EXTRACTING DIGITAL HISTORICAL WEATHER FIELDS FROM U.S. FNWF FILES

PREPARED FOR

TECHNIQUES DEV.LABORATORY
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Extracting Digital Historical Weather Fields from U.S. Fleet Numerical Weather Facility Files

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FINAL REPORT

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by

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Extracting Digital Historical Weather Fields
from
U. S. Fleet Numerical Weather Facility Files

OUTLINE OF REPORT

APPENDICES

Extracting Digital Historical Weather Fields
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I. INTRODUCTION

Early in 1967 the ESSA, Weather Bureau, Techniques Development Laboratory (TDL) discovered a need for certain historical weather grid fields in precipitation studies. These twice-daily, hemispheric fields, in digital form, were found to be available from the files of the U. S. Fleet Numerical Weather Facility (FNWF) in Monterey, California. Contract No. E-166-67 (N) was subsequently let to Mellonics Systems Development Division of Litton Systems, Inc., to provide these data for TDL.

II. STATEMENT OF PROBLEM

The basic tasks involved the extraction of the desired fields from the FNWF files and simultaneous conversion to the ESSA, Weather Bureau National Meteorological Center (NMC) grid format. The FNWF format utilizes a 3969 point grid (page F1) packed into 3 words per 48 bits. These were converted to the standard NMC format of 1977 points with 36 bit words and 12 bit autonomous data values. A description of the FNWF atmospheric analysis program is included in this report as Appendices G, H, and I.

The pressure surfaces of interest were the 1000, 850, 700, 500, and 300 millibar levels. The time frame was from 1 November 1961 through 31 January 1968 inclusive. The twice-daily data consisted of analyses based on observations at 0000Z and 1200Z for:

1. Heights in centimeters, expressed as deviations from the standard atmosphere.

2. Temperatures in degrees centigrade.

3. Humidities expressed as dewpoint depressions in degrees centigrade. (Dewpoint depressions were not included in the 1000 mb and 300 mb levels.)

III. ACCOMPLISHMENTS

Programming for the processing of FNWF data into the ESSA format was begun soon after the effective date of the contract (1 June 1967). With the completion of the programming phase (early August), extraction and conversion began on a test basis.

On 8 September 1967, sample map prints of FNWF plotted fields were forwarded to Mr. Frank Lewis (TDL). A test tape was also forwarded along with tape dumps of the data fields. Tests at TDL proved satisfactory and production of NMC formatted fields began in mid-September.

The following shipments of magnetic tapes were made:

23 Oct 1967	Tapes 1061-1070, 445 and 446	(12 tapes)
20 Nov 1967	Tapes 447-454, 495, and 496	(10 tapes)
22 Nov 1967	Tapes 497 and 498	(2 tapes)
16 Jan 1968	Tapes 499-502	(4 tapes)
12 Feb 1968	Tapes 503 and 504	(2 tapes)
TOTAL		30 tapes

(NOTE: See attached Tape Inventory, Appendix C, for tape content).

Close liaison was maintained between the contractor and ESSA-TDL throughout the contract period, but especially during the programming and check-out phase. Several letters were exchanged between Mr. Woodworth of Mellonics and Mr. Lewis of TDL. This correspondence was supplemented by telephone calls and personal visits. Mr. Woodworth visited TDL on 21 September 1967. Pertinent correspondence included:

28 June	Letter, Woodworth to Lewis, with proposed contract clarification.
24 July	First bi-monthly progress report.
10 August	Letter, Woodworth to Lewis, with description of computer program.
17 August	Letter from Mr. Lewis clarifying TDL requirements.
8 September	Letter forwarding sample map prints and mini-test tape.
26 September	Second bi-monthly progress report.
22 November	Third bi-monthly progress report.

The total manpower used amounted to 600 hours of operator, programmer, and supervisor time.

Computer time utilized (CDC 1604) amounted to about 30 hours for programming and check-outs, and about 150 hours for production.

IV. REMARKS

The extracting of 5 major levels and 3 parameters from FNWF grid files proved somewhat more tedious than earlier estimates. Mostly this was due to the fact that the early FNWF files were not completely reformatted into the 63 x 63 HISTACK tape format. Some time was spent by the contractor in readying the 1961-1963 magnetic tapes before the standard extracting programs could effectively operate on the data. Furthermore, the earlier years were found to have slightly more occurrences of missing fields than the records indicated. However, the inventory of the fields as depicted in the machine printouts should advise the users of these files of all the missing fields.

The conversion from the FNWF 48-bit packed binary word records (3 data values) to the NMC 36-bit packed binary word records was complicated because of certain incompatibilities between the CDC and the IBM machines. A CDC 1604 program now exists to do this conversion. Thus other extractions from the FNWF historical files are now much easier. Certainly a step has been taken to facilitate more exchanges of historical weather or oceanographic data fields at NMC, FNWF and perhaps Global Weather Center (GWC) at Offutt Air Force Base.

Computer and systems analysts working on this problem have posed the question as to why some overt effort has not been taken, up to this time, to standardize the packing and storage of historical weather grids. The differences between the NMC and the FNWF grids in both number of points stored and the format of the storage word are quite obvious. In fact, both grid formats are different from the GWC (Air Force) format which is another major contributor to weather grid history files. The differences are significant and costly in programming time and conversion to various computer types. A standard storage word size and bit packing is certainly needed. Surely this matter of standardization of archived weather grid analyses is a federal problem needing attention and solution now.

V. REFERENCES ON OBJECTIVE ANALYSIS

Bergthórsson, P. and Döös, B., "Numerical Weather Map Analysis", Tellus, Vol. 7, No. 3, August 1955, pp. 329-340.

Carstensen, L.P. and Lawniczak, G.E., Jr., LCDR, USN, "Surface and Tropospheric Analyses", Fleet Numerical Weather Facility, Monterey, California, FNWF Technical Note No. 15, 1966.

Cressman, G.P., "An Operational Objective Analysis System", Monthly Weather Review, Vol. 87, No. 10, October 1959, pp. 367-374.

Döös, B.R. and Eaton, M.A., "Upper-Air Analysis over Ocean Areas", Tellus, Vol. 9, No. 2, May 1957, pp. 184-194.

Gustafson, A.F. and McDonell, J.E., "The Derivation of First-Guess Fields for Objective Analyses, 1000 mb. to 500 mb.", ESSA Technical Memorandum WBTM NMC-31, Suitland, Md., 1965.

Hughes, R.E., LCDR, USN, "Computer Products Manual", Fleet Numerical Weather Facility, Monterey, California, FNWF Technical Note No. 21, July 1966. (Pertinent extracts are appended to this report.)

McDonell, J.E., "A Summary of the First-Guess Fields Used for Operational Analyses", ESSA Technical Memorandum WBTM NMC-38, Suitland, Md., February 1967

U.S. Navy, "General Environmental Computer Product Catalog", Fleet Numerical Weather Facility, Monterey, California, FNWF Technical Note No. 11, Revised March 1966.

VI. ACKNOWLEDGEMENT

CDC 1604 computer time and data file facilities were furnished at no cost by Captain P. M. Wolff, Officer In Charge, FNWF.

APPENDIX A

TAPE FORMAT AND CODES

FOR CONVERTED FNWF HISTORY FIELDS

PRE-IDENTIFIER:

Word	0 bit – 8	8 – 17	17 – 26	26 – 35
1	0			Type of data
2	Pressure*	0		

DATA FIELD:

Word	0 bit – 12	12 – 24	24 – 35
3-661	+ o Magnitude	+ o Magnitude	+ o Magnitude

POST-IDENTIFIER:

Word	0 bit – 8	8 – 17	17 – 26	26 – 35
662	0		Additive Constant	
663	Time*	Day*	Month*	Year*
664	0	Pressure*	0	Type of Data
665	0			Scaling
666	0			
667	0			
668	0			

*2 digits, 4-bit BCD

Each record comprises 668 words. A reel of tape includes either D-Values or temperatures and dewpoint depressions for corresponding months of all years covered. The years are separated by end-of-files.

Pressure	Octal Identifier	Reference Height (Additive Constant)
1000 mb	240	113 meters
850 mb	205	1457 meters
700 mb	160	3011 meters
500 mb	120	5572 meters
300 mb	060	9159 meters

Type of Data	Octal Identifier
D-Values	01
Temperature	20
Dewpoint Depression	31

Data	Scaling
D-Values (1000-500 mb)	B-17
D-Values (300 mb)	B-18
Temperature and dewpoint depression	B-9

APPENDIX B

PARAMETER ARRANGEMENT

Tape Format No. 1		Tape Format No. 2	
D Value Tape		Temp/Dewpoint Depression Tape	
D 1000 D 850 D 700 D 500 D 300	Day 1	T 1000 T 850 DPD 850 T 700 DPD 700 T 500 DPD 500 T 300	Day 1
D 1000 D 850 D 700 D 500 D 300	Day 2	T 1000 T 850 DPD 850 T 700 DPD 700 T 500 DPD 500 T 300	Day 2
Start Date	1 Nov 1961	Start Date	1 Nov 1961
End Date	31 Jan 1968	End Date	31 Jan 1968
		Dewpoint Depression Fields do not start until	1 May 1964
		T 1000 temperature fields started	1 July 1962

APPENDIX C

TAPE INVENTORY OF CONVERTED GRID FIELDS

		Parameter	1961	1962	1963	1964	1965	1966	1967	1968
JAN	WB 497	D-Values		x	x	x	x	x	x	
	WB 498	Temp		x	x	x	x	x	x	
		DPD					x	x	x	
	WB 503	D-Values								x
	WB 504	Temp								x
		DPD								x
FEB	TW 1061	D-Values		x	x	x	x	x	x	
	TW 1062	Temp		x	x	x	x	x	x	
		DPD					x	x	x	
MAR	TW 1063	D-Values		x	x	x	x	x	x	
	TW 1064	Temp		x	x	x	x	x	x	
		DPD					x	x	x	
APR	TW 1065	D-Values		x	x	x	x	x	x	
	TW 1066	Temp		x	x	x	x	x	x	
		DPD					x	x	x	
MAY	TW 1067	D-Values		x	x	x	x	x	x	
	TW 1068	Temp		x	x	x	x	x	x	
		DPD				x	x	x	x	
JUN	TW 1069	D-Values		x	x	x	x	x	x	
	TW 1070	Temp		x	x	x	x	x	x	
		DPD				x	x	x	x	
JUL	WB 445	D-Values		x	x	x	x	x	x	
	WB 446	Temp		x	x	x	x	x	x	
		DPD				x	x	x	x	

				1961	1962	1963	1964	1965	1966	1967	1968
AUG	WB	447	D-Values		x	x	x	x	x	x	
	WB	448	Temp		x	x	x	x	x	x	
			DPD				x	x	x	x	
SEP	WB	449	D-Values		x	x	x	x	x	x	
	WB	450	Temp		x	x	x	x	x	x	
			DPD				x	x	x	x	
OCT	WB	451	D-Values		x	x	x	x	x	x	
	WB	452	Temp		x	x	x	x	x	x	
			DPD				x	x	x	x	
NOV	WB	453	D-Values	x	x	x	x	x	x		
	WB	454	Temp	x	x	x	x	x	x		
			DPD				x	x	x		
	WB	499	D-Values							x	
	WB	500	Temp							x	
			DPD							x	
DEC	WB	495	D-Values	x	x	x	x	x	x		
	WB	496	Temp	x	x	x	x	x	x		
			DPD				x	x	x		
	WB	501	D-Values							x	
	WB	502	Temp							x	
			DPD							x	

APPENDIX D

INVENTORY OF MISSING GRID FIELDS

Month	1961	1962	1963	1964	1965	1966	1967	1968
JAN		7	0	1	0	0	0	0
FEB		13	1	3	3	1	0	
MAR		12	8	0	4	3	0	
APR		11	8	3	2	0	0	
MAY		16	5	6	9	0	0	
JUN		3	3	1	0	1	0	
JUL		8	13	0	0	0	0	
AUG		19	0	0	0	1	0	
SEP		1	9	2	0	0	0	
OCT		5	2	3	0	0	0	
NOV	4	3	1	1	0	0	0	
DEC	2	2	14	7	2	0	0	

1. The above table lists the number of missing complete grid fields.

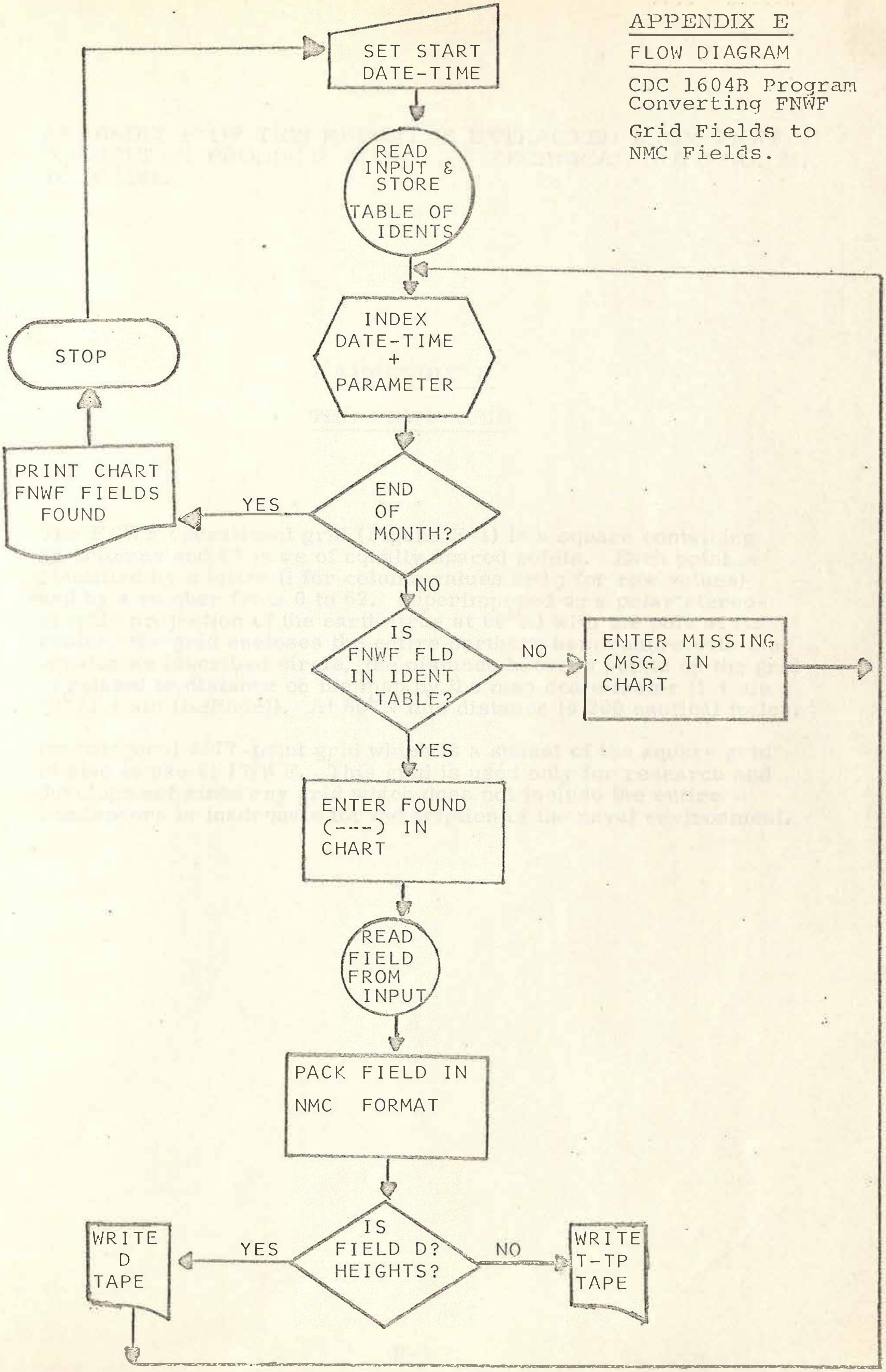
2. Complete grid fields include: D and T 1000, 850, 700, 500, and 300, plus Dew Point Depressions (DPD) 850, 700, and 500. (NOTE: All DPD are missing through April 1964).

3. Other single fields are missing sporadically throughout the period. See computer inventories previously submitted with pertinent tapes for a definitive breakdown of missing fields.

APPENDIX E

FLOW DIAGRAM

CDC 1604B Program Converting FNWF Grid Fields to NMC Fields.



APPENDIX F OF THIS REPORT IS EXTRACTED FROM FNWF "COMPUTER PRODUCTS MANUAL," TECHNICAL NOTE NO. 21, JULY 1966.

APPENDIX F

THE FNWF GRID

The FNWF operational grid (Figure F-1) is a square containing 63 columns and 63 rows of equally spaced points. Each point is identified by a letter (i for column values and j for row values) and by a number from 0 to 62. Superimposed on a polar stereographic projection of the earth (true at 60°N) with the pole at its center, the grid encloses the entire northern hemisphere with the equator an inscribed circle, the distance between points on the grid is related to distance on the map by the map scale factor (1 + sin 60°/1 + sin (latitude)). At 60°N this distance is 200 nautical miles.

An octagonal 1977-point grid which is a subset of the square grid is also in use at FNWF. This grid is used only for research and development since any grid which does not include the entire hemisphere is inadequate for description of the naval environment.

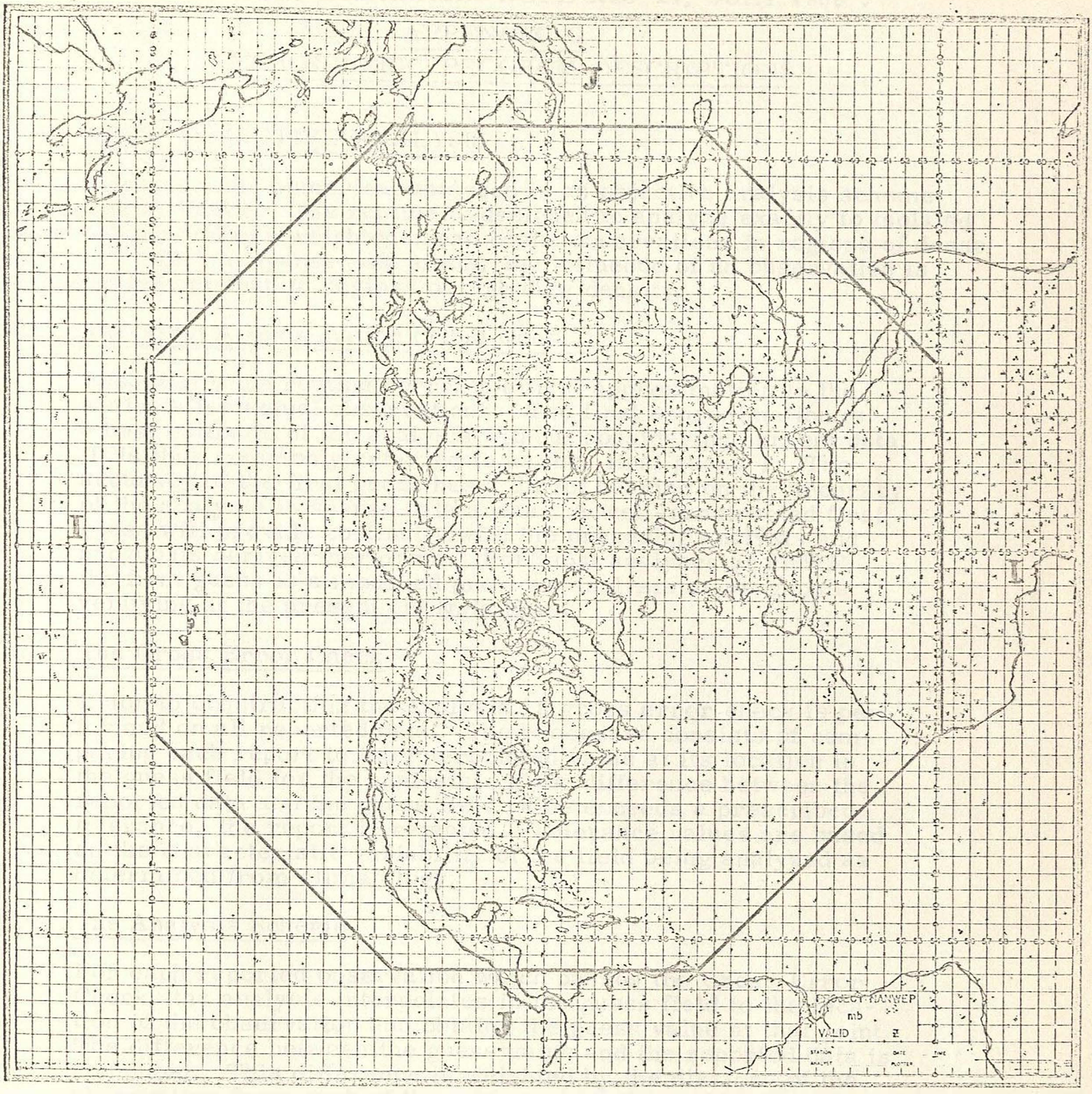


Figure F-1: FNWF HEMISPHERIC NUMERICAL GRID

(Octagonal Grid Superimposed)

APPENDIX G OF THIS REPORT IS EXTRACTED FROM FNWF "COMPUTER PRODUCTS MANUAL," TECHNICAL NOTE NO. 21, JULY 1966".

APPENDIX G

ATMOSPHERIC PROGRAM DESCRIPTIONS

3.1 FNWF OBJECTIVE ANALYSIS

Basic to most numerical analyses is an objective analysis scheme developed at FNWF. The routine is designed to analyze exactly to isolated observations and to a weighted-mean of the observations in regions of dense data coverage. In sparse data areas, the influence of an observation is extended further than in regions of high data density.

A. The First Approximation (First Guess)

Essentially the routine corrects a first approximation to the analysis for actual observations. The first approximation is a best estimate of the analysis without considering current data. (It is thus commonly referred to as the first guess). The accuracy of the first guess has a direct bearing on the accuracy of the analysis in sparse data areas. A well-constructed first guess will provide continuity with the preceding analysis and prognosis derived therefrom. For most analyses at FNWF, the first guess is a modified previous analysis or prognosis verifying at the present analysis time.

B. The Gross Error Check

Prior to constructing the analysis, a gross error check is performed on all reported data. The procedure consists of comparing each report to the interpolated value at its location in the guess field for the analysis. If the difference between the reported data and the guess field value exceeds a prescribed tolerance, the report is rejected. Tolerance values are based on the characteristic variability of the field being analyzed as determined from climatology.

C. The Analysis Scheme

For each reported observation which passes the Gross Error Check, the analysis interpolates in the guess field to the location of the observation and obtains the guess value at that point. The difference between the guess value and the reported data is computed. This difference is weighted by the distance of the observation from each of the four surrounding grid points.

The weighted difference is then applied as a correction to the guess value at each grid point within one mesh length of the observation. Where more than one observation influences a particular grid point, the weighted mean of the corrections computed for that grid point is applied.

After all guess values influenced by observed data have been corrected, the adjusted field is combined with the original guess field by a relaxation process which holds the corrected values constant. This spreads the influence of isolated observations while at the same time exactly fits each observation consistent with surrounding reports.

Portions of the analysis process are repeated depending upon the assumed accuracy of the original guess field. A complete mathematical description of the objective analysis scheme is contained in Appendix H.

D. The Lateral Fitting Check

A lateral fitting check is normally performed after all but the initial pass through the analysis routine. Each report is, in turn, withheld and an analysis of data within the four surrounding grid points is performed without using that report. The difference between the reported data and the value analyzed at its location is compared against a tolerance field similar to the one used in the gross error check except that the tolerances are decreased after each cycle through the analysis. In this manner, a report which does not agree with other reports in the immediate area is rejected.

E. Vorticity Limiting Check

In the literature, it has been shown that negative absolute vorticity in atmospheric flow is rare. This criterion is used as a final check on the validity of most pressure and pressure-height analyses. A pass is made through the analyzed field to reveal any region in which the value of absolute vorticity is less than a suitable fraction of the coriolis parameter. In these regions, the absolute vorticity is adjusted to an adopted minimum value. This limiter is also referred to as the "Ellipticity Criterion."

3.2 SURFACE PRESSURE ANALYSIS (0000Z, 0600Z, 1200Z, and 1800Z)

A. Program Input

1. Reported surface observations (approximately 4000-5000 reports).
2. Hourly history tape of surface pressure prognoses derived from preceding 0000Z or 1200Z analysis.
3. Hourly history tape of 500 mb prognoses derived from the preceding 0000Z or 1200Z analysis.
4. Surface pressure climatology field for the present month.
5. Hemispheric surface coverage for the preceding 0000Z or 1200Z analysis.

B. Program Computations

1. Construction of the First Guess (see Figure G-1).

The first guess to the surface pressure analysis is a modified surface pressure prognosis which verifies at map time. The modification takes place as follows:

a. The 6-hour old surface analysis is updated by a reanalysis using all late ship reports. An error pattern is derived by subtracting from the updated analysis the surface prognosis verifying at that time or the original analysis if the 06Z or 18Z analysis is being performed. This error pattern is advected for three hours with one-half the forecast 500-mb wind.

b. The surface prognosis verifying three hours prior to analysis time is corrected with the advected error pattern. It is then corrected with available three hourly ship reports and with current six hourly land and ship pressures minus the three-hour tendency. The current ship reports are also moved back to their three hour previous position. In this manner, more than 2500 pressure values are provided for each three hourly analysis.

c. Again an error field is obtained by subtracting the original prognosis from the corrected prognosis. This error field is advected for the final three hours with one-half of the 500-mb wind.

d. The new error pattern is now used to correct the surface prognosis which verifies at analysis time. In this manner, the surface prognosis has effectively been updated by all reports received subsequent to its construction.

e. The updated surface prognosis is adjusted toward climatology in regions where data coverage was sparse for the analysis on which it was based. The density of reported observations for the original analysis is contained in the Hemispheric Surface Coverage field.

Figure G-1 is a flow diagram outlining the steps taken to construct the First Guess to the Surface Pressure analysis.

2. Preparation of Data

a. Station location, surface pressure and ship winds are extracted from each reported observation which was previously stored by the ADP program.

b. All analysis-time pressure reports are checked against the previously constructed guess field for gross errors. Tolerance values presently vary from 8.5 millibars south of 30°N to 17 millibars north of 30°N for land reports and 5 to 8.5 millibars for ship reports.

c. Ship winds greater than nine knots are used to provide four extrapolated pressure reports. The reported wind is turned fifteen degrees toward higher pressure to approximate a geostrophic wind. A pressure value equal to that reported by the ship is placed 0.75 of a grid length directly upwind and downwind of the ship. Two pressure values calculated to give the gradient necessary to support the reported wind speed are placed 0.375 of a grid length either side of the ship, normal to the wind direction. These extrapolated reports are then checked for gross errors in the same manner as for other reports.

3. The Analysis

All reported and extrapolated surface pressure reports which have passed the gross error check are now analyzed by the objective analysis program described earlier. The basic accuracy of the first guess analysis is such that only two passes through the objective analysis program are required. After each pass, reported data which fail the lateral fitting check are rejected. In the final pass, the vorticity limiting check is performed to insure that inertial instability does not exist at any point in the analysis.

C. Program Output

1. Surface Pressure Analysis (Catalog No. A01).

2. Hemispheric Surface Coverage (Catalog No. A00).

3. Gross Error Check Reject Coverage.

D. Program Limitations

The surface pressure analysis makes use of reported pressures and ship winds only. No attempt is made to model the pressure distribution using other elements of the reports. For example, isobars crossing a front will be kinked only where reports are sufficiently dense to so indicate; a heavy rain report will not be considered in the analysis of a frontal wave.

Analysis flaws are usually the result of one or all of the following problems:

1. Lack of Data

In regions of no reported data, the final analysis will be a combination of the first approximation and climatology. Initially the contribution made by climatological values is small but increases with the number of synoptic periods in which no reports are received in the area.

2. Erroneous Data

Surface observations reported in error may be used in the analysis. No internal consistency checking of reports is presently attempted. A ship reporting ten degrees out of position or ten millibars off the actual pressure due to transmission error, for example, will not be corrected. The datum will either pass the error checks, resulting in an incorrect analysis, or it will be rejected with the possible loss of some significant information.

Surface pressure and ship wind observations reported in error will normally be rejected in the Gross Error Check (GEC). If the erroneous report should pass the GEC tolerances, it will contaminate the analysis.

If the bad report, accepted in the GEC, is located in a high data density region (e.g. over land), it will probably be rejected when compared with its neighbors in the lateral fitting check. It may, however, have already had a slight adverse influence on the final analysis. If the bad report is located in a sparse data region (e.g. over oceans), it may pass the lateral fitting check as well as the gross error check. In this case, the analysis will depict with utmost precision the pressure distribution represented by the erroneous datum.

3. Extreme Atmospheric Change

Occasionally extreme atmospheric change will manifest itself as an error in the analysis. In this case, strong development results in valid data failing the gross error check tolerances. Gross error check tolerances are predicted on a reasonable forecast being used in construction of the first approximation. If the forecast is abnormally poor and off-time and late reports do not correct it sufficiently, this type of error may occur. Although rare, it represents a serious flaw and should be guarded against.

3.4 TROPOSPHERE ANALYSIS (0000Z and 1200Z)

A. Background

The three dimensional structure of the atmosphere up to 200-mb is modeled such that it can be defined in terms of the 1000-mb height, the 500-1000-mb thickness and the static stability (essentially a measure of temperature lapse rate) in five selected layers (1000-775, 775-600, 600-450, 450-300 and 300-200-mb). The model provides pressure-height values consistent with all reasonable reported data for any level from 1000 to 200-mb, accurate to within the limits of known instrumental errors. The model yields a representative virtual temperature structure with the undesired small scale noise in the synoptic temperature distribution removed. The modeled atmosphere is everywhere statically stable and is therefore suitable for any integrations required in the numerical forecast process.

B. Program Input

1. Reported radiosonde and aircraft wind observations for mandatory levels to 200-mb.

2. Surface Pressure analysis.

3. Twelve-hour previous 1000-mb Temperature analysis.

4. Twelve-hour previous Static Stability analyses for five levels.

5. Twelve-hour 500-mb prognosis from the previous up date analysis.

6. Report Coverage for twelve-hour previous 500-mb update analysis.

C. Program Computations

1. Data Preparation

a. Reported 1000-mb heights are compared with a 1000-mb height field obtained by a hydrostatic conversion of the surface pressure analysis in which the twelve-hour previous 1000-mb temperatures are used. Differences in excess of a prescribed tolerance are interpreted to indicate that the raob cannot reasonably be located at the reported position and the complete sounding is rejected.

b. Each radiosonde sounding is checked for vertical consistency of pressure and virtual temperature at the mandatory levels. Where possible, missing or incorrect values in the reported raob are interpolated hydrostatically from correctly reported elements.

c. Reported 500-mb heights are compared with the twelve-hour 500-mb prognosis verifying at map time. Again, the complete sounding is rejected if the difference is in excess of a prescribed tolerance.

2. Analysis of the Structure Model Variables

a. Stability Analyses

For each raob satisfying the gross error checks, static stabilities in the five selected layers are computed from reported mandatory level pressure-heights. The objective analysis routine is then used to perform a horizontal analysis of stability for each layer. The first guess for each stability analysis is the previous analysis, smoothed heavily and adjusted toward climatology in sparse data regions. The analysis is performed with the constraint that hydrostatic instability is not allowed at any grid point.

b. 1000-mb Analysis

Objective analysis of the 1000-mb level is performed using the same guess field as for the 1000-mb gross error check.

c. 500-mb Analysis

Objective analysis of reported 500-mb heights and heights extrapolated by the geostrophic approximation from reported 500-mb winds is performed. The first guess is obtained by reanalyzing the twelve-hour previous 500-mb analysis using all data collected during the twelve-hour period between synoptic observation times. This "update" analysis usually contains 10 to 20% more 500-mb data than did the original. From the update, a twelve-hour 500-mb prognosis verifying at the present map time is derived. This prog is then modified for the twelve-hour change in 500-1000-mb thickness inferred from the present surface pressure analysis. The prog is also adjusted toward climatology in regions where the update analysis was constructed from sparse data.

Three cycles through the analysis routine are made with the data. The first and second passes with data utilize only the height values from the reports. The second pass provides lateral checking wherein each datum value must be within a prescribed tolerance of the value interpolated from surrounding data.

Upon completion of the second pass, the reported winds are used to compute geostrophic gradients and derived height values at four surrounding points. The extrapolations parallel to the wind are placed 1.5 mesh lengths from the datum and the normal extrapolations are placed 0.75 mesh lengths away. (South of 30 N these distances are changed to 2.0 and 1.0 mesh lengths respectively.) If another report of height and wind falls within this same area, the distances will be modified so that the extrapolations are located no closer than half the distance between the two stations. In the case of aireps with no height values reported, an interpolation of the analysis is used to provide the working height values.

The third and last analysis pass is made using the heights and wind extrapolations with lateral checking as defined previously. The final analysis field is then modified where necessary so that the absolute vorticity always exceeds one-third of the coriolis parameter.

d. 500-1000-mb Thickness Analysis

Simple subtraction of the 1000-mb from the 500-mb analysis produces the 500-1000-mb Thickness which is used as an input to the structure model.

3. Solution for the Tropospheric Structure

A system of matrix equations is entered with the analyzed 1000-mb height, 500-1000-mb thickness and five stability values for each grid point. Solution of these equations produces the pressure and virtual temperature at each mandatory level for that grid point. A complete pass through the grid results in specification of the hemispheric field of pressure-height and virtual temperature for each mandatory level.

D. Program Output

1. Pressure-Height analyses (meters) for the 1000-, 850-, 700-, 500-, 400-, 300-, and 200-mb levels.

2. Temperature analyses (°C) for the 1000-, 850-, 700-, 500-, 400-, 300-, and 200-mb levels.

3. Stability analyses for the layers from 1000-775-mb, 775-600-mb, 600-450, 450-300, and 300-200-mb.

4. UA Radiosonde Coverage analysis.

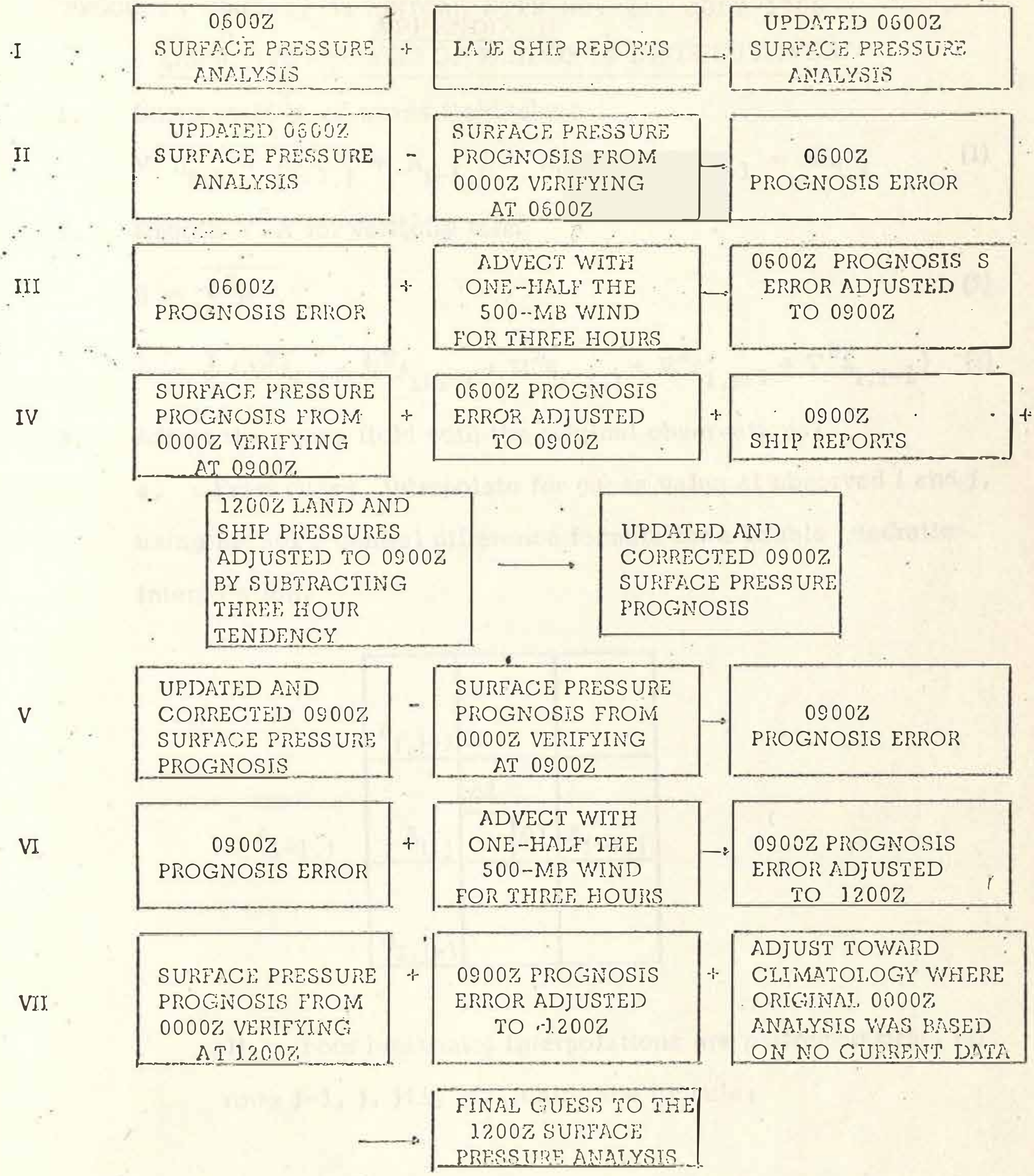


Figure G-1: FLOW DIAGRAM FOR CONSTRUCTION OF THE FIRST GUESS TO THE 1200Z SURFACE PRESSURE ANALYSIS

APPENDIX H OF THIS REPORT IS EXTRACTED FROM FNWF "COMPUTER PRODUCTS MANUAL", TECHNICAL NOTE NO. 21, JULY 1966

APPENDIX H

OBJECTIVE ANALYSIS OF RANDOMLY DISTRIBUTED DATA

1. Compute $\nabla^2 A$ of guess field where

$$\nabla^2 A_{i,j} = A_{i+1,j} + A_{i-1,j} + A_{i,j+1} + A_{i,j-1} - 4A_{i,j} \quad (1)$$

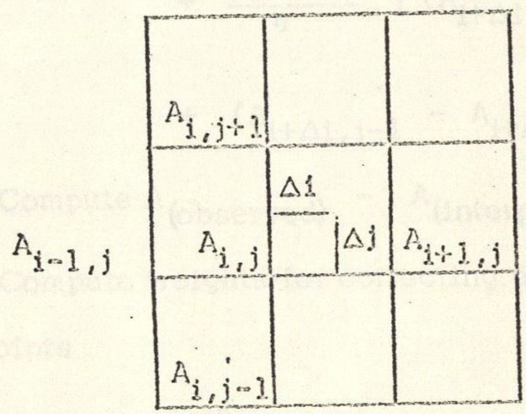
2. Smooth $\nabla^2 A$ for vorticity term

$$B = \overline{\nabla^2 A_{i,j}} \quad (2)$$

$$= \frac{1}{5}\left(\nabla^2 A_{i,j} + \nabla^2 A_{i+1,j} + \nabla^2 A_{i-1,j} + \nabla^2 A_{i,j+1} + \nabla^2 A_{i,j-1} \right) \quad (3)$$

3. Adjust the guess field with the original observations:

a. From guess, interpolate for guess value at observed i and j, using Bessel's central difference formula for a double quadratic interpolation.



1) Four horizontal interpolations are performed first, on rows j-1, j, j+1, j+2, using the formula:

$$A_{i+\Delta i,j} = \frac{A_{i,j} + A_{i+1,j}}{2} + (\Delta i - \frac{1}{2})\ (A_{i+1,j} - A_{i,j})$$

$$+ \frac{\Delta i\ (\Delta i - 1)}{2\,!}\ \left[\frac{(A_{i+2,j} - A_{i+1,j}) + (A_{i-1,j} - A_{i,j})}{2} \right] \quad (4)$$

$$= A_{i,j} + \Delta i\ \{ (A_{i+1,j} - A_{i,j})$$

$$+ \frac{\Delta i - 1}{4}\ [(A_{i+2,j} - A_{i-1,j}) + (A_{i-1,j} - A_{i,j})] \} \quad (5)$$

(Likewise for $A_{i+\Delta i,j-1}$; $A_{i+\Delta i,j+1}$; and $A_{i+\Delta i,j+2}$)

2) One vertical interpolation is then performed on the column $i+\Delta i$:

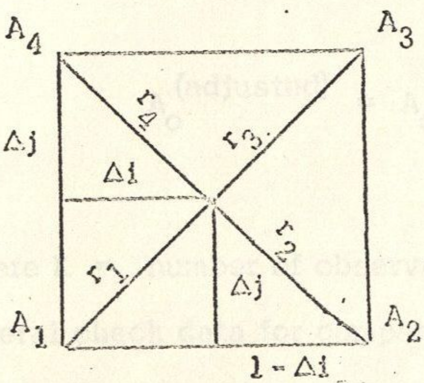
$$A_{i+\Delta i,j+\Delta j} = A_{i+\Delta i,j} + \Delta j\ \{ (A_{i+\Delta i,j+1} - A_{i+\Delta i,j})$$

$$+ \frac{(\Delta j - 1)}{4}\ [(A_{i+\Delta i,j+2} - A_{i+\Delta i,j+1})$$

$$+ (A_{i+\Delta i,j-1} - A_{i+\Delta i,j})] \} \quad (6)$$

b. Compute $A_{(observed)} - A_{(interpolated)}$

c. Compute weights for correcting each of the four surrounding grid points



$$r_1^2 = \Delta i^2 + \Delta j^2 \quad (7)$$

$$r_2^2 = (1 - \Delta i)^2 + \Delta j^2 \quad (8)$$

$$r_3^2 = (1 - \Delta i)^2 + (1 - \Delta j)^2 \quad (9)$$

$$r_4^2 = \Delta i^2 + (1 - \Delta j)^2 \quad (10)$$

$$W_1 = \frac{1 - r_1^2}{\sum_{x=1}^{4} (1 - r_x^2)} \tag{11}$$

$$W_2 = \frac{1 - r_2^2}{\sum_{x=1}^{4} (1 - r_x^2)} \tag{12}$$

$$W_3 = \frac{1 - r_3^2}{\sum_{x=1}^{4} (1 - r_x^2)} \tag{13}$$

$$W_4 = \frac{1 - r_4^2}{\sum_{x=1}^{4} (1 - r_x^2)} \tag{14}$$

d. Compute the weighted difference to be added as a correction to each of the 4 grid points surrounding the observation:

$$W_x D = W_x (A_{obs} - A_{interp}) \tag{15}$$

e. When weights have been computed for all observations, add as correction to each grid point the "mean" of the weighted corrections resulting from each relevant observation. (A grid point is thus corrected from observations in the four surrounding grid squares.)

$$A_o^{(adjusted)} = A_o + \frac{\sum_1^K W_K D_K}{\sum_1^K W_K}$$

where K = number of observations affecting this grid point.

4. Lateral check data for compatibility with neighboring reports.

5. Analyze, holding all adjusted values fixed, using extrapolated Liebmann method of relaxation for solution of the Poisson equation $\nabla^2 A = B$.

a. Iterative step

$$A_{i,j}^{\nu+1} = A_{i,j}^{\nu} + R_{i,j}^{\nu}, \tag{17}$$

where the residual $R_{i,j}$ can be expressed as:

$$R_{i,j} = \frac{1}{4} (\nabla^2 A_{i,j} - B) \tag{18}$$

OR over-relaxing:

$$R_{i,j} = \frac{\lambda}{4} (\nabla^2 A_{i,j} - B) \text{ where } \lambda = 1.28 \tag{19}$$

b. Thus: $A_{i,j}^{\nu+1} = A_{i,j}^{\nu} + .32 (\nabla^2 A_{i,j} - B)$ (20)

c. Continue relaxing until at $(\nu + 1)$ st scan,

$R_{max}^{\nu} < \epsilon$ where ϵ is freely chosen.

6. Smooth the analysis which is the guess for the next cycle.

7. Return to step 1 for additional cycle.

8. On last cycle omit step 6.

9. Exit.

APPENDIX I OF THIS REPORT IS EXTRACTED FROM FNWF "COMPUTER PRODUCTS MANUAL," TECHNICAL NOTE NO. 21, JULY 1966

APPENDIX I

3.7 DEWPOINT DEPRESSION ANALYSIS (0000Z and 1200Z)

A. Program Input

Reported temperatures and dewpoints at the surface, 850-, 700-, and 500-mb levels.

B. Program Computations

Dewpoint depression is computed from raob values of temperature and dewpoint. A gross error check, as such, is not performed; however, values of dewpoint depression greater than 37°C are rejected.

The objective analysis of dewpoint depression is performed independently for each level with the previous analysis for that level used as a first guess. The analysis returns to climatology in regions of no reported data.

C. Program Output

Dewpoint Depression Analysis in °C for the terrain (Catalog No. A50) 850- (D50), 700- (E50) and 500-mb (F50) levels.

D. Program Limitations

Analyzed dewpoint depression values are meaningful only in regions of dense data coverage. The spatial distribution of water vapor is not continuous thus no adequate means has yet been found for its extrapolation into sparse data regions. In these regions, the analysis will portray the climatological distribution of dewpoint depression.

E. Additional Considerations

1. The Dewpoint Depression Analysis portrays the horizontal distribution of moisture on a constant pressure surface.
2. Areas in which dewpoint depression is less than 5°C are generally characterized by precipitation and/or cloudiness.
3. The vertical velocity and dewpoint depression are normally considered together in forecasting total amount of precipitation.

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