NOAA Technical Memorandum NWS TDL-67

COMPUTER WORDED PUBLIC WEATHER FORECASTS

Techniques Development Laboratory
Silver Spring, Md.
November 1978

noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / National Weather Service

NOAA TECHNICAL MEMORANDUMS

National Weather Service, Techniques Development Laboratory Series

The primary purpose of the Techniques Development Laboratory of the Systems Development Office is to translate increases of basic knowledge in meteorology and allied disciplines into improved operating techniques and procedures. To achieve this goal, the laboratory conducts applied research and development aimed at the improvement of diagnostic and prognostic methods for producing weather information. The laboratory performs studies both for the general improvement of prediction methodology used in the National Meteorological Service and for the more effective utilization of weather forecasts by the ultimate user.

NOAA Technical Memorandums in the National Weather Service Techniques Development Laboratory series facilitate rapid distribution of material that may be preliminary in nature and which may be published formally elsewhere at a later date. Publications 1 through 5 are in the former series, Weather Bureau Technical Notes (TN), Techniques Development Laboratory (TDL) Reports; publications 6 through 36 are in the former series, ESSA Technical Memorandums, Weather Bureau Technical Memorandums (WBTM). Beginning with TDL 37, publications are now part of the series NOAA Technical Memorandums National Weather Service (NWS).

Publications listed below are available from the National Technical Information Service, U.S. Department of Commerce, Sills Bldg., 5285 Port Royal Road, Springfield, VA 22161. Prices on request. Order by accession number (given in parentheses). Information on memorandums not listed below can be obtained from Environmental Science Information Center (D822), NOAA, 6009 Executive Boulevard, Rockville, MD 20852.

ESSA Technical Memorandums

WBTM TDL 17 Second Interim Report on Sea and Swell Forecasting. N. A. Pore and W. S. Richardson, January 1969, 7 pp. plus 10 figures. (PB-182-273)

WBTM TDL 18 Conditional Probabilities of Precipitation Amounts in the Conterminous United States. Donald L. Jorgensen, William H. Klein, and Charles F. Roberts, March 1969, 89 pp. (PB-183-144)

WBTM TDL 19 An Operationally Oriented Small-Scale 500-Millibar Height Analysis Program. Harry R. Glahn and George W. Hollenbaugh, March 1969, 17 pp. (PB-184-111)

WBTM TDL 20 A Comparison of Two Methods of Reducing Truncation Error. Robert J. Bermowitz, May 1969, 7 pp. (PB-184-741)

WBTM TDL 21 Automatic Decoding of Hourly Weather Reports. George W. Hollenbaugh, Harry R. Glahn, and Dale A. Lowry, July 1969, 27 pp. (PB-185-806)

WBTM TDL 22 An Operationally Oriented Objective Analysis Program. Harry R. Glahn, George W. Hollenbaugh, and Dale A. Lowry, July 1969, 20 pp. (PB-186-129)

WBTM TDL 23 An Operational Subsynoptic Advection Model. Harry R. Glahn, Dale A. Lowry, and George W. Hollenbaugh, July 1969, 26 pp. (PB-186-389)

WBTM TDL 24 A Lake Erie Storm Surge Forecasting Technique. William S. Richardson and N. Arthur Pore, August 1969, 23 pp. (PB-185-778)

WBTM TDL 25 Charts Giving Station Precipitation in the Plateau States From 850- and 500-Millibar Lows During Winter. August F. Korte, Donald L. Jorgensen, and William H. Klein, September 1969, 9 pp. plus appendixes A and B. (PB-187-476)

WBTM TDL 26 Computer Forecasts of Maximum and Minimum Surface Temperatures. William H. Klein, Frank Lewis, and George P. Casely, October 1969, 27 pp. plus appendix. (PB-189-105)

WBTM TDL 27 An Operational Method for Objectively Forecasting Probability of Precipitation. Harry R. Glahn and Dale A. Lowry, October 1969, 24 pp. (PB-188-660)

WBTM TDL 28 Techniques for Forecasting Low Water Occurrences at Baltimore and Norfolk. James M. McClelland, March 1970, 34 pp. (PB-191-744)

WBTM TDL 29 A Method for Predicting Surface Winds. Harry R. Glahn, March 1970, 18 pp. (PB-191-745)

WBTM TDL 30 Summary of Selected Reference Material on the Oceanographic Phenomena of Tides, Storm Surges, Waves, and Breakers. N. Arthur Pore, May 1970, 103 pp. (PB-193-449)

WBTM TDL 31 Persistence of Precipitation at 108 Cities in the Conterminous United States. Donald L. Jorgensen and William H. Klein, May 1970, 84 pp. (PB-193-599)

WBTM TDL 32 Computer-Produced Worded Forecasts. Harry R. Glahn, June 1970, 8 pp. (PB-194-262)

WBTM TDL 33 Calculation of Precipitable Water. L. P. Harrison, June 1970, 61 pp. (PB-193-600)

WBTM TDL 34 An Objective Method for Forecasting Winds Over Lake Erie and Lake Ontario. Celso S. Barrientos, August 1970, 20 pp. (PB-194-586)

WBTM TDL 35 Probabilistic Prediction in Meteorology: a Bibliography. Allan H. Murphy and Roger A. Allen, June 1970, 60 pp. (PB-194-415)

WBTM TDL 36 Current High Altitude Observations--Investigation and Possible Improvement. M. A. Alaka and R. C. Elvander, July 1970, 24 pp. (COM-71-00003)

(Continued on inside back cover)

NOAA Technical Memorandum NWS TDL 67

COMPUTER WORDED PUBLIC WEATHER FORECASTS

Harry R. Glahn

Techniques Development Laboratory
Systems Development Office
Silver Spring, Md.
November 1978

UNITED STATES
DEPARTMENT OF COMMERCE
Juanita M. Kreps, Secretary

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION
Richard A. Frank, Administrator

National Weather
Service
George P. Cressman, Director

CONTENTS

COMPUTER WORDED PUBLIC WEATHER FORECASTS

Harry R. Glahn
Techniques Development Laboratory
National Weather Service, NOAA
Silver Spring, MD 20910

ABSTRACT. A computer program is available which produces public weather forecasts in worded form from digital forecasts of weather elements. This program was designed to be implemented concurrently with the AFOS (Automation of Field Operations and Services) system. One version of the program operates on NOAA's large computer system and will send forecasts over the National Distribution Circuit; another version can be run on the local AFOS minicomputers. This paper describes input to the program, the options available for use, the decision processes whereby the forecast is constructed, the output of the program, and plans for its use. Also, examples are shown of worded forecasts covering a variety of weather situations.

1. INTRODUCTION

Since the advent of the modern electronic computer, many aspects of the production and dissemination of weather forecasts have been partially or completely automated. Prognostic charts of heights of constant pressure surfaces have been produced operationally by the National Meteorological Center (NMC) since the mid-1950's. Numerical models now produce free-air forecasts of wind, temperature, and moisture, and have been improved to the point that they can usually do better than human forecasters for projections beyond a few hours. Even if the forecaster is given the model output, his improvement upon these numerical forecasts is minimal. One such model that has been run at NMC for over 10 years is the so-called PE model described by Shuman and Hovermale (1968). 1/

Initial conditions provided to the numerical models are produced by automated analysis techniques such as those described by Cressman (1959) and Flattery (1970). Observations are also becoming more automated. Minicomputers "work-up" the raw sounding data from radiosondes. Surface reports are telemetered in from remote sites. Minicomputers digitize and process radar data. Satellite observations are interpreted, mapped, and processed by computer. Communications circuits are controlled by computer,

---

1/This model was run on the standard NMC 381-km (at 60°N) hemispheric grid; starting in January 1978, it is now being run on a 190-km hemispheric grid. During much of this 10-year period it was also run on a 190-km grid covering only North America (Howcroft 1971). Beginning in August 1977, it has been run on a 127-km grid over North America. During this period, many changes and improvements have been made to the model itself, to the analyses used as input, and to the characteristics of its output.

and data are automatically assembled into bulletins and distributed as desired.

Free-air forecasts from numerical models are automatically interpreted in terms of surface weather elements by statistical techniques. Forecasts of maximum/minimum (max/min) temperature; probability of occurrence, amount, and type of precipitation; cloud amount; surface wind; thunderstorms; and severe weather are distributed by teletype and facsimile. Most of these are made by the MOS (Model Output Statistics) technique (Glahn and Lowry 1972) and have recently been described by Glahn (1976a, 1976b). For some elements and projections, forecasters are able to improve upon these guidance forecasts by a small amount. For instance, the mean absolute error of official max/min temperature forecasts is about 0.5°F lower than the guidance (Cooley et al. 1977). On the other hand, MOS produces better wind, cloud, and precipitation type forecasts than are issued from local forecast offices, as indicated by the National Weather Service (NWS) verification program. 2/

For nearly 10 years, the Techniques Development Laboratory (TDL) has been experimenting with producing public weather forecasts in worded form by computer; first efforts were reported by Glahn (1970). 3/ However, completely automated forecasts for the three forecast periods usually covered could not be implemented until all three of the following were available:

- objective forecasts of acceptable accuracy of all weather elements contained in a public weather forecast,
- adequate computer, display, and communications equipment, and
- flexible software.

For about 2 years, we have been producing MOS forecasts which essentially fulfill the first of these requirements. AFOS 4/ will satisfy the second. The software will probably always be undergoing changes for one reason or another, but a program now exists which produces forecasts of good enough quality to be useful as a "starting point" for field forecasters. We believe a forecaster will save considerable time by using the automated product and will still be able to exercise all the control he desires over the final

---

2/Because considerable variation exists by weather element, season, projection, station, and NWS Region, these statements are generalizations. Detailed information can be found in Crisci et al. (1977) and Bocchieri et al. (1977).

3/Other work in this area has been done by Lönnqvist (1973) and Smith (1974). In addition, Auliciems and Hare (1973) have suggested a pictorial display of forecasts that could be automated.

4/AFOS is the acronym for Automation of Field Operations and Services. This NWS system, which will be partially in operation in 1978, will include minicomputers and CRT's (cathode ray tubes) at all forecast offices interconnected by communications lines. (See Klein 1976.)

product. This paper describes the input to the program, options available in its use, decision processes whereby the forecast is constructed, output, and plans for its use.

2. INPUT TO PROGRAM

2.1 Digital Forecasts

The most important input to the computer worded forecast (CWF) program is, of course, the digital weather forecasts.5/ Currently, these are MOS forecasts which are arranged in matrix form as shown in figure 1. These forecasts were made from a 0000 GMT model run. The three forecast periods--today, tonight, and tomorrow--are indicated, as well as the appropriate GMT valid times. Note that for most elements the first valid time, 1200 GMT (Z), is 12 hours after initial data time for the numerical model. The MOS forecasts partially depend, in some cases, on surface observations up to 6 hours after 0000 GMT, depending on which model is being used. 6/ Each of the forecast elements is explained briefly below.

TEMP M/M--The max temperature is given for today and tomorrow and the min for tonight. Actually, these forecasts each cover a 24-hour period (midnight to midnight, local time); therefore, the first max is not for just the daylight hours. (For details, see Klein and Hammons 1975.)

TEMP--A specific-time temperature forecast is currently available for projections of 9, 12, ..., 27, and 30 hours. These forecasts help determine the wording concerning temperature. Since the MOS forecast max is for a 24-hour period and the local forecasts are usually for a 12-hour "daytime" period, adjustment of the MOS forecast max is sometimes made to conform with an expected daytime max.

POP(12)--These are forecasts of the probability of occurrence of $\geq$.01 in of precipitation (liquid equivalent) in each of the 12-hour periods. Besides determining, in large part, what wording to use regarding precipitation, they are used in the probability statements, rounded to tens of percent. (For details, see Lowry and Glahn 1976, and NWS 1977a.)

POP(6)--Forecasts for each of the two 6-hour periods within each of the 12-hour periods are given. They help determine changes in precipitation occurrence and cloudiness within the 12-hour periods.

POF--Forecasts of the probability of frozen precipitation, given that precipitation occurs, are available for seven specific times--every 6 hours starting with 1200 GMT. (For details, see Glahn and Bocchieri 1975, and Bocchieri and Glahn 1976).

5/"Digital" rather than "numerical" is used in this paper, because the latter usually refers to the raw output of "numerical" models.

6/The examples in this paper are based on MOS forecasts made from PE model output and, in some cases, 0500 GMT surface observations.

ELEMENT	UNITS	VALID TIME 12Z	18Z	00Z	06Z	12Z	18Z	00Z
		(---TODAY---)(--TONIGHT--)(--TOMORROW--)						
TEMP M/M	DEG F		46		20		32	
TEMP	DEG F	39 39 37	37 35	32 30	27			
POP(12)	PERCENT			96		32		2
POP(6)	PERCENT		96	57	24	18	0	3
POF	PERCENT	2	23	85	95	99	98	99
R SHR(L)	PERCENT		16		20		24	
DRZL(L)	PERCENT		27		35		18	
RAIN(L)	PERCENT		57		45		58	
TSTM	PERCENT		1		0		1	
QPF	CATEGORY			2		1		1
CLOUDS	CATEGORY	4	4	4	1	1	1	4
WIND D/S	DEG MPH	2307	2909	3009	3105	3403	2308	2408

Figure 1.--Sample forecast matrix.

R SHR(L), DRZL(L), and RAIN(L)--These are forecasts of the probability of rain showers, drizzle, and nonshowery rain, respectively, given that liquid precipitation occurs. There is one forecast of each variable valid in the middle of each 12-hour period. These are mutually exclusive and exhaustive categories; therefore, except for roundoff, the sum of the three probabilities equals unity. These forecasts are not disseminated by teletype or facsimile; the technique was developed specifically for input to the CWF's. (See Carter 1974 and 1975a for details.)

TSTM--The unconditional probability of a thunderstorm occurring at the station sometime during each 12-hour period is given. Actually, this predictand was determined from 3-hourly observations and will, therefore, be biased toward low values. This is no real problem for use in the CWF's, since a correspondingly low threshold can be used to determine when thunderstorms will be mentioned. The threshold is quite arbitrary, in any case, and must be determined by experience. Relatively little effort has gone into producing these thunderstorm forecasts. (See Carter 1974 and 1975a.) 7/

QPF--Categorical forecasts of quantitative precipitation are given for each of the 12-hour periods. Categories 1 through 5 indicate <.25 in, .25-.49 in, .50-.99 in, 1.0-1.99 in, and ≥2.0 in, respectively. 8/ Threshold probabilities were determined for each category 2 through 5 for transforming probability forecasts into categorical forecasts in such a way that the threat score is maximized. (See Bermowitz 1975, and Bermowitz and Zurndorfer 1975, for details.)

CLOUDS--Clear, scattered, broken, and overcast sky conditions are given by category numbers 1 through 4, respectively, for each of seven projections. 9/ Probabilities of each of these categories are objectively determined (Carter

---

7/Short and medium range thunderstorm forecasts are also produced by Charba (1977) and Reap and Foster (1977). However, these do not cover all three 12-hour periods or the whole United States. At present, they are not used in the CWF.

8/The fifth category is never forecast for some stations and seasons.

9/For our purposes, these four categories are defined as 0-1, 2-5, 6-9, and 10 tenths of total sky coverage, respectively. Category 4 also includes the obscured condition.

and Glahn 1976), and the categories are specified from these probabilities as described by Carter (1976).

WIND D/S--Wind direction to tens of degrees and speed are given in the usual convention for each of seven projections. A separate regression equation is evaluated for speed and for the U and V components. Direction is determined from the components and the regression estimate of speed is inflated. 10/ (See Carter 1975b, for details.)

2.2 Climatological Maximum and Minimum Temperature

Climatological max and min temperatures are provided for each station. They are used in determining temperature phraseology.

2.3 Current Observations

Surface observations of temperature and weather are input to assist in the determination of precipitation type.

2.4 Station Directory

The station directory lists station names and identifying numbers for which forecasts are to be made.

2.5 Text Phrases

Nearly all words and phrases used in the CWF program are read from data sets rather than being "built in" to the program; this increases flexibility. Each phrase has a number and, if appropriate, a type associated with it.

2.6 Text Composition Information

Information is provided concerning the order of phrases, their punctuation, and how they are to be connected to other phrases.

2.7 Control Information

Control information for each of the weather elements included in the CWF--wind, temperature, cloud, and precipitation--is provided. It specifies, among other things, the maximum complexity of wording to be used for each element and forecast period. This information is explained more fully in later sections.

10/Inflation was proposed by Isadore Enger and first applied by Klein et al. (1959). The inflated estimate $\hat{y}'$ is defined by

$$\hat{y}' = \frac{\hat{y} - \bar{y}}{R} + \bar{y},$$

where $\hat{y}$ is the regression estimate, $\bar{y}$ the mean of the variable in the dependent sample, and R the multiple correlation associated with the regression equation. This procedure increases the root mean square error (Glahn and Allen 1966) but gives a more desirable distribution of wind speed forecasts.

3. CHARACTERISTICS OF FORECASTS

The main goal in developing the CWF program was that the resulting forecasts would be saleable and operationally useful. Therefore, no major departures from the forecast format currently in use by local forecasters were made. Generally, the NWS operational manuals were followed, 11/ although these have been under revision during recent years and, for that reason, could not provide absolute guidance.

To achieve the above goal, the program was designed to allow considerable flexibility in choice of phrases. For instance, one station or NWS Region might desire quite detailed forecasts while another might want considerably abbreviated forecasts. Also, different preferences may prevail as to what constitutes "windy," "very cold," etc.

Even with the desire to allow flexibility by a "user" in specifying control parameters, certain guidelines had to be adopted. Three of these are:

- four basic weather elements would be included--wind, temperature, cloud, and precipitation;
- the forecasts would be segmented by period--today, tonight, and tomorrow--except for very simple forecasts in which periods could be easily combined; and
- the most important elements would be put near the beginning of the segment.

It was soon found that each basic weather element had to be treated differently from all the rest. For instance, a change (or lack thereof) in temperature from the previous day is many times mentioned, but seldom is a change in wind from the previous day mentioned. Also, wind statements are based almost solely upon the wind vector itself (given at the beginning, middle, and end of each period) while the precipitation statement is based on POP(12), POP(6), POF, R SHR(L), DRZL(L), RAIN(L), TSTM, QPF, TEMP M/M, and CLOUDS (some given once per period, some twice, and some three times).

The following sections describe in some detail how the phrases are selected. Even this description may leave questions that only a detailed flow diagram of the computer program could answer.

4. SELECTION OF PHRASES

4.1 Wind

Figure 2 summarizes how the wind forecasts are stated, what the phrase selection is a function of, the approximate number of different phrases available, and how the phrases are divided into five types. This typing is

---

11/For instance, NWS (1972), NWS (1977b), and NWS (1978).

WIND

OBJECTIVE FORECASTS—

HOW STATED: DIRECTION / SPEED

WHEN VALID: THREE TIMES PER FORECAST PERIOD
(1) BEGINNING
(2) MIDDLE
(3) END

PHRASES—

FUNCTION OF: (1) WIND SPEED IN 4 CATEGORIES FOR 3 TIMES PER PERIOD
(2) CHANGE IN DIRECTION IN 2 CATEGORIES FOR 3 PAIRS
(3) PERIOD
(4) COMPLEXITY

TOTAL NUMBER: 35

TYPES: 5

TYPE 1: BREEZY / WINDY } NO INTRAPERIOD CHANGES

TYPE 2: BREEZY IN THE MORNING } BEGINNING OF PERIOD MENTIONED

TYPE 3: NORTHERLY WINDS 10 MPH. / LIGHT AND VARIABLE WINDS. / (NONE) } LIGHT WINDS

TYPE 4: STRONG NORTHERLY WINDS 20 TO 30 MPH BECOMING WESTERLY 25 TO 35 MPH BY EVENING. } STRONG WINDS

TYPE 5: BREEZY IN THE AFTERNOON } END OF PERIOD MENTIONED

Figure 2.--Information on wind forecasts and phrases.

all-important to the CWF program. All phrases within a type can be put into a sentence with the same connectives and punctuation. 12/ The phrases listed with the types in figure 2 are examples only; many other phrases are, of course, available for use.

Control information for wind phrase selection includes a complexity for each period of 1, 2, or 3 and four constants LW4, LW5, LW6, and LW7. Figure 3 shows how wind phrases would be selected for complexity 1 based on four ranges of speed--defined by LW4, LW5, and LW6--and 2 categories of wind direction change within a speed category--defined by LW7. The speed and direction changes in parentheses are based on the present control values and would be different if the control values were changed. For instance LW4, LW5, LW6, and LW7 are currently 7, 12, 19, and 60, respectively.

Figure 4 shows how the phrase selection indicated in figure 3 is modified when the complexity is specified as 2 or 3. Note that the reduction in phrase complexity depends on the period.

Some filtering (smoothing) of wind speeds is done prior to their use in figure 3. This is necessary to keep a very small change in forecast speed during the period from unduly influencing phrase selection. Finally, direc-

---

12/This is generally true; however, in some special cases individual treatment of a particular phrase is required.

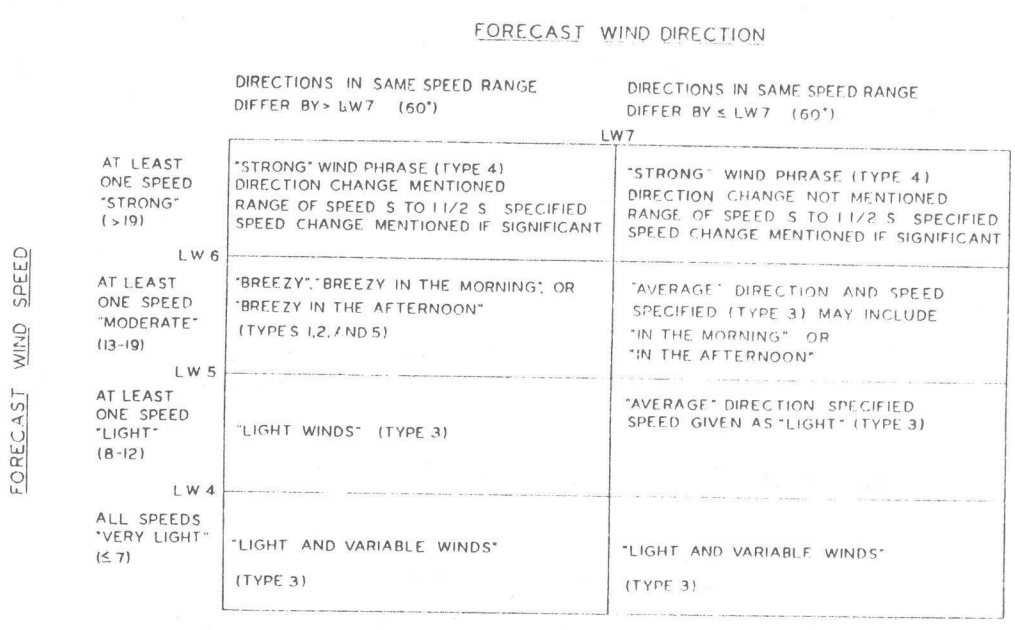

Figure 3.--Wind phrases indicated as a function of forecast wind speed and direction change during a period. For strong winds, approximately 50% is added to the speed S to account for gusts.

tion (to eight points of the compass) and speed (filtered and rounded to the closest 5 mph) are inserted where necessary. In many cases, these will be average values from two or three projections. For instance, suppose the filtered speed forecasts at the beginning, middle, and end of a period were between LW5 and LW6, less than LW6, and between LW5 and LW6, respectively, and the direction change between the forecasts for the beginning and end of the period was less than LW7. Then the direction and speed used in the wind phrase would be an average of the forecasts for the beginning and end of the period. When winds are "strong," the word "gusty" is sometimes inserted and a range of speed indicated such that the lower value is the filtered value and the upper value nearly 1 1/2 times that value. 13/

4.2 Temperature

Figure 5 is similar to figure 2 except it pertains to temperature. Note that the temperature descriptor phrases fall into four types, including the case when a descriptor is not used. Temperature information is inserted in two parts--a descriptor, such as "unusually cool" or "little change in temperature," and a statement such as "high in the low 90's." The latter, a categorization of the digital temperature forecasts, is always included for each of the three periods, but the descriptor is sometimes omitted.

Control information for temperature descriptor selection includes a complexity for each period of 1, 2, or 3 and 17 constants LT1, LT2, LT4 through LT17, and LT19. Figure 6 shows all of the max temperature descriptor phrases

13/The actual upper value G, before rounding, is computed from the filtered value S and the equation suggested by Tattleman (1975) $G=S(1.+.6 \exp(-.011S))$.

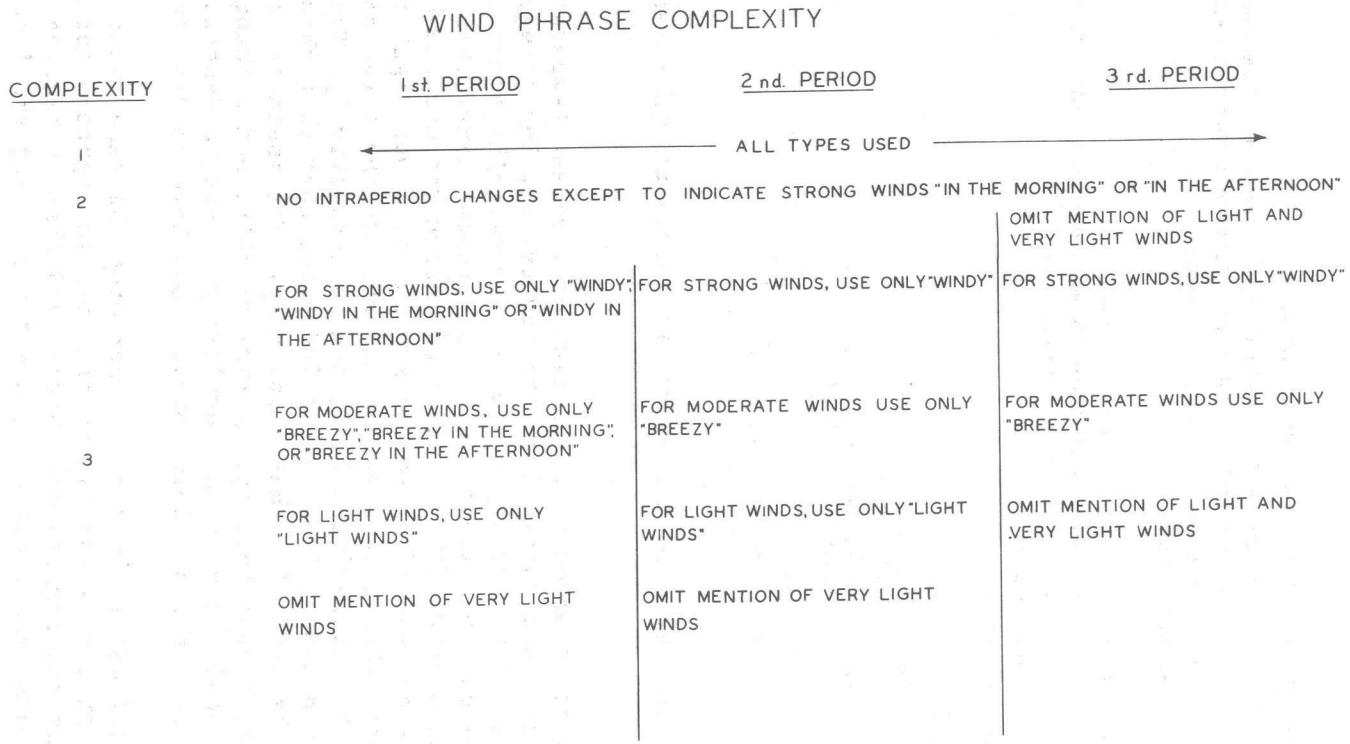

Figure 4.--Modification of wind phrase selection as a function of complexity and period.

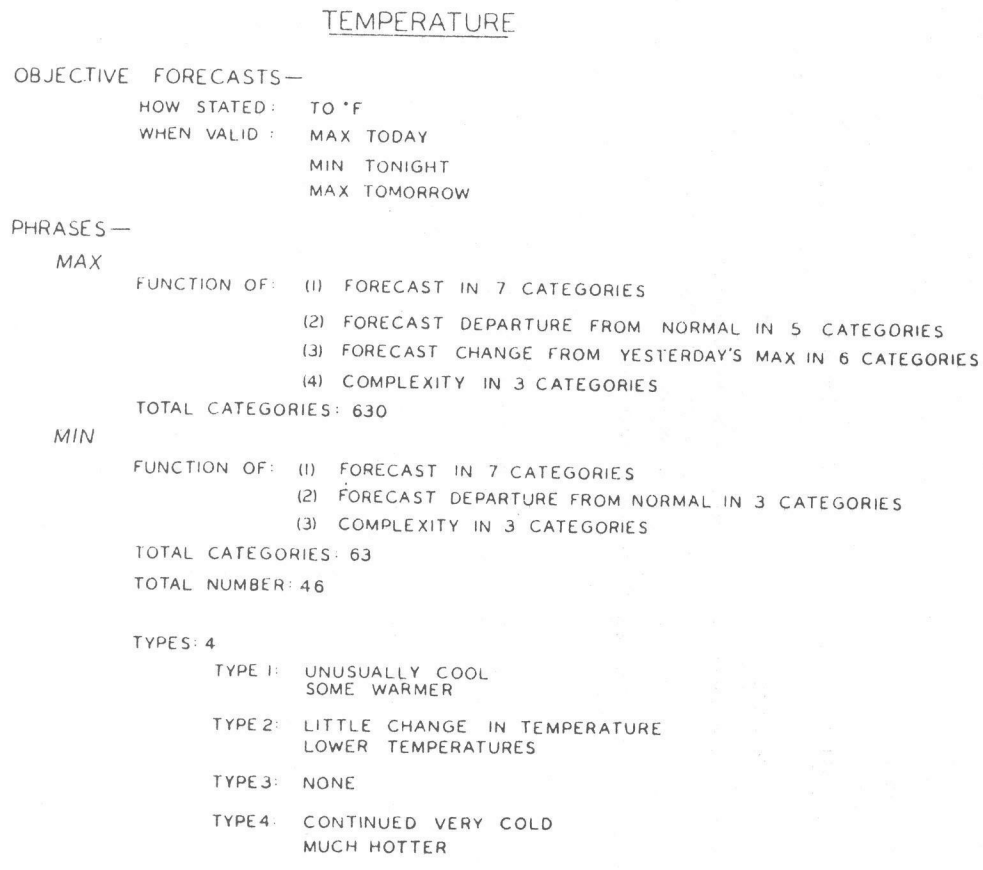

Figure 5.--Information on temperature forecasts and phrases.

and how they would be selected as a function of forecast temperature, departure from normal, and change from the day before. The categories are actually determined by the LT constants as shown--the numerical values indicate what these control values are at the present time. This is really a three-dimensional matrix with the third dimension represented by the six phrases in each box corresponding to the key in the lower right corner. The number preceding each phrase is a phrase number, and the three columns of numbers correspond to complexities 1, 2, and 3, respectively. The presence (absence) of a phrase number in a column indicates that that phrase would be used (would not be used) for that complexity. For instance, for a forecast temperature of 70°F, a departure from normal of -8°F, and a change from yesterday of 2°F, "cool" would be used for complexity 1, but no descriptor would be used for complexities 2 and 3. Some combinations have no descriptor defined.

The two-dimensional matrix in figure 7 performs the same function for min temperature as the three-dimensional matrix does in figure 6 for max temperature. Note that the min temperature phrases and their selection are very simple compared to max temperature. Figure 8 summarizes the function of the temperature complexity constants.

The digital temperature forecasts are generally presented in four categories--for instance, low 60's (61-63°F), mid 60's (64-66°F), upper 60's (67-

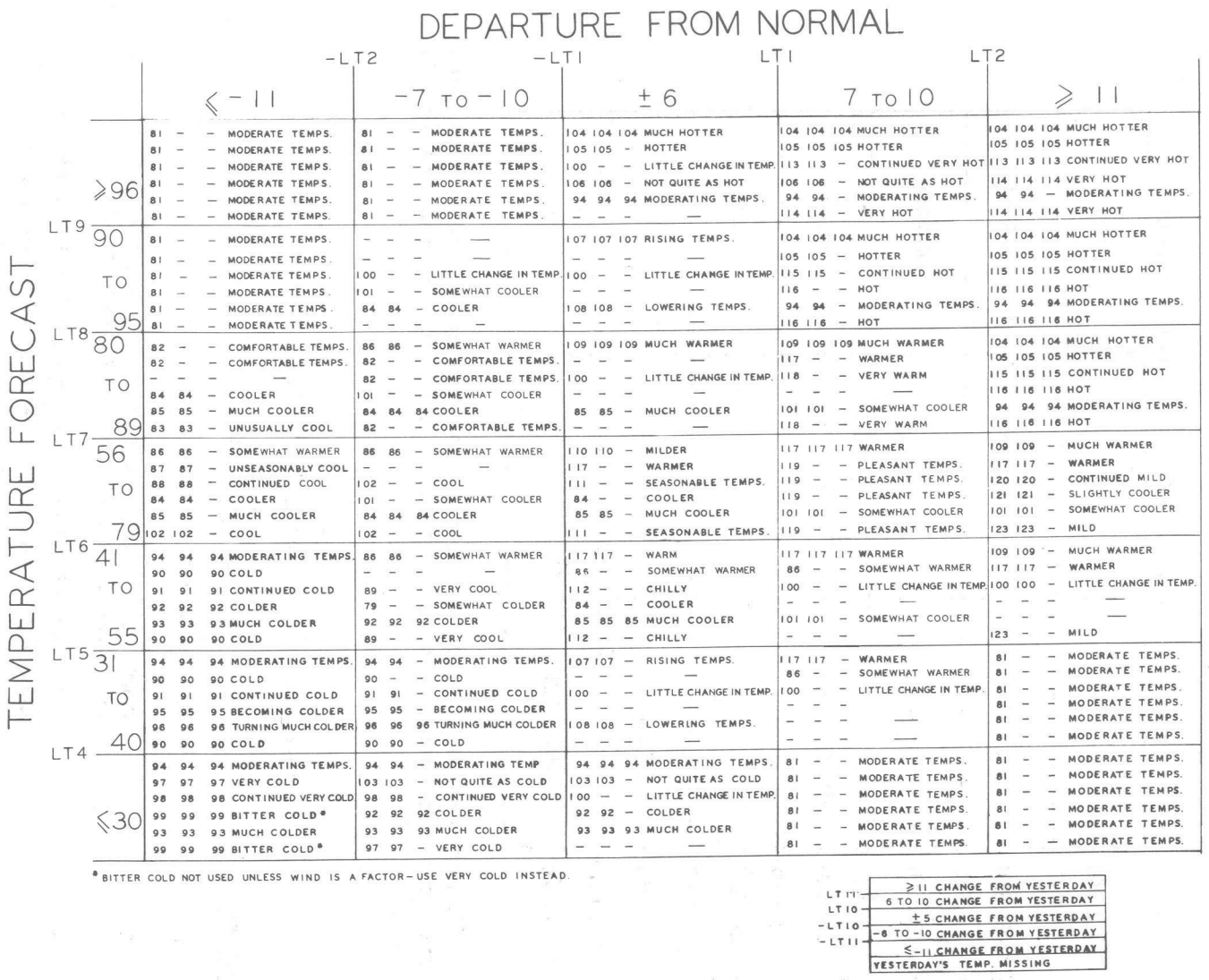

Figure 6.--Maximum temperature descriptors indicated as a function of forecast temperature, departure from normal, and change from the day before. All temperatures are in °F.

69°F), and near 70 (70°F). Departures from this categorization are made for forecasts below 20°F.

DEPARTURE FROM NORMAL

FORECAST TEMPERATURE	(≤-9)	-LT19	(±8)	LT19	(≥9)
(≥80)	———		———		HOT
LT17					
(61-80)	COOL		———		WARM
LT16					
(51-60)	COOL		———		WARM
LT15					
(31-50)	VERY COOL		———		MILD
LT14					
(16-30)	COLD		———		MILD
LT13					
(1-15)	COLD		———		———
LT12					
(≤0)	VERY COLD		———		———

Figure 7.--Minimum temperature descriptors indicated as a function of forecast temperature and departure from normal. All temperatures are in °F.

TEMPERATURE PHRASE COMPLEXITY

COMPLEXITY	ALL PERIODS
1	ALL DESCRIPTIVE TERMS
2	OMIT "MODERATE", "SEASONABLE", "COMFORTABLE", AND SOME OTHER UNIMPORTANT DESCRIPTORS.
3	OMIT ALL DESCRIPTIVE TERMS EXCEPT EXTREMES— REQUIRES A CHANGE FROM YESTERDAY OF ± LT 11 EXCEPT FOR EXTREME HOT OR COLD.

Figure 8.--Modification of temperature descriptor selection as a function of complexity.

Not infrequently, the 3-hourly temperature forecasts indicate the max will not occur in the afternoon. For instance, a warming trend may be indicated by a higher forecast temperature at a projection of 27 or 30 hours than at any other time. Or, a cold frontal passage may be indicated by a higher forecast temperature at 0900 or 1200 GMT than at any later time. Nine different temperature "traces" have been identified. The program determines which of these traces the 3-hourly forecasts fit, and wording is chosen appropriately.

4.3 Cloud

Figure 9 is similar to figure 2 except it pertains to clouds (total sky cover). All cloud phrases fall into one of two types--those with no intraperiod changes and those with intraperiod changes. The three letters in parentheses following each example for types 1 and 2 indicate what sequence of cloud forecasts for a period would lead to that particular phrase selection. For instance, SSC (scattered at the beginning and middle and clear at the end of the period) would lead to "partly cloudy."

Control information for cloud phrase selection is limited to a complexity for each period of 1, 2, or 3. Figure 10 indicates how cloud phrase selection is modified by complexities 2 and 3; complexity 1 selection is what is shown in figure 9.

CLOUD

OBJECTIVE FORECASTS—

HOW STATED: BY CATEGORY (1) CLEAR
(2) SCATTERED
(3) BROKEN
(4) OVERCAST

WHEN VALID: THREE TIMES PER FORECAST PERIOD
(1) BEGINNING
(2) MIDDLE
(3) END

PHRASES—

FUNCTION OF: (1) FORECAST AT BEGINNING OF PERIOD
(2) " " MIDDLE " "
(3) " " END " "
(4) PERIOD
(5) COMPLEXITY

TOTAL NUMBER: 35

TYPES: 2

TYPE 1: CLEAR (CCC)
PARTLY CLOUDY (SSC)
VARIABLE CLOUDINESS (CBC)
BECOMING OVERCAST (SOO)

TYPE 2: SUNNY THIS MORNING, BECOMING MOSTLY CLOUDY BY NOON. (CBB)
SUNNY, WITH INCREASING CLOUDINESS IN THE AFTERNOON. (CCB)

Figure 9.--Information on cloud forecasts and phrases.

4.4 Precipitation

Figure 11 is similar to figure 2 except it pertains to precipitation. Phrase selection for precipitation is more complicated than for the other three elements. It depends on 10 of the 11 variables appearing in the forecast matrix in figure 1. Eight types are required. Types 3 and 4 (6 and 7) are like type 2 (5) except that they pertain to morning and afternoon, respectively, instead of to the whole period. The eighth type is a special case and is used when it is desired to omit mention of clouds; this is discussed again in the next section.

Precipitation phrases can have three parts, as indicated in figure 12. One is a qualifier; if it is "chance of," for instance, it will be first; if it is "likely," it will be second. Another part, which can also be first or second, is the precip descriptor such as "snow" or "showers." The third part, if there is one, is always a time definition such as "in the morning." Besides these basic two- or three-part phrases, there are also lengthy phrases describing intraperiod changes which are complete within themselves except that the qualifier must be inserted; an example is "snow likely in the afternoon turning to rain before evening," the qualifier "likely" having been inserted. If the QPF category is greater than the control constant LP22, the words "heavy at times" are appropriately inserted within the descriptor.

Control information for precip phrase selection includes a complexity for each period of 1, 2, or 3 and 23 other constants. Figure 13 shows very briefly how the selection indicated in figure 12 is modified when complexity 2 or 3 is used. The roles of some of the other constants, such as LP1, are shown in figure 12. The numbers in parentheses, such as 20 percent for LP1, are the present values of the associated constants.

5. ORGANIZATION OF PHRASES

The above section described how words, phrases, and complete sentences are selected to be included in the complete CWF. A more difficult job is the combining of these so that the final text reads smoothly and follows the guidelines stated in section 3.

The typing of phrases explained in the last section is the first major step. With some exceptions, which are treated as special cases, a phrase for a particular weather element and a particular type is placed in the text in exactly the same way as are all other phrases for the same weather element and type. This "placement" involves punctuation, connectors (such as "and" and "with"), and order with respect to other phrases.

Referring to figures 2, 5, 9, and 11, one can see that there are 5, 4, 2, and 8 types for wind, temperature, cloud, and precip, respectively. Generally, the particular phrase used for one weather variable does not influence what phrase is used for another variable. There are some exceptions, the most notable being the option (specified on the control set) to exclude a cloud phrase when the precip phrase has no qualifier. In this special case, an eighth precip type is defined to better handle the composition.

CLOUD PHRASE COMPLEXITY

COMPLEXITY	1 ST. PERIOD	2 ND. AND 3 RD. PERIODS
1	ALL INTRAPERIOD CHANGES	SOME INTRAPERIOD CHANGES
2	NO INTRAPERIOD CHANGES	CHANGES ONLY, NOT BEGINNING CONDITIONS
3	NO INTRAPERIOD CHANGES	ABBREVIATED CHANGES ONLY, NOT BEGINNING CONDITIONS

Figure 10.--Modification of cloud phrase selection as a function of complexity and period.

PRECIPITATION

OBJECTIVE FORECASTS—

HOW STATED: 12-HR PROBABILITY—POP(12)
6-HR PROBABILITY—POP(6)

CONDITIONAL PROBABILITY OF RAIN
" " " SHOWERS } CONDITIONAL ON LIQUID PRECIP
" " " DRIZZLE }
" " " FROZEN PRECIP—POFP(P) } CONDITIONAL ON PRECIP

PROBABILITY OF THUNDERSTORMS—POT
QUANTITATIVE AMOUNTS—QPF

WHEN VALID: GENERALLY ONE OR TWO TIMES PER PERIOD

PHRASES—

FUNCTION OF: (1) ALL FORECASTS LISTED ABOVE
(2) PERIOD
(3) COMPLEXITY

TOTAL NUMBER: 100

TYPES: 7

TYPE 1: NONE
TYPE 2: SLIGHT CHANCE OF RAIN
TYPE 3: SLIGHT CHANCE OF RAIN IN THE MORNING
TYPE 4: SLIGHT CHANCE OF RAIN IN THE AFTERNOON
TYPE 5: CHANCE OF RAIN
RAIN LIKELY
RAIN
TYPE 6: RAIN LIKELY IN THE MORNING
TYPE 7: RAIN LIKELY IN THE AFTERNOON
TYPE 8: RAIN (NO CLOUDS TO BE SPECIFIED)

Figure 11.--Information on precipitation forecasts and phrases.

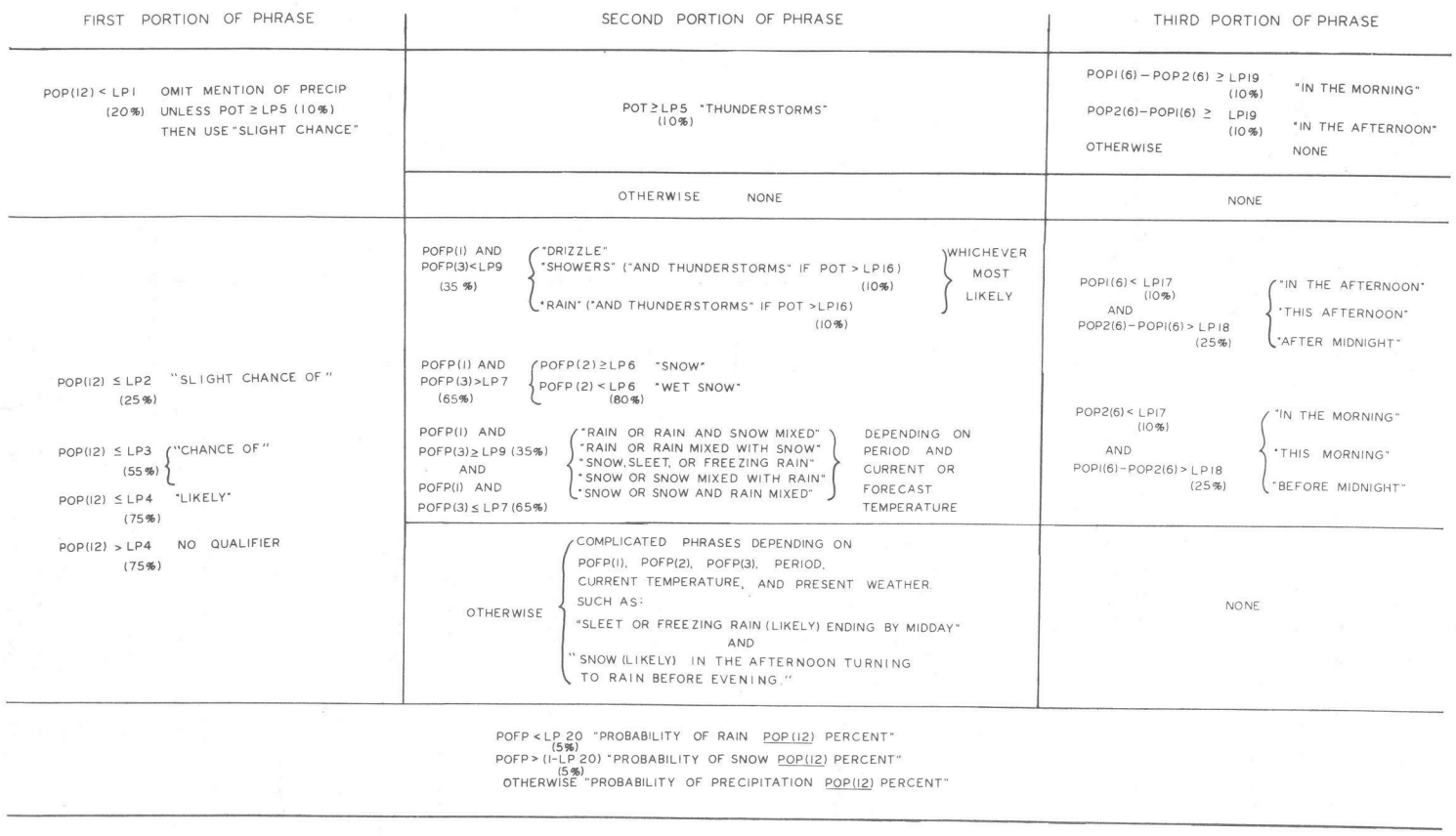

Figure 12.--Precipitation phrases in three parts as a function of precipitation variables. POP1(6) and POP2(6) are the first and second 6-hour POP's, respectively, in the 12-hour period. POFP(1), POFP(2), and POFP(3) are the POF forecasts for the beginning, middle, and end of the period, respectively.

PRECIP PHRASE COMPLEXITY

COMPLEXITY	ALL PERIODS
1	ALL INTRAPERIOD CHANGES
2	NO COMPLICATED INTRAPERIOD CHANGES NO MENTION OF "SLIGHT CHANCE OF THUNDERSTORMS"
3	NO COMPLICATED INTRAPERIOD CHANGES NO MENTION OF " SLIGHT CHANCE OF THUNDERSTORMS" NO MENTION OF " IN THE MORNING" OR " IN THE AFTERNOON"

Figure 13.--Modification of precipitation phrase selection as a function of complexity.

Therefore, there are 320 (5x4x2x8) ways that phrases can be combined into a completed text for each of the three segments (periods). Input to the CWF program includes, for each period, a predetermined set of numbers which define the order, punctuation, and connectives to be used for each of these 320 combinations. (See sec. 2.6.) This is done rather simply by providing, on one card (or record), a group of 26 digits; for example,

34181 326 522 300 200 000 000 000.

The first four digits mean, in order, that this record pertains to phrase types 3, 4, 1, and 8 for wind, temperature, cloud, and precip, respectively. The next digit (1) means that this sequence is for the first period. In each of the following three-digit groups, the first digit defines the variable to which that group applies--2 for wind, 3 for temperature, 4 for cloud, and 5 for precip. The other two digits in each group define the punctuation and trailer words to follow the phrase in addition to what is contained in the phrase. The order of the three-digit groups define the order of the phrases in the forecast segment.

For instance, in the above example, 326 means the temperature phrase will come first and it will be followed by "bTODAYbWITHb". 14/

The precip descriptor will come next followed by ",b" (522); the forecast max temperature will come next with no extra punctuation (300) 15/; the wind phrase will come next with no extra punctuation (200) 16/; and the other three groups of 000 indicate that no other phrases are required for this segment.

14/ b indicates a blank. When the phrases, punctuation, and connectives are actually put together, some special cases are identified. For these special cases, the information being discussed may be ignored.

15/ The program always puts a period after this temperature phrase.

16/ This type of wind phrase includes a period, so no other punctuation is required.

Provision is made for seven phrases (there are seven three-digit groups). Note that there is no cloud phrase in this example. This agrees with the type for precipitation being 8.

At the end of the three-period text, the probability of precip statement is appended in the usual manner. Probabilities are rounded to tens of percent and if 0 or 100 percent is indicated, the word "near" is used.

6. EXAMPLES OF FORECASTS

Figure 14 shows an example of a CWF prepared from the digital data in figure 1. The complexities used for wind, temperature, cloud, and precip, respectively, were 1,1,1, and 1 for period 1; 2,2,1, and 1 for period 2; and 3,2,3, and 2 for period 3.

6.1 First Period

Precipitation is the most important element; no qualifier is used since the probability (near 100 percent) is greater than LW4. (See fig. 12.) The option to not include a cloud statement has been exercised. Because the QPF forecast category is greater than 1, "heavy at times" has been inserted in the precip phrase. The probability of thunderstorms (TSTM) is less than LT16, and the conditional probability of rain (RAIN(L)) exceeds the conditional probabilities of drizzle (DRZL(L)) and rain showers (R SHR(L)). Also, the conditional probability of frozen precip (POF) is less than LP9 at the beginning of the period and greater than LP7 at the end of the period. And finally, the 6-hour probabilities of precip (PoP(6)) are both high, indicating precip in both halves of the 12-hour period. This translates into the precip statement in figure 14.

COLD TODAY WITH RAIN THIS MORNING, HEAVY AT TIMES, CHANGING TO SNOW IN THE AFTERNOON. EARLY MORNING HIGH IN THE UPPER 30S. LIGHT WINDS. TONIGHT--COLD, LOW NEAR 20. CLOUDY WITH A CHANCE OF SNOW IN THE EARLY EVENING, CLEARING BY MIDNIGHT. LIGHT NORTHWESTERLY WINDS. WEDNESDAY--MOSTLY SUNNY AND CONTINUED COLD, HIGH IN THE LOWER 30S. PROBABILITY OF PRECIPITATION NEAR 100 PERCENT TODAY, 30 PERCENT TONIGHT, AND NEAR 0 PERCENT TOMORROW.

Figure 14.--Example of a three-period forecast prepared by the CWF program from the digital data shown in figure 1.

The max temperature forecast (46F) is only one degree below normal for the station for which this forecast was made. However, the 3-hourly temperature forecasts indicate a cooling trend throughout the day, so quite likely the max would have already occurred before the "daytime" period. (Note that the wind shift between 1200 and 1800 GMT indicates a frontal passage.) Therefore, an "early morning high" is indicated, the numerical value being taken from the 1200 GMT forecast (39F). A "representative" temperature for the day of 35°F is computed which is 12°F below normal. Given that the max for the day before is missing, the descriptor "cold" can be found in figure 6.

The temperature phrase is put first mainly to make the forecast read more smoothly.

The filtering process applied to the wind speeds gives 9 mph for all three values (beginning, middle, and end of period). This value falls between LW4 and LW5 and the directions differ by more than LW7; therefore, "light winds" is forecast according to figure 3.

The example for the organization of phrases discussed in section 5 is for this particular first period forecast. Note that the precip phrase is an "exception" and the punctuation indicated for it is not used.

6.2 Second Period

The precip probability has decreased to 32 percent and the combination of 6-hour POP's and cloud forecasts indicate clearing by midnight. POF is greater than LP7 so any precipitation is expected to be snow. (See fig. 12.) Therefore, "cloudy with a chance of snow in the early evening, clearing by midnight" is used. The three filtered wind speeds are 9, 5, and 3 mph. The first of these is greater than LW4, and the corresponding direction is northwest.

The min temperature of 20°F is judged to be the most important element, being 9 degrees below normal, and figure 7 indicates "cold" is called for.

6.3 Third Period

The 12-hour POP has now decreased to "near 0". Although an overcast sky condition is forecast for the end of the period, "mostly sunny" is used because clear is forecast for the beginning and middle of the period. The forecast max of 32°F is 15 degrees below normal and a change of only -3 degrees from the "representative" forecast of 35°F for the day before; therefore, "continued cold" is used. Although the cloud condition is not as important as the temperature, it is put first to make the forecast read more smoothly.

The filtered wind speeds are 7, 7, and 7. When complexity 3 is used, these speeds are not large enough to occasion the mentioning of wind.

Figure 15 shows two other forecasts, each having been made from the digital data in figure 1 but with a different set of complexity constants. The top one is the most complex possible with this set of data; the bottom one is the least complex.

Figure 16 shows several three-period forecasts, each prepared from a different set of digital data with the same complexity constants used for figure 14. Note that these cover a rather wide variety of weather situations.

7. PLANS FOR THE FUTURE

The CWF program was originally written for the IBM 360/195, and forecasts can be produced daily for any of about 230 stations. As AFOS equipment is

COLD TODAY WITH RAIN THIS MORNING, HEAVY AT TIMES, CHANGING TO SNOW IN THE AFTERNOON. EARLY MORNING HIGH IN THE UPPER 30S. LIGHT WINDS. TONIGHT--COLD, LOW NEAR 20. CLOUDY WITH A CHANCE OF SNOW IN THE EARLY EVENING, CLEARING BY MIDNIGHT. LIGHT NORTHWESTERLY WINDS. WEDNESDAY--CONTINUED COLD. HIGH IN THE LOWER 30S. CLEAR, BECOMING CLOUDY BY EVENING. LIGHT AND VARIABLE WINDS. PROBABILITY OF PRECIPITATION NEAR 100 PERCENT TODAY, 30 PERCENT TONIGHT, AND NEAR 0 PERCENT TOMORROW.

COLD TODAY WITH RAIN OR RAIN AND SNOW MIXED, HEAVY AT TIMES, EARLY MORNING HIGH IN THE UPPER 30S. LIGHT WINDS. TONIGHT--CLEARING WITH A CHANCE OF SNOW. LOW NEAR 20. LIGHT WINDS. WEDNESDAY--MOSTLY SUNNY AND CONTINUED COLD, HIGH IN THE LOWER 30S. PROBABILITY OF PRECIPITATION NEAR 100 PERCENT TODAY, 30 PERCENT TONIGHT, AND NEAR 0 PERCENT TOMORROW.

Figure 15.--Two other examples of forecasts produced from the digital data shown in figure 1 with different combinations of complexity values.

CLEAR AND MILD TODAY, HIGH IN THE LOWER 60S. LIGHT AND VARIABLE WINDS. TONIGHT--CLEAR, LOW IN THE LOWER 20S. LIGHT AND VARIABLE WINDS. WEDNESDAY--CLEAR AND CONTINUED MILD, HIGH IN THE UPPER 60S. PROBABILITY OF PRECIPITATION NEAR 0 PERCENT THROUGH TOMORROW.

COLD TODAY, HIGH IN THE UPPER 40S. OVERCAST THIS MORNING, CLEARING BY EVENING. LIGHT NORTHWESTERLY WINDS. TONIGHT--CLEAR, LOW IN THE UPPER 30S. LIGHT AND VARIABLE WINDS. WEDNESDAY--CLEAR AND MILDER, HIGH NEAR 60. PROBABILITY OF PRECIPITATION NEAR 0 PERCENT THROUGH TOMORROW.

RAIN, HEAVY AT TIMES, TODAY. BREEZY AND MILD, HIGH IN THE MID 60S. TONIGHT--STRONG NORTHWESTERLY WINDS 20 TO 30 MPH BY MIDNIGHT. CLOUDY WITH A SLIGHT CHANCE OF RAIN IN THE EARLY EVENING, CLEARING BY MIDNIGHT. LOW IN THE LOWER 30S. WEDNESDAY--SUNNY, HIGH IN THE UPPER 50S. BREEZY IN THE MORNING. PROBABILITY OF PRECIPITATION NEAR 100 PERCENT TODAY, 20 PERCENT TONIGHT, AND 10 PERCENT TOMORROW.

OVERCAST WITH SNOW OR SNOW AND RAIN MIXED, HEAVY AT TIMES, THIS MORNING, WITH SOME SUNSHINE THIS AFTERNOON. HIGH IN THE MID 30S. WINDS 10 TO 15 MPH. TONIGHT--COLD, LOW NEAR 10. MOSTLY CLOUDY WITH A CHANCE OF SNOW IN THE EARLY EVENING, CLEARING BY MIDNIGHT. NORTHWESTERLY WINDS 10 TO 15 MPH. WEDNESDAY--SUNNY AND COLDER, HIGH IN THE UPPER 20S. PROBABILITY OF PRECIPITATION 80 PERCENT TODAY, 30 PERCENT TONIGHT, AND 20 PERCENT TOMORROW.

Figure 16.--Examples of CWF's prepared for a variety of weather situations.

installed at a Weather Service Forecast Office (WSFO), we will produce forecasts for that station and for the stations and zones for which it is responsible. These will be sent via the National Distribution Circuit (NDC) and will be available to the WSFO before the issue time of the early morning forecast.

When MOS forecasts are not available for a particular station and for zones, interpolation will be made from two to four stations for which MOS forecasts are available. Both a CWF and the digital forecast matrix will be transmitted.

A version of the CWF program will also be available for the local AFOS minicomputer. This will allow four options for the use (or nonuse) of the CWF at the WSFO:

1. Complete Acceptance. If the forecaster is satisfied with both the wording and the digital values in the CWF, he can disseminate the CWF with little more than the push of a button.

2. Minor Revision. If the forecaster wants to make minor changes to the wording or numerical values, that can be done with the text-editing capability of the AFOS equipment.

3. Major Revision. If the forecaster wants to make considerable revision of the digital forecasts, he can do so on the AFOS KCRT and then initiate the CWF program on the local minicomputer. Wording will then be generated which conforms to the amended digital forecast. Options 1, 2, and 3 are then available for this locally-produced CWF.

4. Total Disregard. This option is always open. It may turn out, as AFOS implementation nears completion, that all CWF's should be produced on the local minicomputer rather than be sent over the NDC. This option would trade circuit loading for minicomputer time and can be exercised any time it seems appropriate.

The present program does not combine periods when the forecast conditions are much the same for two or more of the periods. This feature will be added at a later date. In addition, terminology dealing with "watch" situations, blizzards and winter storms, and snow fall depths will be added.

The present program produces forecasts for the today, tonight, and tomorrow periods in that order. After we get the initial reaction from field forecasters using it in the AFOS environment and make any necessary modifications, we will write the software to produce CWF's for the tonight, tomorrow, and tomorrow night periods for use in the late afternoon and early evening. Another extension of the effort will be to produce "updates" that can be issued in the late morning and late evening.

ACKNOWLEDGMENTS

The work of many people in the Techniques Development Laboratory has made the production of a CWF possible; some, but not all, are included in the references. To each of these dedicated people I say, "thank you very much." I especially thank Thomas Bethem for programming support and Mary Heffernan for converting the CWF program to the AFOS minicomputer. I also wish to acknowledge the helpful suggestions of Larry Hughes, Fred Zuckerberg, Paul Moore, and Leonard Snellman of the NWS Regional Offices, William Klein of the Systems Development Office, Dale Lowry of TDL, and Steve Harned and Duane Cooley of the Office of Meteorology and Oceanography.

REFERENCES

Auliciems, A., and F. K. Hare, 1973: Visual presentation of weather forecasting for personal comfort. Weather, 28, 478-480.

Bermowitz, R. J., 1975: An application of model output statistics to forecasting quantitative precipitation. Mon. Wea. Rev., 103, 149-153.

Bermowitz, R. J., and E. A. Zurndorfer, 1975: Current status of probability of precipitation amount (PoPA) forecasting. TDL Office Note 75-10, 13 pp.

Bocchieri, J. R., G. M. Carter, R. L. Crisci, D. B. Gilhousen, K. F. Hebenstreit, G. W. Hollenbaugh, and D. J. Vercelli, 1977: Comparative verification of guidance and local aviation/public weather forecasts--No. 3. TDL Office Note 77-14, Techniques Development Laboratory, Silver Spring, Md., 49 pp.

Bocchieri, J. R., and H. R. Glahn, 1976: Verification and further development of an operational model for forecasting the probability of frozen precipitation. Mon. Wea. Rev., 104, 691-701.

Carter, G. M., 1974: Automated prediction of thunderstorms, drizzle, rain, and showers, TDL Office Note 74-7, Techniques Development Laboratory, Silver Spring, Md., 8 pp.

Carter, G. M., 1975a: Automated prediction of thunderstorms, drizzle, rain and showers, TDL Office Note 75-4, Techniques Development Laboratory, Silver Spring, Md., 4 pp.

Carter, G. M., 1975b: Automated prediction of surface wind from numerical model output. Mon. Wea. Rev., 103, 866-873.

Carter, G. M., 1976: Testing LFM- and PE-based statistical cloud prediction for the cool season. TDL Office Note 76-18, Techniques Development Laboratory, Silver Spring, Md., 11 pp.

Carter, G. M., and H. R. Glahn, 1976: Objective prediction of cloud amount based on model output statistics. Mon. Wea. Rev., 12, 1565-1572.

Charba, J. P., 1977: Operational system for predicting thunderstorms two to six hours in advance, NOAA Technical Memorandum, NWS TDL-64, 24 pp.

Cooley, D. S., G. S. Doore, A. F. Sadowski, and G. F. Cobb, 1977: National Weather Service public forecast verification from 1973 through 1976. Preprints, Fifth Conference on Probability and Statistics in Atmospheric Sciences, Las Vegas, Nev., Nov. 1977, Amer. Meteor. Soc., 344-346.

Cressman, G. P., 1959: An operational objective analysis system. Mon. Wea. Rev., 87, 367-374.

Crisci, R. L., G. M. Carter, and G. W. Hollenbaugh, 1977: Comparative verification of guidance and local aviation/public weather forecasts--No. 2. TDL Office Note 77-5, Techniques Development Laboratory, Silver Spring, Md., 32 pp.

Flattery, T. W., 1970: Spectral models for global analysis and forecasting. Proceedings of the 6th AWS Technical Exchange Conference, Air Weather Service Technical Report 242, 42-49.

Glahn, H. R., 1970: Computer-produced worded forecasts. Bull. Amer. Meteor. Soc., 51, 1126-1131.

Glahn, H. R., 1976a: Progress in the automation of public weather forecasts. Mon. Wea. Rev., 104, 1505-1512.

Glahn, H. R., 1976b: Automated forecasts of surface weather elements. Proceedings, Seventh Technical Exchange Conference, El Paso, Tex., 29-36.

Glahn, H. R., and R. A. Allen, 1966: A note concerning the "inflation" of regression forecasts. J. Appl. Meteor., 5, 124-126.

Glahn, H. R., and J. R. Bocchieri, 1975: Objective estimation of the conditional probability of frozen precipitation. Mon. Wea. Rev., 103, 3-15.

Glahn, H. R., and D. A. Lowry, 1972: The use of model output statistics (MOS) in objective weather forecasting. J. Appl. Meteor., 11, 1203-1211.

Howcroft, J. J., 1971: Local forecast model: Present status and preliminary verification. NMC Office Note 50, National Meteorological Center, Camp Springs, Md., 6 pp.

Klein, W. H., 1976: The AFOS program and future forecast applications. Mon. Wea. Rev., 104, 1494-1504.

Klein, W. H., and G. A. Hammons, 1975: Maximum-minimum temperature forecasts based on model output statistics. Mon. Wea. Rev., 103, 796-806.

Klein, W. H., B. M. Lewis, and I. Enger, 1959: Objective prediction of five-day mean temperatures during winter. J. Meteor., 16, 672-682.

Lönnqvist, O., 1973: Weather forecasts in tabulated and worded form by computer interpretation of forecast charts. J. Appl. Meteor., 12, 192-301.

Lowry, D. A., and H. R. Glahn, 1976: An operational model for forecasting probability of precipitation--PEATMOS PoP. Mon. Wea. Rev., 104, 221-232.

NWS, 1972: National Weather Service Operations Manual, Chapter C-11, Zone and local forecasts, Silver Spring, Md., 14 pp.

NWS, 1977a: The use of model output statistics for predicting probability of precipitation. Tech. Proc. Bull. No. 196, Silver Spring, Md., 14 pp.

NWS, 1977b: National Weather Service Operations Manual, Chapter C-91, Probability of precipitation forecasts, Silver Spring, Md., 6 pp.

NWS, 1978: National Weather Service Operations Manual, Chapter C-90, Public forecast wording, Silver Spring, Md., (in press).

Reap, R. M., and D. S. Foster, 1977: Automated prediction of thunderstorms and severe local storms. NOAA Technical Memorandum NWS TDL-62, 20 pp.

Shuman, F. G., and J. B. Hovermale, 1968: An operational six-layer primitive equation model. J. Appl. Meteor., 7, 525-547.

Smith, D. L., 1974: An automated procedure for composition of worded forecasts. Proceedings of Fifth Conference on Weather Forecasting and Analysis, Amer. Meteor. Soc., March 1974, 13-18.

Tattleman, P., 1975: Surface gustiness and wind speed range as a function of time interval and mean wind speed. J. of Appl. Meteor., 14, 1271-1276.

(Continued from inside front cover)

NOAA Technical Memorandums

NWS TDL 37 Prediction of Surface Dew Point Temperatures. R. C. Elvander, February 1971, 40 pp. (COM-71-00253)

NWS TDL 38 Objectively Computed Surface Diagnostic Fields. Robert J. Bermowitz, February 1971, 23 pp. (COM-71-00301)

NWS TDL 39 Computer Prediction of Precipitation Probability for 108 Cities in the United States. William H. Klein, February 1971, 32 pp. (COM-71-00249)

NWS TDL 40 Wave Climatology for the Great Lakes. N. A. Pore, J. M. McClelland, C. S. Barrientos, and W. E. Kennedy, February 1971, 61 pp. (COM-71-00368)

NWS TDL 41 Twice-Daily Mean Monthly Heights in the Troposphere Over North America and Vicinity. August F. Korte, June 1971, 31 pp. (COM-71-00826)

NWS TDL 42 Some Experiments With a Fine-Mesh 500-Millibar Barotropic Model. Robert J. Bermowitz, August 1971, 20 pp. (COM-71-00958)

NWS TDL 43 Air-Sea Energy Exchange in Lagrangian Temperature and Dew Point Forecasts. Ronald M. Reap, October 1971, 23 pp. (COM-71-01112)

NWS TDL 44 Use of Surface Observations in Boundary-Layer Analysis. H. Michael Mogil and William D. Bonner, March 1972, 16 pp. (COM-72-10641)

NWS TDL 45 The Use of Model Output Statistics (MOS) To Estimate Daily Maximum Temperatures. John R. Annett, Harry R. Glahn, and Dale A. Lowry, March 1972, 14 pp. (COM-72-10753)

NWS TDL 46 SPLASH (Special Program To List Amplitudes of Surges From Hurricanes): I. Landfall Storms. Chester P. Jelesnianski, April 1972. 52 pp. (COM-72-10807)

NWS TDL 47 Mean Diurnal and Monthly Height Changes in the Troposphere Over North America and Vicinity. August F. Korte and DeVer Colson, August 1972, 30 pp. (COM-72-11132)

NWS TDL 48 Synoptic Climatological Studies of Precipitation in the Plateau States From 850-, 700-, and 500-Millibar Lows During Spring. August F. Korte, Donald L. Jorgensen, and William H. Klein, August 1972, 130 pp. (COM-73-10069)

NWS TDL 49 Synoptic Climatological Studies of Precipitation in the Plateau States From 850-Millibar Lows During Fall. August F. Korte and DeVer Colson, August 1972, 56 pp. (COM-74-10464)

NWS TDL 50 Forecasting Extratropical Storm Surges For the Northeast Coast of the United States. N. Arthur Pore, William S. Richardson, and Herman P. Perrotti, January 1974, 70 pp. (COM-74-10719)

NWS TDL 51 Predicting the Conditional Probability of Frozen Precipitation. Harry R. Glahn and Joseph R. Bocchieri, March 1974, 33 pp. (COM-74-10909)

NWS TDL 52 SPLASH (Special Program to List Amplitudes of Surges From Hurricanes): Part Two. General Track and Variant Storm Conditions. Chester P. Jelesnianski, March 1974, 55 pp. (COM-74-10925)

NWS TDL 53 A Comparison Between the Single Station and Generalized Operator Techniques for Automated Prediction of Precipitation Probability. Joseph R. Bocchieri, September 1974, 20 pp. (COM-74-11763)

NWS TDL 54 Climatology of Lake Erie Storm Surges at Buffalo and Toledo. N. Arthur Pore, Herman P. Perrotti, and William S. Richardson, March 1975, 27 pp. (COM-75-10587)

NWS TDL 55 Dissipation, Dispersion and Difference Schemes. Paul E. Long, Jr., May 1975, 33 pp.(COM-75-10972)

NWS TDL 56 Some Physical and Numerical Aspects of Boundary Layer Modeling. Paul E. Long, Jr. and Wilson A. Shaffer, May 1975, 37 pp. (COM-75-10980)

NWS TDL 57 A Predictive Boundary Layer Model. Wilson A. Shaffer and Paul E. Long, Jr., May 1975, 44 pp. (PB-265-412)

NWS TDL 58 A Preliminary View of Storm Surges Before and After Storm Modifications for Alongshore-Moving Storms. Chester P. Jelesnianski and Celso S. Barrientos, October 1975, 16 pp. (PB-247-362)

NWS TDL 59 Assimilation of Surface, Upper Air, and Grid-Point Data in the Objective Analysis Procedure for a Three-Dimensional Trajectory Model. Ronald M. Reap, February 1976, 17 pp. (PB-256-082)

NWS TDL 60 Verification of Severe Local Storm Warnings Based on Radar Echo Characteristics. Donald S. Foster, June 1976, 9 pp. plus supplement. (PB-262-417)

NWS TDL 61 A Sheared Coordinate System for Storm Surge Equations of Motion With a Mildly Curved Coast. Chester P. Jelesnianski, July 1976, 52 pp. (PB-261-956)

NWS TDL 62 Automated Prediction of Thunderstorms and Severe Local Storms. Ronald M. Reap and Donald S. Foster, April 1977, 20 pp. (PB-268-035)

NWS TDL 63 Automated Great Lakes Wave Forecasts. N. Arthur Pore, February 1977, 13 pp. (PB-265-854)

NWS TDL 64 Operational System for Predicting Thunderstorms Two to Six Hours in Advance. Jerome P. Charba, March 1977, 24 pp. (PB-266-969)

NWS TDL 65 Operational System for Predicting Severe Local Storms Two to Six Hours in Advance. Jerome P. Charba, May 1977, 36 pp. (PB-271-147)

NWS TDL 66 The State of the Techniques Development Laboratory's Boundary Layer Model: May 24, 1977. P. E. Long, W. A. Shaffer, J. E. Kemper, and F. J. Hicks, April 1978, 58 pp.

NOAA SCIENTIFIC AND TECHNICAL PUBLICATIONS

The National Oceanic and Atmospheric Administration was established as part of the Department of Commerce on October 3, 1970. The mission responsibilities of NOAA are to assess the socioeconomic impact of natural and technological changes in the environment and to monitor and predict the state of the solid Earth, the oceans and their living resources, the atmosphere, and the space environment of the Earth.

The major components of NOAA regularly produce various types of scientific and technical information in the following kinds of publications:

PROFESSIONAL PAPERS — Important definitive research results, major techniques, and special investigations.

CONTRACT AND GRANT REPORTS — Reports prepared by contractors or grantees under NOAA sponsorship.

ATLAS — Presentation of analyzed data generally in the form of maps showing distribution of rainfall, chemical and physical conditions of oceans and atmosphere, distribution of fishes and marine mammals, ionospheric conditions, etc.

TECHNICAL SERVICE PUBLICATIONS — Reports containing data, observations, instructions, etc. A partial listing includes data serials; prediction and outlook periodicals; technical manuals, training papers, planning reports, and information serials; and miscellaneous technical publications.

TECHNICAL REPORTS — Journal quality with extensive details, mathematical developments, or data listings.

TECHNICAL MEMORANDUMS — Reports of preliminary, partial, or negative research or technology results, interim instructions, and the like.

Information on availability of NOAA publications can be obtained from:

ENVIRONMENTAL SCIENCE INFORMATION CENTER (D822)
ENVIRONMENTAL DATA AND INFORMATION SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

6009 Executive Boulevard
Rockville, MD 20852

NOAA--S/T 78-332