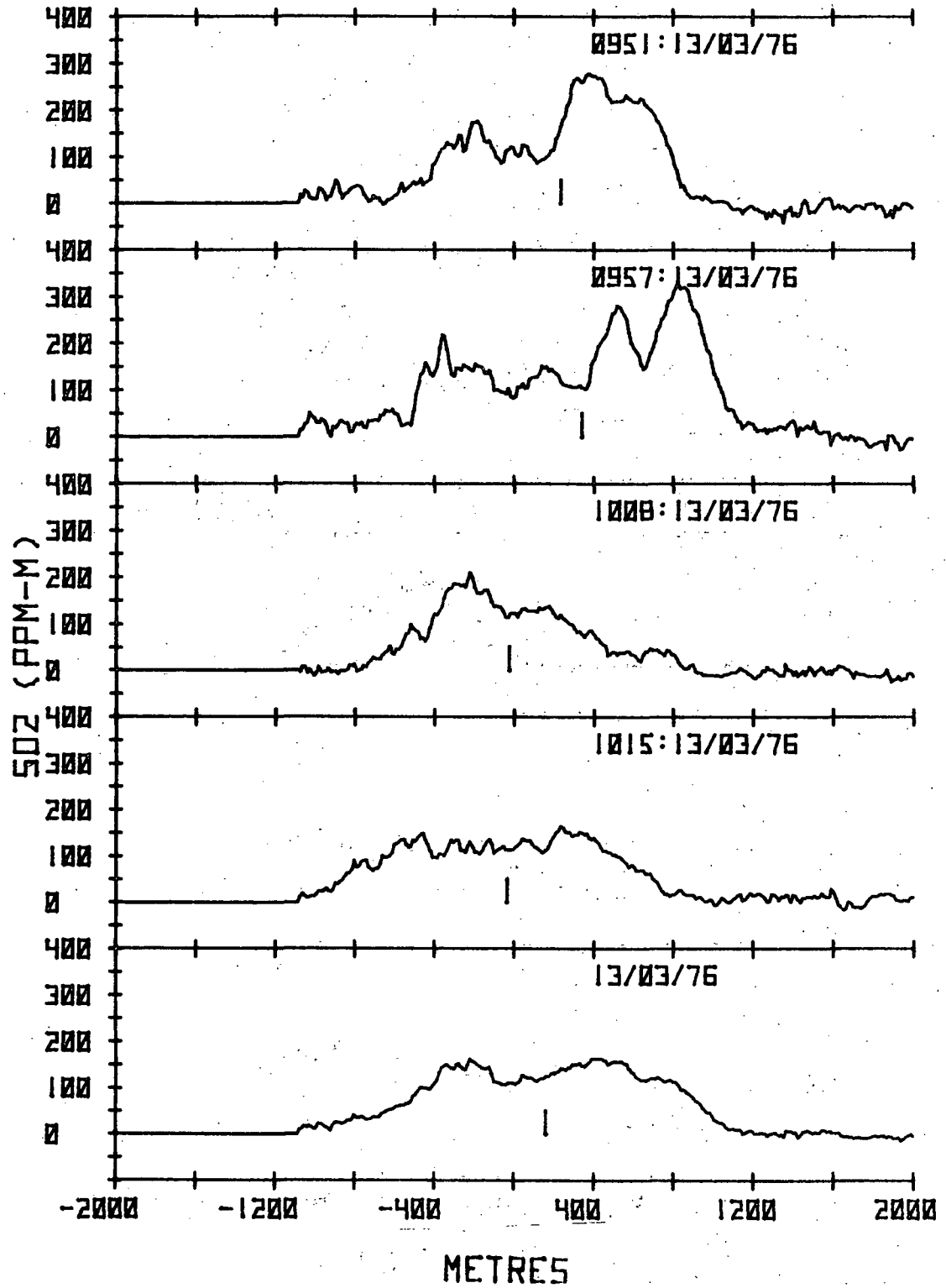
Figure 9

EUL (EULERIAN) plot of the profiles of
Figure 8 projected onto effective plane
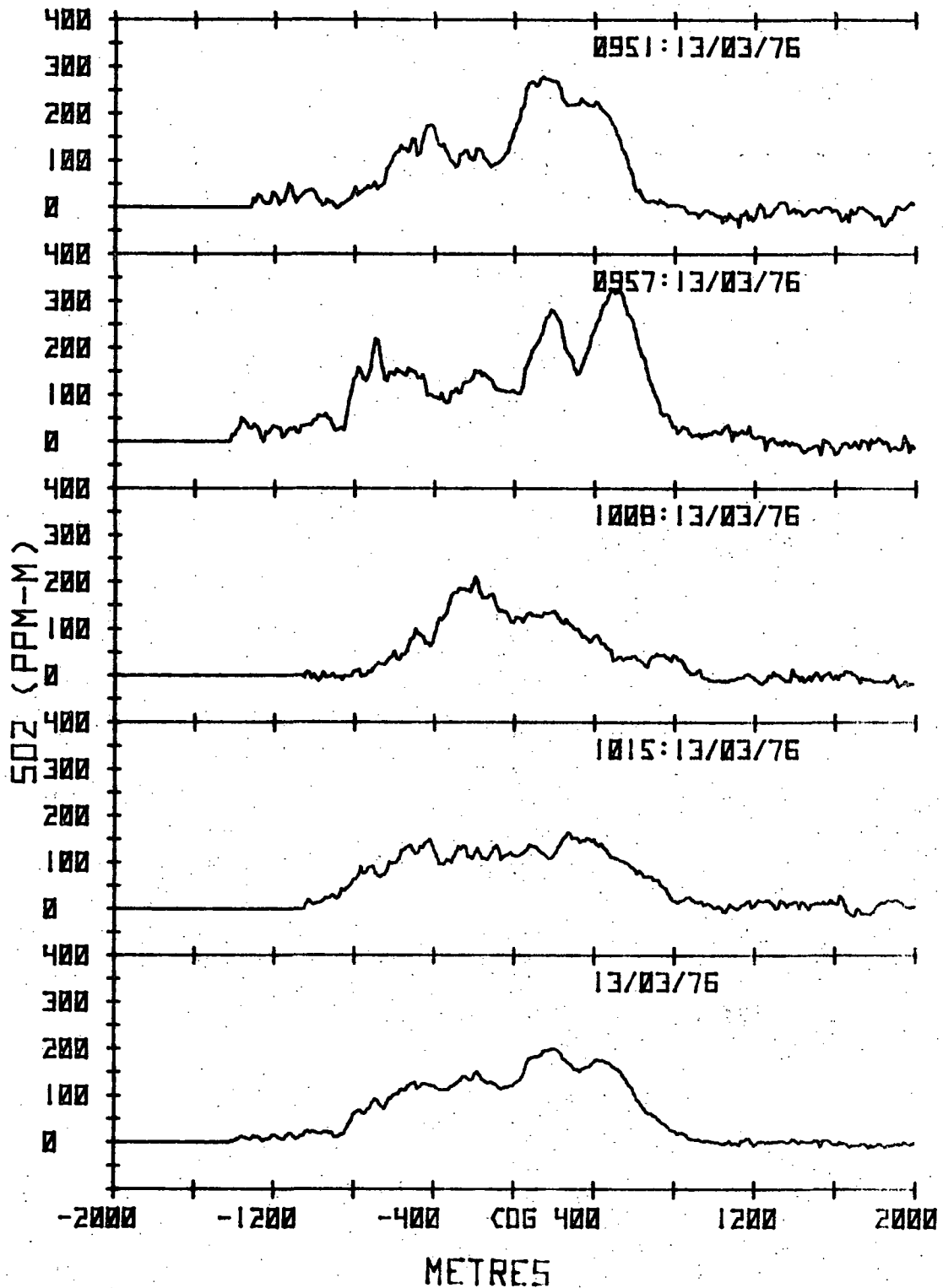
Figure 10

LAG (Lagrangian) plot of the profiles
of Figure 8 with superimposed COG's

TEC 860   UDC: 551.508.99
12 May 1978   ISSN: 0068-7804
CANADA
Fisheries and Environment
Atmospheric Environment Service
4905 Dufferin Street, Downsview, Ontario

Data Processing Procedures for the Barringer
Correlation Spectrometer (COSPEC)
by
R. M. Hoff, A. J. Gallant and M. M. Millán

8 pp.   10 figs.   4 refs.   5 appendices

Subject Reference: 1.   Barringer Correlation
Spectrometer
2.   Data Processing Procedures

ABSTRACT: Use of a Barringer Correlation Spectrometer (COSPEC) at the Atmospheric Environment Service research facilities in Toronto has led to the development of a data-processing methodology for the acquisition of plume dispersion data from remote-sensing instruments. The techniques described in this report are applicable to the use of COSPECs and other mobile sensing equipment. The computer codes, written in the BASIC language, are documented along with a user's guide for those interested in employing these techniques.