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An Operationally Oriented
Small-Scale 500-Millibar Height
Analysis Program



Technical Memorandum WBTM TDL 19

U.S. DEPARTMENT OF COMMERCE / ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION

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Weather Bureau

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AN OPERATIONALLY ORIENTED SMALL-SCALE
500-MILLIBAR HEIGHT ANALYSIS PROGRAM

Harry R. Glahn and George W. Hollenbaugh



OFFICE OF SYSTEMS DEVELOPMENT
TECHNIQUES DEVELOPMENT LABORATORY

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ABSTRACT

A computer program which performs analyses of 500-mb heights over the relatively dense data region of the United States and Canada by the method of successive approximations is described. The program includes error-detecting routines and can be used in an operational environment. The detail specified by the radiosonde reports is retained with a gridlength of about 100 miles. A listing of the program is included.

INTRODUCTION

In support of a task to investigate the possible advantages of reducing the gridlength used in numerical prediction models, a computer program was developed to perform small-scale 500-mb height analyses over the relatively dense data network of the United States and Canada. The method used is basically that of Bergthorssen and Döös [1] and Cressman [2]; however, differences in details do exist. Error-detecting routines are included, and observed winds are used in implying height gradients in a geostrophic manner.

ANALYSIS AREA AND DATA

The analysis area, shown in Figure 1., is covered by a 35 x 35 grid which has a gridlength of about 100 miles, exactly $\frac{1}{2}$ that normally used at the National Meteorological Center (NMC). Alternate gridpoints in the "half grid" are gridpoints in the NMC "full grid". The upper air reporting stations are also shown in Fig. 1; the station spacing is somewhat greater than the grid spacing even in the most dense data areas.

The data used are the 500-mb height and wind reports from the radiosonde network which are collected on magnetic tape, decoded, and checked for hydrostatic consistency at NMC.

THE ANALYSIS METHOD

The basic analysis method used at NMC is still that described by Cressman [2] in 1959, although some of the details have undergone change.* This method is one of successive approximations and allows the use of the geostrophic or some other wind-height relationship so that reported winds can be used together with reported heights in adjusting the required "first guess" height analysis.

* McDonell, J. E., "Notes on NMC Objective Analysis Programs" and attachments, unpublished manuscript, March, 1968.

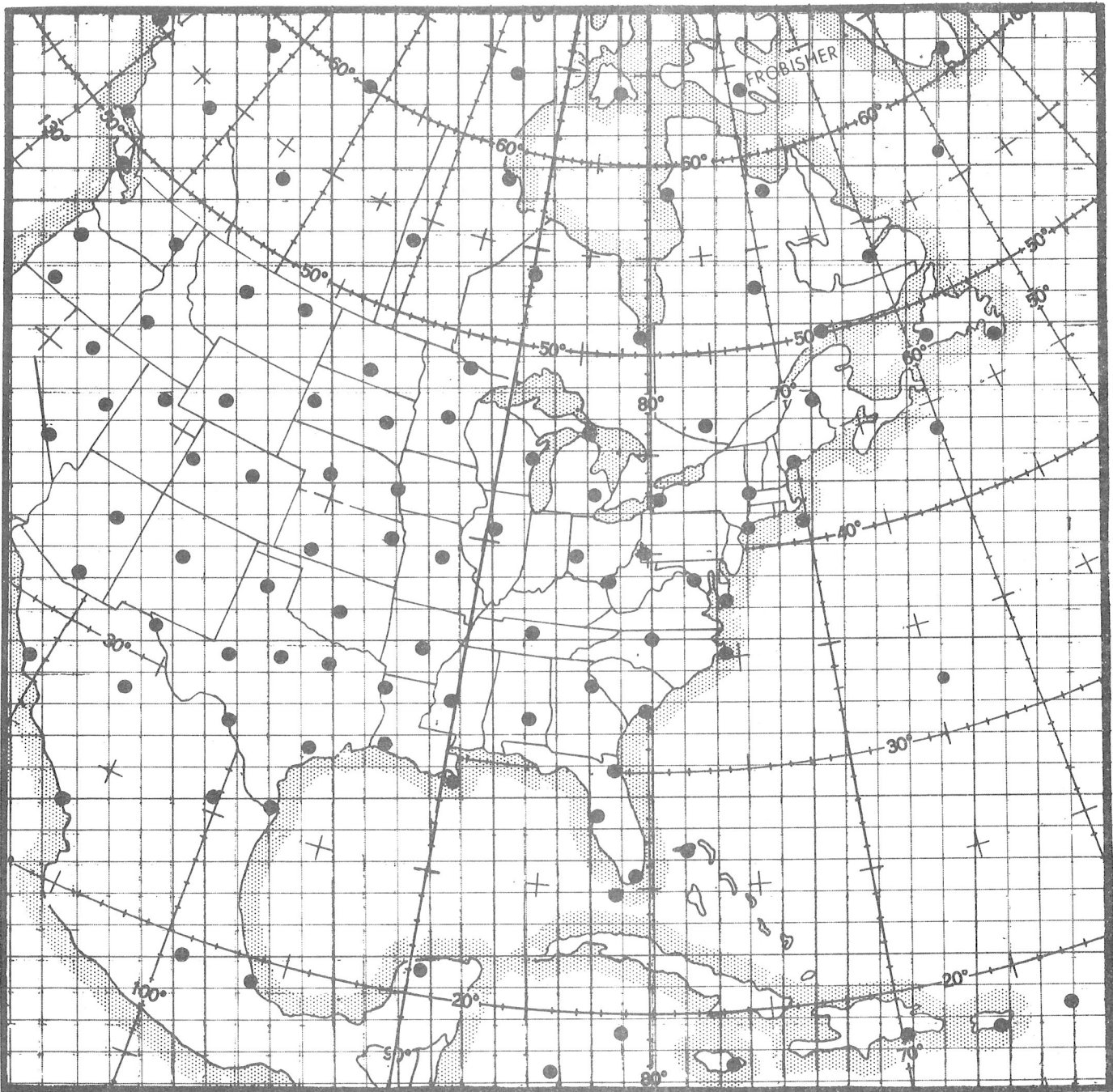


Figure 1. The Analysis area and superimposed 35 x 35 grid. The observing stations are shown by black dots.

The analysis is performed in a series of cycles or passes over the data. In most applications the first guess may be considerably in error, and 3 or 4 passes are necessary. However, in this application, the first guess is the analysis performed by NMC on the full grid and interpolated to the half grid. Therefore, the first guess is very good, and only 2 scans are necessary to insert the detail possible with the half grid.

On each pass, an observation occasions a change or correction to all gridpoints within a distance of R gridlengths, where R is called the scan radius or radius of influence. R varies with pass number and usually decreases for later passes.

A correction term is computed based on each observation. This correction is one of three types:

$$C_{1,i,j} = (Z_{x,y} - \hat{Z}_{x,y}) \quad \text{if only height is available}$$

$$C_{2,i,j} = [Z_{x,y} + (i - x) \frac{\partial Z}{\partial x} + (j - y) \frac{\partial Z}{\partial y} - \hat{Z}_{i,j}] \quad \text{if both height and wind are available}$$

$$C_{3,i,j} = [\hat{Z}_{x,y} + (i - x) \frac{\partial Z}{\partial x} + (j - y) \frac{\partial Z}{\partial y} - \hat{Z}_{i,j}] \quad \text{if only wind is available}$$

where

$Z_{x,y}$ = observed height at station at position x,y

$\hat{Z}_{x,y}$ = height at station interpolated from current analysis

$\frac{\partial Z}{\partial x}, \frac{\partial Z}{\partial y}$ = height gradients in x and y directions respectively

$\hat{Z}_{i,j}$ = height at gridpoint i,j from current analysis

The height gradients are computed by the geostrophic relationships:

$$\frac{\partial Z}{\partial x} = \frac{fV}{g} = .782 \sin \Phi (1 + \sin \Phi) V$$

$$\frac{\partial Z}{\partial y} = -\frac{fU}{g} = -.782 \sin \Phi (1 + \sin \Phi) U$$

where U and V are the observed eastward and northward wind components, respectively, Φ is the latitude of the observing station, g is the gravitational acceleration, and f the Coriolis parameter. When U and V are used in knots, $\frac{\partial Z}{\partial x}$ and $\frac{\partial Z}{\partial y}$ will be in meters/grid unit at the latitude of the station.

The individual correction terms are then combined into a total correction for the gridpoint in one of three ways:

$$C_a = \frac{1}{n} \sum_{k=1}^n C_{mk}$$

$$C_b = \frac{1}{n} \sum_{k=1}^n \frac{R^2 - d_k^2}{R^2 + d_k^2} C_{mk}$$

$$C_c = \frac{\frac{1}{n} \sum_{k=1}^n \frac{R^2 - d_k^2}{R^2 + d_k^2} C_{mk}}{\frac{1}{n} \sum_{k=1}^n \frac{R^2 - d_k^2}{R^2 + d_k^2}}$$

Where n = number of observations within R of the gridpoint,

d_k = the distance from the observation to the gridpoint,

m = the type of correction 1, 2, or 3, and

C_{mk} = the individual correction terms.

The type of correction to make for each observation is determined by the program; a height or wind is available only if reported and acceptable by the error-detection routine. The way the corrections are combined is controlled by a word on a control card.

C_b and C_c perform a variable weighting of the individual corrections; the closer a station is to the gridpoint, the greater is its weight. The effect of using C_a or C_c rather than C_b is a greater change being made at the gridpoint and more rapid convergence to the general level of the data within the influence circle.

ERROR-DETECTING PROCEDURE

Errors in the observations are detected by comparing them to the current analysis (first guess for the first pass). The height is judged to be in error and not used in the analysis if

$$|Z_{x,y} - \hat{Z}_{x,y}| > ERZ$$

where ERZ is specified by control card. The wind is judged to be in error and not used if

$$|D_{x,y} - \hat{D}_{x,y}| > ERD \quad \text{and} \quad V_{x,y} \geq 15$$

or

$$|V_{x,y} - \hat{V}_{x,y}| > ERS$$

where D and V are the direction and speed of the wind, respectively, and the carat indicates interpolated values. The direction difference is measured so as to be not greater than 180°. A wind will not be discarded because of its direction unless its speed is ≥ 15 kts. ERD and ERS are specified by control card.

SMOOTHING

Usually some type of smoothing is done after one or more of the data passes. The smoothing operator employed in this program is that used by the Travelers Research Center [3] and is a generalization of the one given by Cressman [2]:

$$S_{i,j} = \frac{A_{i,j} + b\bar{A}_{i,j}}{1 + b}$$

where

$$\bar{A}_{i,j} = \frac{1}{4}(A_{i+1,j} + A_{i,j+1} + A_{i,j-1} + A_{i-1,j})$$

and $S_{i,j}$ is the smoothed gridpoint value. Specific values of b used are given in the following section.

APPLICATION OF THE ANALYSIS PROGRAM

The first guess is arrived at by interpolating with Bessel's formula from the NMC full grid analysis. An example of a contoured first guess field is shown in Fig. 2. A specific combination of type of correction and values of R, ERZ, ERD, ERS, and b which gives good results is shown in Table 1.

Table 1. A combination of program parameters which gives good results

Pass No.	R(Grid Units)	ERZ (Meters)	ERD (Degrees)	ERS (Knots)	Type of Correction	b
1	3	35	35	25	C _c	2
2	2	35	35	25	C _b	1

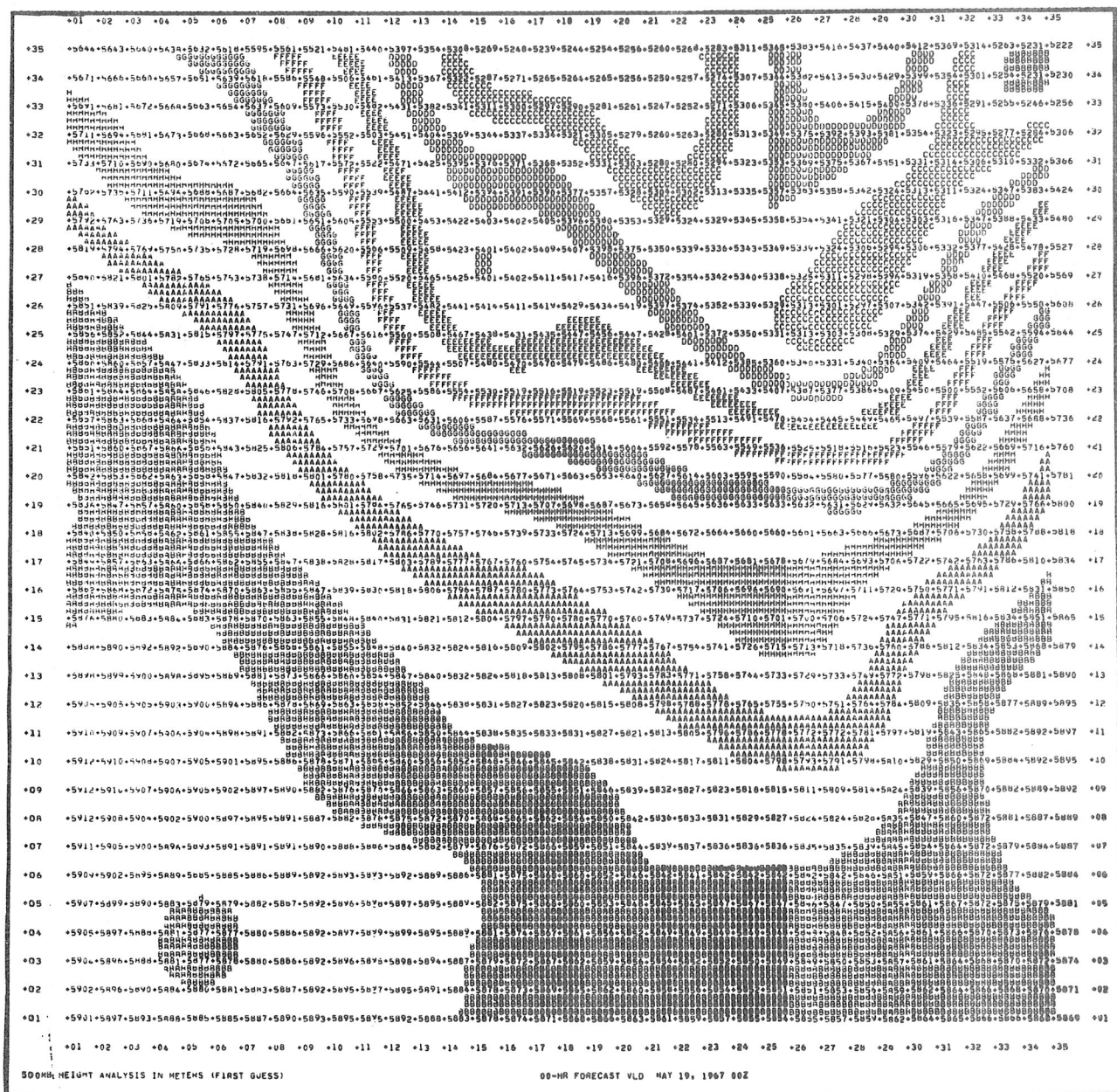


Figure 2. First guess 500-mb height field for May 19, 1967, 0000 GMT, interpolated from NMC analysis.

Combinations of parameters other than that shown in Table 1 will also give good results, and repeated use of the program might suggest a better set. If the acceptance criteria ERZ, ERD, and ERS are lowered, more data will be discarded; an erroneous value will more likely be thrown out, but also some good data will be judged incorrect.

Figure 3 shows the final analysis after two data passes for the same case as shown in Figure 2. The data on which the analysis is based are shown in Figure 4, with the final analysis traced from Figure 3.

The small-scale analysis and the interpolated NMC analysis are, of course, much the same. More detail is shown in the small-scale analysis in a few areas:

- (1) The low center near 55N and 95W (see Fig. 4 for location) on the small-scale analysis is lower and slightly to the northwest of the low on the full-grid analysis
- (2) The low center near 65N and 80W is deeper on the small-scale analysis
- (3) The low center in eastern Quebec is more distinguishable from the trough to the northeast on the TDL analysis
- (4) The ridge from the northeast extends farther into the Labrador-Newfoundland area on the half-grid analysis.

In each case the detail seems justified and the data are fit very nicely. Only two data within the 35 x 35 grid area were judged incorrect and not used by the program--the wind in north-central Mexico (near 29N, 106W) and the wind at Caribou, Maine. In the former case, the direction appeared to be incorrect, and in the latter, the speed seemed to be too low. Data outside the analysis area but plotted in Fig. 4 were included in making the analysis.

Mean-square and mean absolute differences were computed between both the observed wind speeds and heights and the wind speeds and heights interpolated from the NMC and TDL analyses. The NMC analysis had already been interpolated by Bessel's formula to the TDL half grid. Then interpolation to station locations was also done with Bessel's formula. Geostrophic winds were calculated at each grid point before interpolation. The results are given in Table 2.

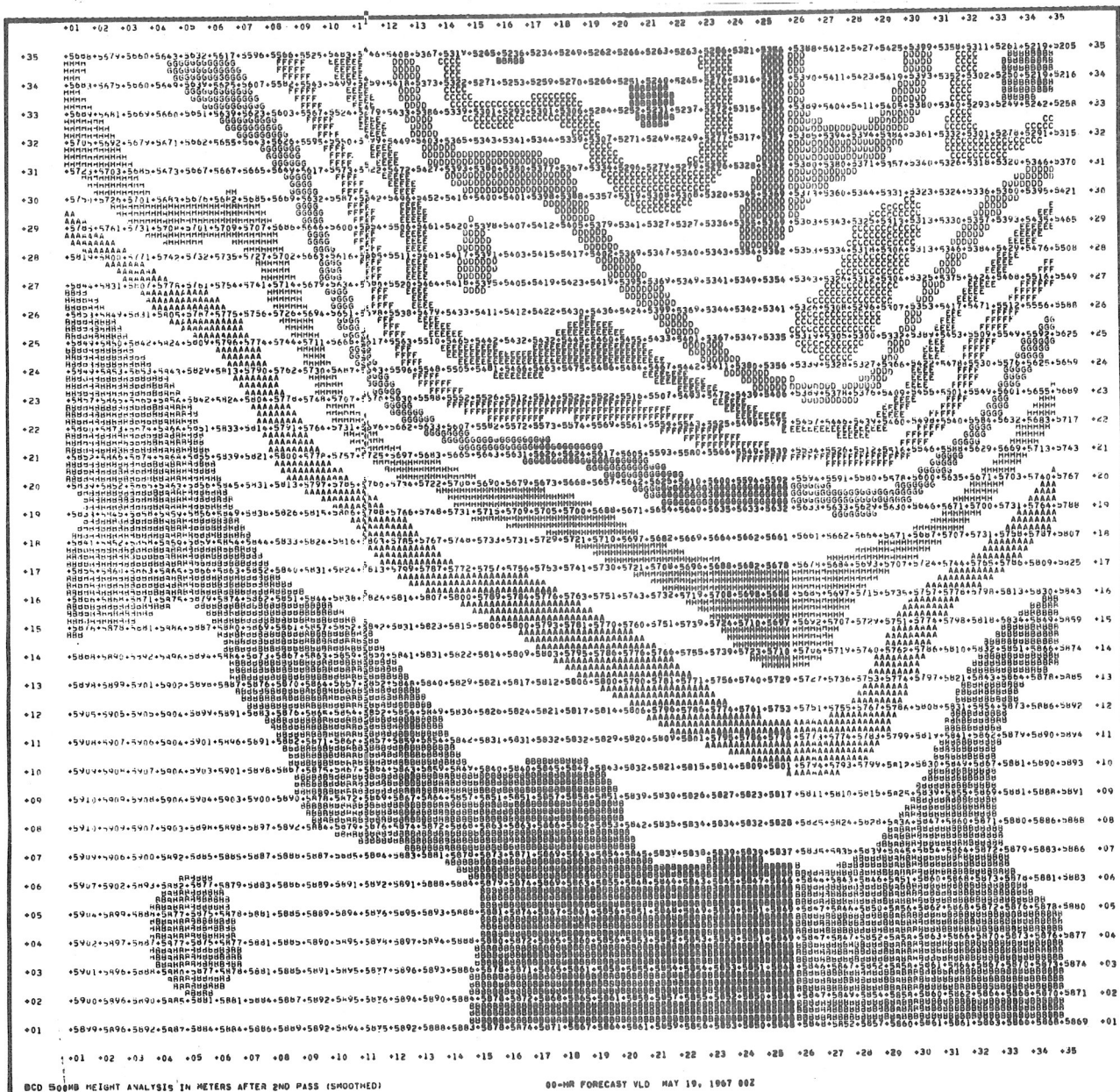


Figure 3. Final 500-mb height analysis for May 19, 1967, 0000 GMT.

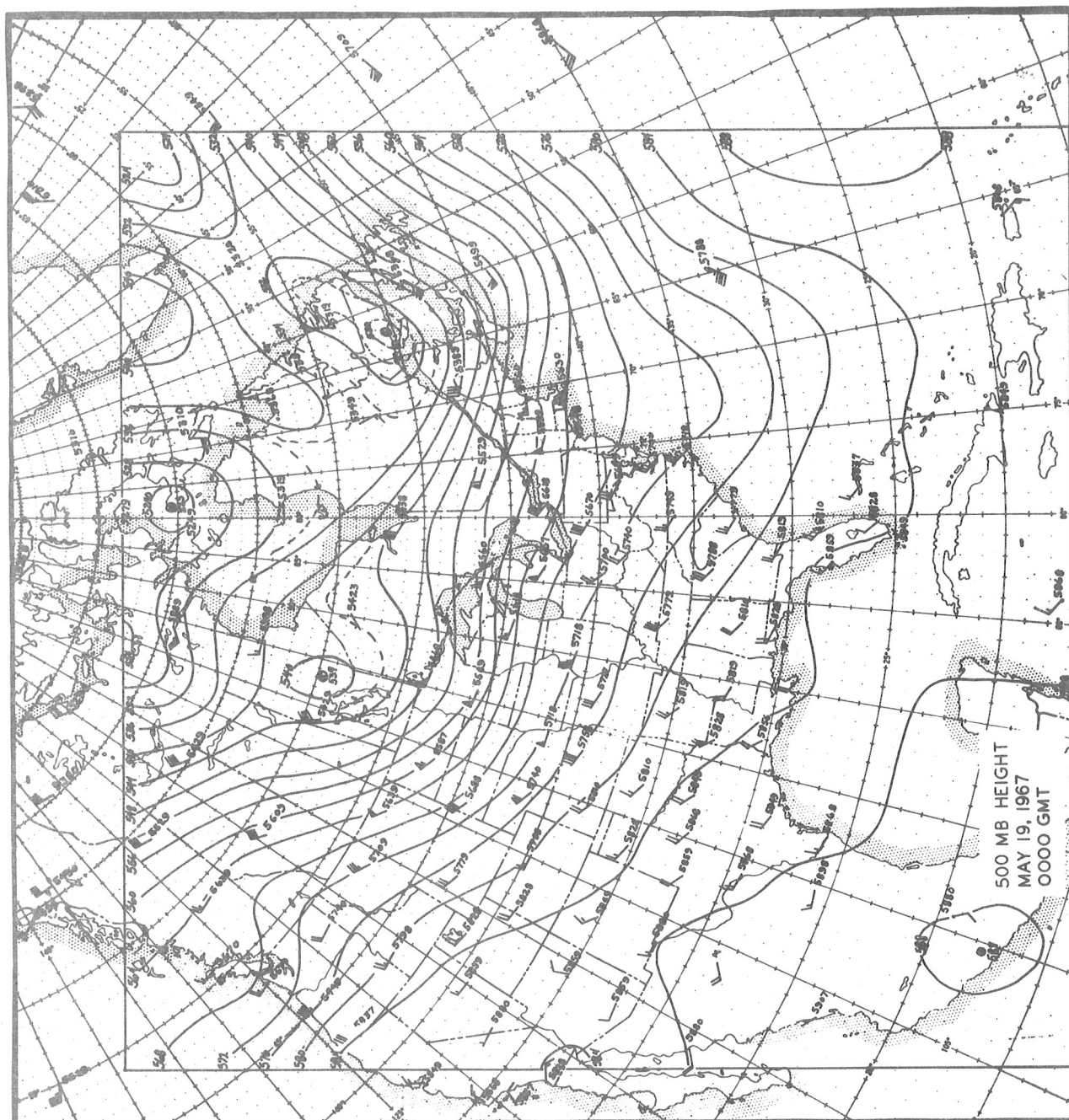


Figure 4. Observed data and final analysis traced from Figure 3.

Table 2. Mean-square (MSD) and mean absolute differences (MAD) in wind speed in m/sec. and height in meters between observations and analyses

Analysis	Wind Speed			Height		
	No. of Stations	MAD	MSD	No. of Stations	MAD	MSD
NMC	93	4.9	6.3	96	6.6	8.7
TDL	93	4.1	5.5	96	3.4	4.9

All of the reported winds within the grid were used in computing the differences. The observations contain some error and the computed differences are partly due to these errors. Also, the observations can be fit too closely, resulting in a ragged analysis. This ragged analysis would not be desirable and statistics like those shown in Table 2 might be misinterpreted. However, it is felt the TDL analysis is of about the desired smoothness and that the statistics in Table 2 indicate a better analysis is possible with a grid length of about 100 miles than with a grid length of twice that. This conclusion is based on several such comparisons.

The geostrophic wind relationship is used in this program. Considerable effort was expended in an attempt to produce a better analysis with an approximation to the gradient wind relationship. However, no overall improvement was noted, and, in fact, statistics like those in Table 2 indicated the analysis with the gradient wind approximation to be less desirable.

REFERENCES

1. Bergthorssen, P. and B. R. Doos, "Numerical Weather Map Analysis", Tellus, Vol. 7, No. 3, August, 1955, pp. 329-340.
2. Cressman, G. P., "An Operational Objective Analysis System", Monthly Weather Review, Vol. 87, No. 10, October, 1959, pp. 367-374.
3. Thomasell, A., Jr., and J. G. Welsh, "Objective Analysis of Sea Level Pressure and Surface Temperature, Dew Point and Wind", The Travelers Research Center, Inc., Tech. Publication 19, Contract FAA/BRD-363, November, 1962, 87 pp.

APPENDIX

This appendix contains the listings of two subroutines in FORTRAN language necessary for performing the analysis described. These subroutines are in the form for use with the SCOPE Operating System on the CDC 6600 at Suitland, Maryland.

Subroutine ANALYZ is called when an analysis is desired and it, in turn, uses NTRP for interpolation. Comment cards describe the program parameters.

Upon entry to ANALYZ, certain information must be present in COMMON:

ADP (150,9): Basic data, and computed variables described in
comment cards

T(35,35) : First guess field of 500-mb heights in meters

NADP : Number of datum values in ADP, that is, the number of
rows occupied.

The lower left corner of the grid is considered to be position (1,1) with the first subscript increasing upward to 35 and the second subscript increasing to the right to 35.

The subroutine OUTPT called by ANALYZ is used for outputting maps. The calling statement can be eliminated or another subroutine substituted.

SUBROUTINE ANALYZ

D523

JUNE, 1968 HOLLERBAUGH

TO MAKE A 500 MB ANALYSIS BY THE BERGTHORSSSEN-CRESSMAN-DOOS
(BCD) METHOD

SUBROUTINE ARGUMENTS AND CONTROL INFORMATION

ERZ=MAX ERROR FROM LAST PASS (OR FIRST GUESS) HEIGHT
IN METERSERD=MAX ERROR FROM LAST PASS (OR 1ST GUESS) WIND DIR.
IN DEGREESERS=MAX ERROR FROM LAST PASS (OR 1ST GUESS) WIND SPD.
IN KNOTS

RDS=RADIUS OF INFLUENCE IN GRID UNITS

SMH=SMOOTHING PARAMETER (NO SMOOTHING DONE IF SMH=0)

KRT=CORRECTION TYPE

1 MEANS W=1

2 MEANS $W = (RSQ - DSQR) / (RSQ + DSQR)$

3 MEANS SAME AS TYPE 2 EXCEPT SUM OF WTS IN DEN.

NPS=NUMBER OF PASSES

NADP=HOLDS NUMBER OF DATA POINTS

T(,)=HOLDS CURRENT ANALYSIS

ADP(N,1)=HOLDS STATION DATA X-POSITION

ADP(N,2)=HOLDS STATION DATA Y-POSITION

ADP(N,3)=HOLDS STATION DATA HEIGHT IN METERS

ADP(N,4)=HOLDS STATION DATA WIND DIRECTION IN DEGREES

ADP(N,5)=HOLDS STATION DATA WIND SPEED IN KNOTS

ADP(N,6)=HOLDS STATION DATA GRID ORIENTED WIND DIRECTION
IN VECTOR NOTATION MEASURED CLOCKWISE FROM NORTH
IN RADIANSADP(N,7)=HOLDS STATION DATA GRID ORIENTED WIND GRADIENT
SCALING FACTOR IN M/GRID INTERVALADP(N,8)=HOLDS STATION DATA WIND GRADIENT (DZ/DX) IN X
DIRECTION IN M/GRID INTERVALADP(N,9)=HOLDS STATION DATA WIND GRADIENT (DZ/DY) IN Y
DIRECTION IN M/GRID INTERVALKILH(N) =0 IF STATION HEIGHT IS JUDGED TO BE CORRECT AND
IS USED IN ANALYSIS, OTHERWISE = 1KILW(N) =0 IF STATION WIND IS JUDGED TO BE CORRECT AND
IS USED IN ANALYSIS, OTHERWISE = 1

DX(,)=DZ/DX IN M/GRID INTERVAL

DY(,)=DZ/DY IN M/GRID INTERVAL

CORR(,)=HOLDS CORRECTIONS TO BE MADE ON CURRENT PASS

CONT(,)=HOLDS NUMBER OF STATIONS AFFECTING GRID POINT
ON CURRENT PASS

A MISSING DATUM IS INDICATED IN VARIOUS ARRAYS BY 9999.

DIMENSION ADP(150,9),T(35,35),CORR(35,35),CONT(35,35),

1 KILH(150),KILW(150),VALZ(150),VALX(150),VALY(150),

2 DX(35,35),DY(35,35)

COMMON/BLOCK3/ADP,NADP

COMMON/BLOCK12/T

READ 110,ERZ,ERD,ERS,RDS,SMH,KRT,NPS

110 FORMAT(5F4.0,2I4)

PRINT 112

```

112  FORMAT(1H1)
      DO 480 LP=1,NPS
      IF(LP-1)125,125,115
115  READ 120,ERZ,ERD,ERS,RDS,SMH,KRT
120  FORMAT(5F4.0,I4)
125  RSQ=RDS*RDS
      PRINT 128,LP,RDS,KRT,SMH,ERZ,ERD,ERS
128  FORMAT(///,I4,F5.1,I4,4F7.1,/)
      ERD=.01745329252*ERD
C      CHANGES ERD FROM DEGREES TO RADIANS
      DO 130 J=1,35
      DO 130 I=1,35
      CORR(J,I)=CONT(J,I)=0.
130  CONTINUE
      DO 131 J=2,34
      DO 131 I=2,34
      DX(J,I)=(T(J,I+1)-T(J,I-1))/2.
      DY(J,I)=(T(J+1,I)-T(J-1,I))/2.
131  CONTINUE
      DO 132 I=2,34
      DX(1,I)=DX(2,I)
      DY(1,I)=DY(2,I)
      DX(35,I)=DX(34,I)
      DY(35,I)=DY(34,I)
132  CONTINUE
      DO 133 J=1,35
      DX(J,1)=DX(J,2)
      DY(J,1)=DY(J,2)
      DX(J,35)=DX(J,34)
      DY(J,35)=DY(J,34)
133  CONTINUE
      DO 245 K=1,NADP
      KILH(K)=KILW(K)=0
      IF(1.-RDS-ADP(K,1))135,135,150
135  IF(RDS+35.-ADP(K,1))150,140,140
140  IF(1.-RDS-ADP(K,2))145,145,150
145  IF(RDS+35.-ADP(K,2))150,155,155
150  VALZ(K)=VALX(K)=VALY(K)=9999.
      KILH(K)=KILW(K)=1
      GO TO 245
155  CALL NTRP(T,ADP(K,2),ADP(K,1),VALZ(K))
      IF(ADP(K,3)-9999.)160,175,160
160  IF(ABSF(ADP(K,3)-VALZ(K))-ERZ)180,180,165
165  PRINT 170,ADP(K,3),VALZ(K),ADP(K,1),ADP(K,2),LP
170  FORMAT(*CSTATION REPORTED HEIGHT*,F9.2,* NOT ACCEPTED, INCONSISTEN
1T WITH ANALYSIS*,F9.2,* COORDINATES*,2F7.2,* PASS*,I3)
175  KILH(K)=1
180  IF(ADP(K,6)-9999.)185,240,185
185  CALL NTRP(DX,ADP(K,2),ADP(K,1),VALX(K))
      CALL NTRP(DY,ADP(K,2),ADP(K,1),VALY(K))
      IF(VALX(K))195,190,195
190  TANTH=-VALY(K)*999999.
      GO TO 200
195  TANTH=-VALY(K)/VALX(K)

```

```

200  EPHI=ATANF(TANTH)
      IF(EPHI)202,208,208
202  IF(VALX(K))204,206,206
204  EPHI=EPHI+3.14159265
      GO TO 210
206  EPHI=EPHI+6.28318530
      GO TO 210
208  IF(VALX(K))204,210,210
210  ADIFF=ABSF(ADP(K,6)-EPHI)
      IF(ADIFF-3.14159265)212,212,211
211  ADIFF=6.28318530-ADIFF
212  IF(ADIFF-ERD)225,225,213
213  IF(ADP(K,5)-15.)225,215,215
215  PRINT 220,ADP(K,6),EPHI,ADP(K,1),ADP(K,2),LP
220  FORMAT(*STATION WIND DIRECTION*,F10.2,* NOT ACCEPTED, INCONSISTEN
1T WITH ANALYSIS*,F9.2,* COORDINATES*,2F7.2,* PASS*,I3)
      GO TO 240
225  ESPD=(SQRTF(VALX(K)**2+VALY(K)**2))/ADP(K,7)
      IF(ABSF(ADP(K,5)-ESPD)-ERS)245,245,230
230  PRINT 235,ADP(K,5),ESPD,ADP(K,1),ADP(K,2),LP
235  FORMAT(*STATION WIND SPEED*,F14.2,* NOT ACCEPTED, INCONSISTENT WI
1TH ANALYSIS*,F9.2,* COORDINATES*,2F7.2,* PASS*,I3)
240  KILW(K)=1
245  CONTINUE
      DO 380 K=1,NADP
      IF(KILH(K).EQ.1.AND.KILW(K).EQ.1)380,260
260  IMIN=ADP(K,1)-RDS+.999
      IF(IMIN)265,265,270
265  IMIN=1
      GO TO 275
270  IF(IMIN-35)275,275,380
275  IMAX=ADP(K,1)+RDS+.001
      IF(IMAX)380,380,280
280  IF(IMAX-35)290,290,285
285  IMAX=35
290  JMIN=ADP(K,2)-RDS+.999
      IF(JMIN)295,295,300
295  JMIN=1
      GO TO 305
300  IF(JMIN-35)305,305,380
305  JMAX=ADP(K,2)+RDS+.001
      IF(JMAX)380,380,310
310  IF(JMAX-35)320,320,315
315  JMAX=35
320  DO 375 J=JMIN,JMAX
      DO 375 I=IMIN,IMAX
      DSQR=(FLOATF(I)-ADP(K,1))**2+(FLOATF(J)-ADP(K,2))**2
      IF(DSQR-RSQ)325,325,375
325  IF(KILH(K).EQ.0.AND.KILW(K).EQ.0)330,335
330  EHGT=ADP(K,3)+(I-ADP(K,1))*ADP(K,8)+(J-ADP(K,2))*ADP(K,9)-T(J,I)
      GO TO 350
335  IF(KILH(K).EQ.1.AND.KILW(K).EQ.0)340,345
340  EHGT=VALZ(K)+(I-ADP(K,1))*ADP(K,8)+(J-ADP(K,2))*ADP(K,9)-T(J,I)
      GO TO 350

```

```
345 EHGT=ADP(K,3)-VALZ(K)
350 IF(KRT-1)355,355,365
355 CORR(J,I)=CORR(J,I)+EHGT
360 CONT(J,I)=CONT(J,I)+1.
    GO TO 375
365 WT=(RSQ-DSQR)/(RSQ+DSQR)
    CORR(J,I)=CORR(J,I)+WT*EHGT
    IF(KRT-2)360,360,370
370 CONT(J,I)=CONT(J,I)+WT
375 CONTINUE
380 CONTINUE
    DO 405 J=1,35
    DO 405 I=1,35
    IF(CONT(J,I))405,405,400
400 T(J,I)=T(J,I)+CORR(J,I)/CONT(J,I)
405 CONTINUE
    CALL OUTPT(T,1.,0.,0,40,0,LP*2+1)
    IF(SMH)480,480,425
425 SM=SMH+1.
    DO 470 J=1,35
    DO 470 I=1,35
    SUM=0.
    KT=0
    K5=I-1
    IF(K5)435,435,430
430 KT=KT+1
    SUM=SUM+T(J,K5)
435 K5=I+1
    IF(K5-35)440,440,445
440 KT=KT+1
    SUM=SUM+T(J,K5)
445 K5=J-1
    IF(K5)455,455,450
450 KT=KT+1
    SUM=SUM+T(K5,I)
455 K5=J+1
    IF(K5-35)460,460,465
460 KT=KT+1
    SUM=SUM+T(K5,I)
465 CORR(J,I)=(T(J,I)+SMH*SUM/FLOAT(KT))/SM
470 CONTINUE
    DO 475 J=1,35
    DO 475 I=1,35
    T(J,I)=CORR(J,I)
475 CONTINUE
    CALL OUTPT(T,1.,0.,0,40,0,LP*2+2)
480 CONTINUE
    RETURN
    END
```

```

SUBROUTINE NTRP(P,BY,BX,BB)
  D521
  JUNE, 1968      HOLLENBAUGH
  PERFORMS BI-QUADRATIC INTERPOLATION WHERE POSSIBLE, LINEAR
    INTERPOLATION IN OUTSIDE GRID INTERVAL, AND LINEAR
    EXTRAPOLATION OUTSIDE GRID
  ARGUMENTS
    P( , )=ARRAY FROM WHICH INTERPOLATION IS MADE
    BY=Y-COORDINATE, FROM BOTTOM
    BX=X-COORDINATE, FROM LEFT
    BB=INTERPOLATED (OR EXTRAPOLATED) VALUE
  DIMENSION P(35,35),B(4)
    *****

104  NBX=BX
    NBY=BY
    IF(NBX-1)114,120,111
111  IF(NBX-34)112,120,115
112  IF(NBY-1)121,130,113
113  IF(NBY-34)140,130,123
114  NBX=1
    GO TO 120
115  NBX=34
120  IF(NBY-1)121,130,122
121  NBY=1
    GO TO 130
122  IF(NBY-35)130,123,123
123  NBY=34
    STATEMENT 130 STARTS BI-LINEAR INTERPOLATION-EXTRAPOLATION
130  NBXP1=NBX+1
    NBYP1=NBY+1
    DX=BX-FLOATF(NBX)
    DY=BY-FLOATF(NBY)
    BB=P(NBY,NBX)+(P(NBY,NBXP1)-P(NBY,NBX))*DX+(P(NBYP1,NBX)-
1P(NBY,NBX))*DY+(P(NBY,NBX)+P(NBYP1,NBXP1)-P(NBYP1,NBX)-P(NBY,
2NBXP1))*DX*DY
    RETURN
    STATEMENT 140 STARTS BI-QUADRATIC INTERPOLATION
140  DX=BX-FLOATF(NBX)
    DY=BY-FLOATF(NBY)
    NBYP2=NBY+2
    NBYP1=NBY+1
    NBYP1=NBY+1
    NBYP1=NBY+1
    FCT=(DY**2-DY)/4.
    FET=(DX**2-DX)/4.
    DO 145 J=1,4
      N=NBX-2+J
      B(J)=P(NBY,N)+(P(NBYP1,N)-P(NBY,N))*DY+(P(NBYP1,N)+P(NBYP2,N)-
1P(NBY,N)-P(NBYP1,N))*FCT
145  CONTINUE
    BB=B(2)+(B(3)-B(2))*DX+(B(1)+B(4)-B(2)-B(3))*FET
    RETURN
  END

```


(Continued from inside front cover)

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- WBTM TDL 17 Second Interim Report on Sea and Swell Forecasting. N. A. Pore and Lt. W. S. Richardson, USESSA, January 1969. (PB-182 273)
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