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AN AUTOMATED PROCEDURE FOR COMPOSITION OF ZONE FORECASTS

Daniel L. Smith

SOUTHERN REGION HEADQUARTERS
SCIENTIFIC SERVICES DIVISION
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1. INTRODUCTION

At least three times each day the National Weather Service Forecast Offices (WSFOs) issue zone forecasts similar in format to those shown in Fig. 1. The zones are designated to cover areas that are meteorologically homogeneous and the forecast is so written that it can be used by news media as a local forecast for any point within the zone. The preparation of even routine forecasts, such as those in Fig. 1, involves the professional forecaster in the time-consuming and mechanical tasks of composing and typing the messages. The potential advantages of an automated procedure for message composition are fairly obvious and have been well documented in several recent studies (see, for example, URS Data Sciences Co., 1971). Perhaps most significantly such a system would free the forecaster to concentrate on his most important responsibility - the preparation of amendments, advisories and warnings during high-impact weather situations.

A first step toward an automated procedure was achieved by the Techniques Development Laboratory (TDL) of the National Weather Service (Glahn, 1970). Although not yet operational, their program produces worded forecasts using as input objectively derived forecasts of individual weather elements. Using statistical methods to infer these elements from the output of the dynamic weather prediction models, the TDL technique converts these numerical forecasts to words. The program however has yet to be expanded to more than a few cities or beyond the first of the three or four 12-hr periods for which zone forecasts are made. In addition, the state of the communications system within the Weather Service will prohibit for some time the true man-machine mix (lucidly described by Klein, 1969) which will allow such a forecast system to become operational.

We have developed a local-use program which is similar to that described by Glahn in requiring as input to a computer forecasts for only a few basic parameters - temperatures, winds, probabilities of precipitation (PoPs), etc. These input parameters are the end result of the forecaster's decision process and may or may not be the same as his objective guidance (some elements of which, incidently, are just those parameters which are used in TDL's worded forecast program). Parameters are input for each period covered by the forecast. Although developed for the Fort Worth zone area there is no reason why the program cannot be expanded to other WSFOs where suitable computer facilities are available.

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```
#A
TEXAS ZONE FORECASTS ...1045 AM CDT    THURSDAY SEPT  7 1972


 ZONES 19 20 21 22
PARTLY CLOUDY THIS AFTERNOON AND FRIDAY. PARTLY CLOUDY WITH
SLIGHT CHANCE OF THUNDERSHOWERS TONIGHT WARM THIS AFTERNOON
AND FRIDAY. AFTERNOON HIGHS MID 90S. LOW TONIGHT LOW 70S.
WIND SOUTHWESTERLY 12 TO 22 MPH BECOMING SOUTHWESTERLY 10
TO 15 MPH FRIDAY. PROBABILITY OF RAIN 20PCT TONIGHT.

P ZONES 24 29
PARTLY CLOUDY AND WARM THIS AFTERNOON THRU FRIDAY. AFTERNOON
HIGHS MID 90S. LOW TONIGHT LOW 70S. WIND SOUTHWESTERLY 12
TO 20 MPH BECOMING SOUTHWESTERLY 10 TO 15 MPH FRIDAY.

P ZONES 25 30 31 26
INCLUDING THE DALLAS FORT WORTH AREA
PARTLY CLOUDY AND WARM THIS AFTERNOON THRU FRIDAY. AFTERNOON
HIGHS UPPER 90S. LOW TONIGHT MID 70S. WIND SOUTHERLY 8 TO
18 MPH BECOMING SOUTHERLY 6 TO 15 MPH FRIDAY.

A
TEXAS ZONE FORECASTS ...1045 AM CDT    THURSDAY SEPT  7 1972


##

 ZONES 23 27 28 32 33
TX27
PARTLY CLOUDY AND WARM THIS AFTERNOON THRU FRIDAY. AFTERNOON
HIGHS MID 90S. LOW TONIGHT MID 70S. WIND SOUTHERLY 6 TO 15
MPH BECOMING SOUTHERLY 5 TO 10 MPH FRIDAY.

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Zone Forecast Areas
Fort Worth WSFO

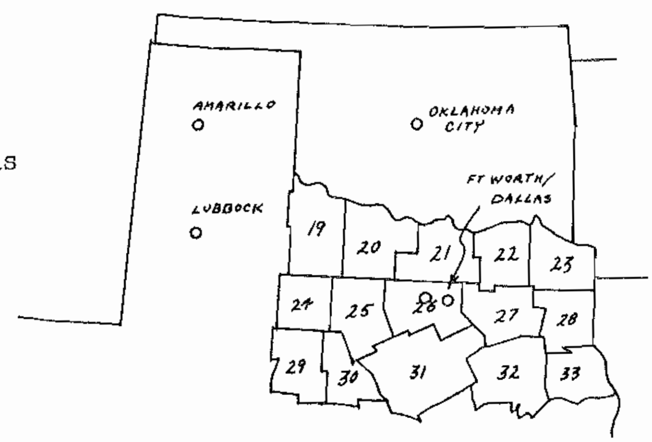

Fig. 1. Example of zone forecast package. Inset map shows 15 zones for which Fort Worth WSFO has forecast responsibility.

2. CAWF PROGRAM

a. Input The basic operation of the Computer Assisted Worded Forecast program (CAWF) is outlined in Fig. 2. The input data are typed into a time-share computer* using a conversational mode. Because the intermediate forecasts are often simply updates of previous primary forecasts, the input is simplified for intermediate times by automatically recalling the earlier data and requiring input of only the necessary revisions. This "store-and-recall" feature of the computer allows the forecaster usually to type only a few numbers in lieu of retyping the entire zone message. Fig. 3 shows an example of the input routine for the 3-period ("today", "tonight", "tomorrow") 1000 GMT forecast. A summary of the input parameters is shown in Table 1. It is important to notice that not all the parameters are always input. In the frequent case of the "no rain" forecast, for example, P1, P2, P3 and the three PoPs are omitted. Note also that the zones can usually be grouped to reduce the number of forecasts. The time and effort involved in the input routine depends on the number and complexity of the forecasts.

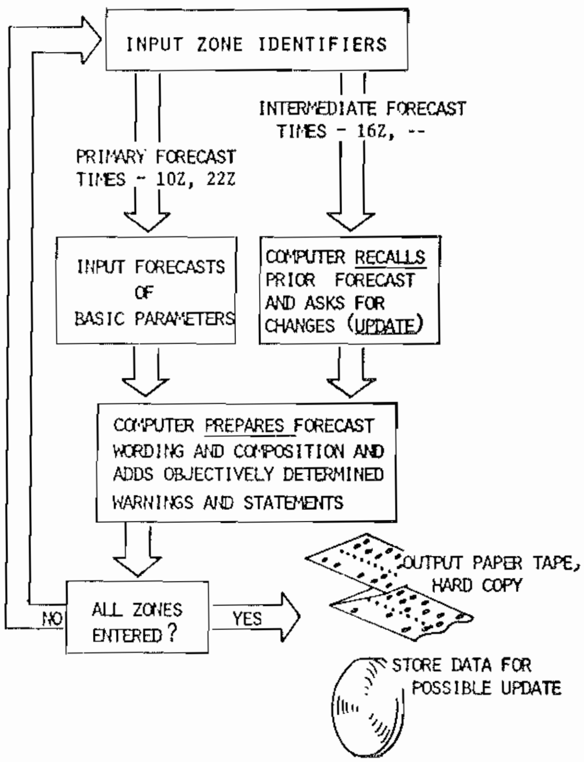

Fig. 2. Schematic of CAWF operation.

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GREETINGS..ENTER MØ,DAY,TIME,DAY ØF WEEK...11,7,10,3

WHAT ZØNES...19,20,25,29,36
IMPRØPER ZØNE NUMBER..MUST BE BETWN 19-33

WHAT ZØNES...19,20,25,29,30

MAX MIN MAX S1P1 S2P2 S3P3 PØP PØP PØP DDF1F2 DDF1F2 DDF1F2
 60  48  76   10   9    6   90            SE1020        SW1020

WHAT ZØNES...21,26,31
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Fig. 3. Example of input routine for CAWF (only data for one set of zones are shown). Parameters entered by forecaster are underlined.

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* Computer services were made available by the Engineering Divisions of the NWS Regional and Central Headquarters.

Table 1. Summary of input parameters for CAWF. See Fig. 3 for example of format.

Input Code		Parameter*
MAX, MIN	----	High or low temperature (nearest °F)
$S_{1,2,3,4}$	----	Sky condition (see Table 2)
$P_{1,2,3,4}$	----	Precipitation type (entered only if corresponding PoP ≥20%)
PoP	----	Probability of precipitation
DD	----	Wind direction (N,NE,E,SE,S,SW,W,NW,LV)
F1,F2	----	Range of wind speed (mph)

*Each parameter represents a forecast for a 12-hour period. As Fig. 3 shows, even though CAWF requests input of winds, for example, for three periods, forecasts need not be entered for all periods.

b. Message Composition In its general form the zone forecast first includes a specification of the expected sky and weather conditions for all periods with elements and periods combined to the extent possible to produce a clear and concise statement. The forecast then continues with a statement of the expected high or low temperatures in each period followed by the wind forecasts for at least the first period. Expected PoPs, if significant*, are the last elements of the forecast. CAWF attempts to duplicate this format. Table 2 shows the code numbers which are used for forecast sky conditions and precipitation types.

Table 2. Numbers used for input of forecast sky and precipitation types.

PRECIPITATION TYPE (P1, P2, P3, P4)	SKY (S1, S2, S3, S4)
1. DRIZZLE	1. CLEAR
2. OCCASIONAL DRIZZLE	2. SUNNY
3. RAIN	3. MOSTLY SUNNY
4. LIGHT RAIN	4. CLEAR TO PARTLY CLOUDY
5. OCCASIONAL RAIN	5. CLOUDY
6. OCCASIONAL LIGHT RAIN	6. PARTLY CLOUDY
7. RAIN OCCASIONALLY HEAVY	7. MOSTLY CLOUDY
8. SHOWERS	8. CONSIDERABLE CLOUDINESS
9. AFTERNOON AND EVENING THUNDERSHOWERS	9. DECREASING CLOUDINESS
10. THUNDERSHOWERS	10. INCREASING CLOUDINESS
11. THUNDERSTORMS	11. FAIR
12. SNOW	12. MOSTLY FAIR
13. LIGHT SNOW	13. CLEARING
14. OCCASIONAL SNOW	14. FOG
15. OCCASIONAL LIGHT SNOW	15. SOME MORNING FOG OR LOW CLOUDS OTHERWISE MOSTLY FAIR
16. SNOW OCCASIONALLY HEAVY	
17. SLEET	
18. SLEET MIXED WITH SNOW	
19. FREEZING RAIN	
20. FREEZING DRIZZLE	
21. RAIN AND SNOW MIXED	
22. SLEET OR FREEZING RAIN	

*In general, in the Southern Region PoPs are not mentioned unless ≥20%.

For periods in which non-zero precipitation code numbers are specified, the computer determines from the corresponding PoP values the proper probability modifiers as specified in Table 3.

Table 3. Precipitation probability modifiers used in zone forecasts.

PoP < 20%	---- precipitation not mentioned
PoP = 20%	---- SLIGHT CHANCE OF...
30% ⩽ PoP ⩽ 50%	---- CHANCE OF...
60% ⩽ PoP ⩽ 70%	---- ...LIKELY
PoP > 70%	---- no modifier used

In each phase of the message composition CAWF compares forecasts for each period and combines them when possible. The first part of the zone forecast might read:

FAIR THIS AFTERNOON, PARTLY CLOUDY TONIGHT AND MONDAY...

or, CLOUDY WITH RAIN LIKELY TODAY AND TONIGHT. CLEARING FRIDAY... .

CAWF chooses the descriptive temperature for each period by locating the forecast temperatures relative to the curves shown in Figs. 4 and 5. The curves and descriptive terms were subjectively determined with reference to the daily normals and are intended to apply to the North Texas area. Once developed such figures allow a completely objective specification of temperature conditions. Shak, et al (1966) suggested a similar approach which they felt would insure consistent terminology and avoid confusion to the public and from one forecaster to the next. CAWF has considerable flexibility to combine periods and specify inter-period trends, although no attempt has been made to allow for first period temperature trends since this would require input of an additional parameter to give some indication of the previous day's temperature. This part of the message might read:

WARM THRU SATURDAY...

or, COLD TODAY AND FRIDAY, VERY COLD TONIGHT...

or, WARM THIS AFTERNOON, MILD TONIGHT, WARMER MONDAY... .

To account for a fairly common summertime situation the computer may combine the sky and temperature parts of the message when there is no precipitation forecast. Such a "short forecast" might read:

SUNNY AND WARM THRU THURSDAY... .

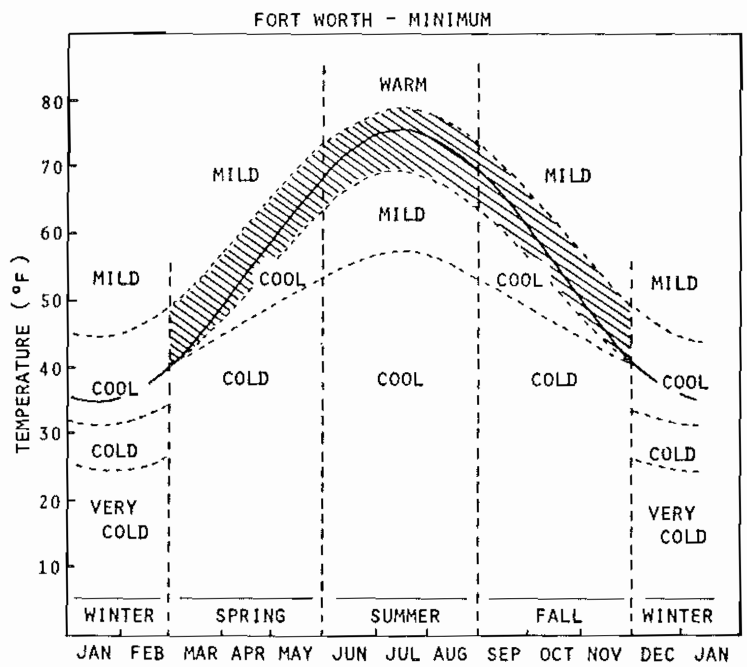

Fig. 4. Terminology used to describe the minimum temperature forecast for Fort Worth zones. Solid curve is Fort Worth normal minimum. A forecast of an overnight low of 55° in mid-September, for example, would be termed "cool" by CAWF. Temperatures which fall within the cross-hatched areas are "seasonal" and not mentioned in the forecast except in the HI/LO part of the message.

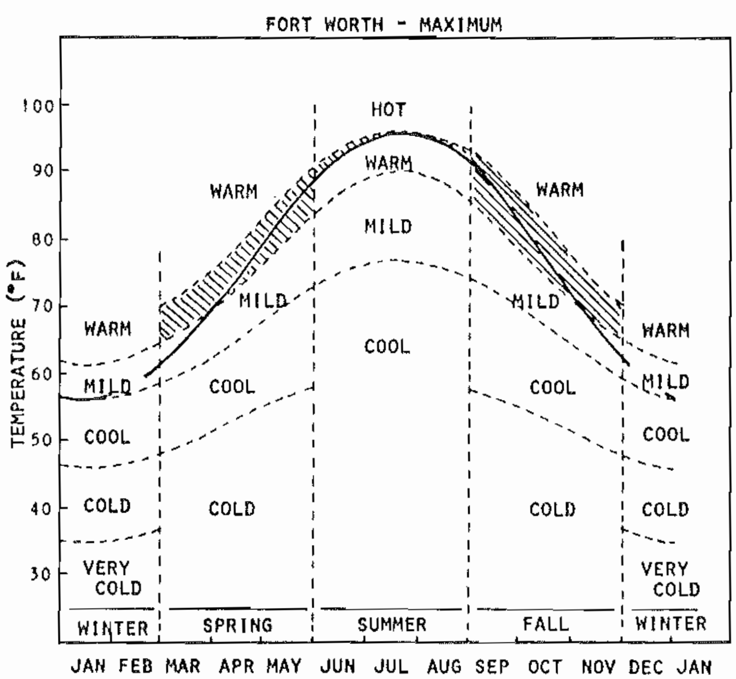

Fig. 5. Same as Fig. 4 but for maximum temperature.

Except during the winter season no descriptive temperature is mentioned for those periods in which the max or min is expected to fall within a few degrees of the normal max or normal min. This helps prevent a monotonous, and sometimes meaningless, "seasonable" statement.

Examples so far have shown the development of the first few sentences of the 3-period forecast. The sky, weather and descriptive temperature parts of the 4-period ("tonight", "tomorrow", "tomorrow night", "day-after-tomorrow") 2200 GMT forecast are handled differently. First period forecasts of these elements, along with the forecast overnight low temperature, are included in the first two sentences of the message as a statement of the expected conditions for tonight. For example:

CLEAR AND VERY COLD TONIGHT. OVERNIGHT LOW NEAR 20...

or, SLIGHT CHANCE OF RAIN TONIGHT. MILD WITH OVERNIGHT LOW UPPER 60S... .

The remainder of the 2200 GMT forecast is composed in the same way as a 3-period forecast by simply relabeling the periods. Fig. 6 shows the correspondence between the periods of the 3- and 4-period forecast. To illustrate further, consider the first example which was given in this section, a forecast issued at 1600 GMT on a Sunday:

FAIR THIS AFTERNOON, PARTLY CLOUDY TONIGHT AND MONDAY... .

In the composition of the subsequent 2200 GMT forecast THIS AFTERNOON becomes MONDAY, TONIGHT becomes MONDAY NIGHT, and MONDAY becomes TUESDAY. The composition of the second, third, and fourth periods of the 2200 GMT forecast then proceeds in the same manner as the three periods of the previous forecast.

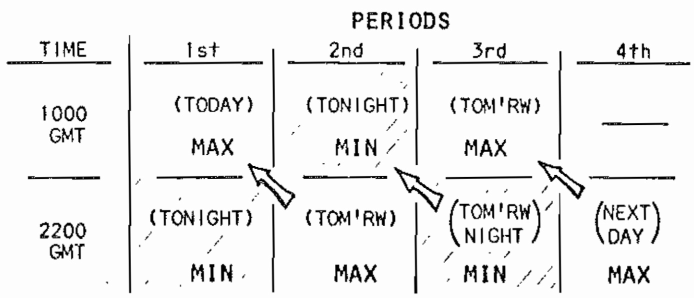

Fig. 6. "Lagging" of periods in composition of 4-period forecast.

The max/min/max part of the forecast is composed next by using the following range modifiers: NEAR (for a forecast of, say, 40), LOWER (41-43), MID (44-46) and UPPER (47-49). The wording is varied somewhat depending on the way in which the periods are combined. For example:

AFTERNOON HIGHS NEAR 90. LOW TONIGHT UPPER 60S...

or, HIGH THIS AFTERNOON MID 50S. LOW TONIGHT LOWER 40S. HIGH SUNDAY NEAR 60... .

Wind forecasts may be input for any or all of the first three periods. Examples of the computer phraseology for this part of the forecast are given in Table 4. A forecast of wind speeds in excess of 24 mph in the first period triggers the appending of a "wind warnings" statement to the end of the message (See Fig. 7).

Table 4. Examples of wind forecast part of CAWF message.

Input Parameters			Worded Forecast
DDFIF2	DDFIF2	DDFIF2	
S10			WIND SOUTHERLY ABOUT 10 MPH.
SW 812		NW1015	WIND SOUTHWESTERLY 8 TO 12 MPH BECOMING NORTHWESTERLY 10 TO 15 MPH SATURDAY.
N1520	N1015	LV	WIND NORTHERLY 15 TO 20 MPH DECREASING TONIGHT BECOMING LIGHT AND VARIABLE FRIDAY.
	S1218	NE	WIND SOUTHERLY 12 TO 18 MPH TONIGHT BECOMING LIGHT NORTHEASTERLY MONDAY.

The probabilities of precipitation are included as the last part of the zone forecast and are stated only for those periods in which they are forecast to be ≥20%. CAWF uses the term PROBABILITY OF RAIN unless at least one of the forecast precipitation types is frozen (code number >11), in which case it uses PROBABILITY OF PRECIPITATION.

c. Output. As shown in Fig. 2, forecasts are composed for each zone or groups of zones until all zones are accounted for. The complete set of forecasts is then recalled from memory and output on the teletype terminal. (Fig. 1 is a CAWF forecast, and incidently has the distinction of being the first computer-composed forecast of this type ever issued to the public.) The time involved for an "average" set of forecasts, from initiation of input to this stage of output, is about 5-10 minutes.

In the WSFO the end product of the forecast preparation cycle must be a 5-channel, Baudot code, punched paper tape by means of which the forecasts are transmitted to the users via the NOAA Weather Wire Service. This tape cannot be prepared simultaneously with the above output because the ASR-33 terminal on which CAWF is run is equipped with an 8-channel ASCII-code, paper tape I/O. Suitable programing, however, allows for the translation of the composed forecast message to a coded message which is punched on 8-channel tape following the "plain language" output. This tape is then manually split to 5-channel width and the "plain language" forecast is recovered.

The composed forecasts are output in tape form as the last part of the CAWF operation. Various characters are added to the tape which serve as Weather Wire routing codes and activation symbols. For example, the notation "TX27" must follow the heading which contains zone 27 (see Fig. I) and serves to activate a cable TV device for automatically displaying the forecast in the local area of zone 27.

3. OPERATIONAL TEST

An operational test of the CAWF program at Fort Worth began with the September 7 forecasts shown in Fig. I. Forecasters were asked, but not required, to use the computer in preparing their messages. One of the ground rules of the test allowed them to accept, reject, or modify the computer output. The experiment was well received by the WSFO and with few exceptions the forecasters seemed enthusiastic about the novelty and challenge of using the computer. In attempting to duplicate the format of the local zone forecast the phraseology of the CAWF message sometimes differs from that the forecaster would probably use. Even so, an evaluation of test results showed that CAWF usually produced an acceptably worded forecast. Man-and computer-worded forecasts seem to be of about equal length and when the computer forecast was modified, it was usually lengthened slightly. No attempt was made to inform users that computer-composed forecasts were being released and the lack of response or comments concerning the forecasts can be interpreted to mean that, in terms of utility, there was little difference between man-and computer-composed versions.

Between September 7 and December 31, 1972, an attempt was to be made to use the computer twice each day; for forecasts issued at 1000 GMT and 1600 GMT. This tested both the primary and intermediate (update) forecast routines of the program. The test included 231 such forecast periods. For 94 (40%) of these periods the CAWF output was transmitted without modification. The computer forecasts were modified - usually only slightly - in 64 (28%) of the periods. Fig. 7 shows forecasts from two of these 64 periods. The usual modifications changed the computer's assessment of the descriptive temperature or reflected a first period temperature trend. For the other 73 (32%) of the periods the computer was not used or its output was rejected entirely. It was obvious before the test began that situations would arise for which CAWF could not produce an acceptable forecast, for example, when a frontal passage was expected to produce an intraperiod change of temperature or wind. Such situations accounted for about half of the 73 periods during which CAWF was not used. Two examples of forecaster-composed messages are shown in Fig. 8. Only about twenty times was the computer or its output unavailable because of mechanical failures. This failure rate is encouraging in light of the fact that the rigid time frame during which the forecasts are prepared allows usually only one attempt at the time-share system.

Discounting the month of September, during which time the forecasters were familiarizing themselves with the computer program (and, indeed, usually with the operation of a computer for the first time), test data

ZONES 19 20 21 AND 24 25
CLOUDY WITH RAIN LIKELY TODAY THRU FRIDAY. ~~COLD~~ COLDER TODAY, ~~AND~~ COOL
TONIGHT ~~COOL~~ FRIDAY. HIGH THIS AFTERNOON LOW 50S. LOW TONIGHT
LOW 40S. HIGH FRIDAY MID 50S. WIND NORTHERLY 15 TO 25 MPH
BECOMING NORTHEASTERLY 10 TO 15 MPH TONIGHT. PROBABILITY
OF RAIN 70PCT TODAY 70PCT TONIGHT 70PCT FRIDAY.

WIND WARNINGS ARE IN EFFECT ON AREA LAKES.

ZONES 21 22 23 25 27 30 31 26
INCLUDING THE DALLAS FORT WORTH AREA
TX27 FREEZE WARNING FREEZE TONIGHT LOW AROUND
CLEAR TO PARTLY CLOUDY TODAY THRU THURSDAY. COOL TODAY COLD
TONIGHT NOT AS COOL THURSDAY. HIGH THIS AFTERNOON MID 50S.
~~LOW TONIGHT NEAR~~ 30. HIGH THURSDAY NEAR 60. WIND NORTHERLY
ABOUT 10 MPH BECOMING LIGHT AND VARIABLE TONIGHT.

Fig. 7. Examples of computer-prepared zone forecasts showing changes which were made by forecaster prior to issuance.

ZONES 21 22 25 26 27 29 30 31 INCLUDING THE DALLAS AND FORT WORTH AREA
TX27
SHOWERS AND FEW THUNDERSTORMS ENDING THIS AFTERNOON. DECREASING
CLOUDINESS THIS AFTERNOON AND EARLY TONIGHT. FAIR AND WARMER
THURSDAY. HIGH TODAY NEAR 60. LOW TONIGHT UPPER 40S. HIGH
THURSDAY UPPER 60S. WIND NORTHWEST 8 TO 18 MPH. PROBABILITY OF
RAIN 60 PERCENT TODAY.

ZONES 19 24
TRAVELERS ADVISORY
OCCASIONAL SNOW THIS AFTERNOON CAUSING LOCALLY HAZARDOUS DRIVING
CONDITIONS. DECREASING CLOUDINESS AND COLD TONIGHT. CLEAR TO PARTLY
CLOUDY AND COOL THURSDAY. HIGH THIS AFTERNOON MID 30S. LOW TONIGHT
UPPER 20S. HIGH THURSDAY LOWER 50S. WIND SOUTHEASTERLY 10 TO 15
MPH BECOMING NORTHERLY TONIGHT. PROBABILITY OF PRECIPITATION
80 PERCENT THIS AFTERNOON.

Fig. 8. Examples of zone forecast phraseology which CAWF, as presently configured, cannot duplicate. The top example contains more than one precip type in the same period as well as intraperiod changes. The bottom example contains special wording as part of the travelers' advisory.

from the October-December period (Table 5) show encouraging results in terms of utility and efficiency of the automated system.

Table 5. Summary of test results, October-December 1972.

Month	Fcst Periods (2/day)	Usable CAWF Fcsts	Avg Time per Fcst (min)* 1000 GMT	1600 GMT
OCT	62	44 (71%)	11	12
NOV	60	39 (65%)	9	12
DEC	62	45 (73%)	12	12

*Time from computer sign-on to sign-off

The time required for each usable CAWF run averaged about the same for each month. On the average, zone forecasts during October and December contained 4-5 zone groupings (different forecasts) while November's zones usually had only 3-4 groups. This probably accounts for the reduced time per run required during November. The results shown in Table 5 should not be considered too rigorously since several factors are ignored: longer, more difficult forecasts are selectively omitted because these are the forecasts CAWF cannot as yet handle; indicated average times per run do not include the time required for establishing contact with the computer or the time needed to edit the CAWF forecast, if necessary; in addition, there has been no attempt to account for forecaster experience with the system. The update (1600 GMT) forecasts take on the average a few minutes longer to prepare, probably because of the more involved question-and-answer input routine. This suggests that a more streamlined update procedure is required.

The time required by the computer to prepare a CAWF forecast is comparable to that required by the forecaster to compose and type a similar routine message*. Of course, this time does not include that used by the forecaster in arriving at the input forecast parameters. This preparation time may be extensive - even though the forecast is "routine" - and it is a fundamental part of CAWF that the parameters are determined by the forecaster, regardless of whether CAWF is used to compose the message. It should be remembered, however, that once forecasts of the input parameters have been made the forecaster's real job is done. Someone must monitor the computer I/O but it need not be the professional forecaster.

The Fort Worth test has revealed several ways in which the CAWF program can be modified to increase its reliability and the flexibility of its wording. The need to allow for the input of some indicators of the previous day's temperatures (max and min) as well as allowing for the

* The Fort Worth forecasters are reasonably good typists. It is not an insignificant sidelight that an automated procedure such as CAWF no longer requires the forecaster to be a typist!

specification of intraperiod changes of some parameters has already been illustrated. This cannot be done, however, with an attendant significant increase in the number of input parameters since this would increase operator time and act counter to the philosophy of using the computer. The number of input parameters might be reduced by allowing for the automatic incorporation of objectively derived forecast parameters such as temperatures (Klein and Lewis, 1970) or PoPs (Glahn, et al, 1971) which are routinely received on teletype at the forecast office. Such input would be subject to forecaster modification much as the 1000 GMT data are updated in the 1600 GMT execution of CAWF. It might also be possible to input data for only a few reference cities in the zone area and allow the computer to interpolate for and group like zones together to produce the local forecasts. This is essentially the same procedure the forecaster follows to arrive at the forecast parameters for each of the zones. Intraperiod changes can be handled to some extent by inclusion of new phrases in the vocabulary shown in Table 2. Note S(15), for example.

Most importantly, there must be some allowance in CAWF for means of fast and easy modification, editing and updating of the forecasts. This is essential if the computer is to free the forecaster when his time is most valuable - during severe weather situations when the preparation of amendments and warnings becomes vital. Such procedures could probably be most easily developed for use with a KCRT terminal.

4. CONCLUSIONS

The Fort Worth experiment has shown that it is possible, even with a limited computer capability, to develop an automated forecast composition program which functions in an operational system. The results of the test give us sufficient encouragement to continue the development of the program along the lines presented in the previous section. Such local-use automation procedures as CAWF will undoubtedly be supplanted by future developments in Weather Service operations (U.S. Dept. of Commerce, 1972), but this fact should not prevent the initiation, in the interim, of new techniques and programs which will begin to answer such basic questions as how the forecaster will react to a computerized operation.

Peterman (1972) concluded that the major advantage of a computer time-share system was the ability to perform a vast number of laborious computations while allowing the operator to maintain a creative subjectivity. This is the essence of CAWF. There is precedent for the operational use of a time-share system elsewhere in the National Weather Service (Parry, 1969) and it should not be difficult to develop a more generalized form of CAWF which would be adaptable to any WSFO with even such a limited computer capability. Alternatively, the needed computer facilities might be provided by the on-site location of, or remote terminal access to, minicomputers which are being phased into the NWS upper-air observing system (Dept. of Commerce, 1972).

ACKNOWLEDGEMENTS -

It is a fundamental fact of computer programming that when errors occur in a program they will be undetectable by the author but will be immediately obvious to the first passer-by who hasn't the slightest idea what that particular program's about!. Quite frequently Dave Smith, now Regional Hydrologist for the NWS Pacific Region, was that disinterested passer-by. Paul Moore and Allen Cummings of SSD participated with the author in many helpful discussions concerning forecast composition. Of course, special thanks are due Jeter Pruett, MIC of the Fort Worth WSFO, and his staff for participating in the test of CAWF. Finally, the assistance of Russ Hovey, Central Headquarters Engineering Division, made possible the adaptation of CAWF to the time-share system.

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