ESSA WBTM WR 59

A UNITED STATES
DEPARTMENT OF
COMMERCE
PUBLICATION

ESSA Technical Memorandum WBTM WR 59

U.S. DEPARTMENT OF COMMERCE
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
Weather Bureau

Application of P. E. Model Forecast Parameters to Local-Area Forecasting

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Western Region

SALT LAKE CITY,
UTAH

October 1970

WESTERN REGION TECHNICAL MEMORANDA

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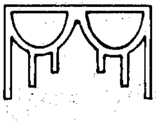

A western Indian symbol for rain. It also symbolizes man's dependence on weather and environment in the West.

U. S. DEPARTMENT OF COMMERCE
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
WEATHER BUREAU

Weather Bureau Technical Memorandum WR-59

APPLICATION OF P.E. MODEL FORECAST PARAMETERS TO LOCAL-AREA FORECASTING

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Western Region Headquarters

WESTERN REGION
TECHNICAL MEMORANDUM NO. 59

SALT LAKE CITY, UTAH
OCTOBER 1970

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PREFACE

The following paper with minor augmentation was presented at the 1970 AWS Meteorological Technical Exchange Conference held at the U. S. Naval Academy, September 21-24, 1970. This was the sixth such conference and was cosponsored this year by the U. S. Naval Weather Service and U. S. Air Force Air Weather Service.

Each conference has a central theme, and all papers are invited 30-minute presentations related to that theme. This year's theme was "Automation". The presentations are the personal opinions and ideas of the speaker and do not necessarily express the official policy of his employing agency.

Proceedings of the conference will be published within the next few months and will be distributed to most Western Region stations.

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APPLICATION OF P.E. MODEL FORECAST PARAMETERS TO LOCAL-AREA FORECASTING

I. INTRODUCTION

My approach to the subject of application of P.E. model forecast parameters in local-area forecasting will be to discuss the philosophy that is developing in operational use of dynamic predictions. Illustrations of current use of P.E. model products will also be given. During this discussion I hope to bring out the changing role of the meteorologist in local-area forecasting because there is no doubt in my mind that the forecast structure of the 1970s should be the man-machine mix. It is also important at this time that we emphasize the role of the forecaster because many forecasters are interpreting the considerable work being done in automation as efforts to eliminate their jobs rather than to help them do a better job. Unfortunately, this erroneous interpretation is affecting forecaster morale, and such work should really be improving morale.

Since evidence to date indicates that a completely automated local forecast is not in the foreseeable future, I suggest that our development efforts be directed toward projects that will help the forecaster provide better weather service to his users, rather than automating forecasting functions for automation's sake. I put the recent work of producing worded local forecasts by computer in this latter category [1].

There is considerable evidence to show that present local-area forecasting routines are closely tied to the P.E. model forecast output and that this tie is increasing. Over the past four years, operational forecasters have developed increased confidence in using NWP guidance to prepare their local forecasts. A large surge of this confidence came after the 6-layer P.E. model became operational in 1966. This confidence was earned by the model's excellent handling of routine as well as some difficult synoptic regimes such as the formation of the cut-off lows along the West Coast and certain types of deepening troughs. Furthermore, useful numerical forecasts of moisture and thermal parameters were made available for the first time. These were soon used both qualitatively and quantitatively in preparing precipitation and temperature forecasts.

Most operational forecasts are now so closely tied to P.E. model outputs that the accuracy of local forecasts rises and falls to a large extent with the accuracy of P.E. model prognoses. As Dr. Stackpole pointed out yesterday, the P.E. model was not quite as good in handling many important precipitation situations last winter as it was in the winter of 1968-69. Verification data show that this resulted in decreased accuracy of local forecasts too.

II. VERIFICATION COMPARISONS

Figure I shows the verification by threat score of the P.E. model measurable precipitation forecasts (so-called PEP forecasts) and the final NMC manual products based on this P.E. guidance. The higher the threat score the better the forecast. Note that the manual improvement over PEP is essentially constant and that it is in phase with the rise and fall of accuracy of the P.E. product.

Figure 2 shows the marked changes in the PEP forecasts from the winter 1968-69 to last winter [2,3]. The two charts on the left give the threat score as a function of geography. The stippled areas indicate threat scores of over 50, i.e., relatively good forecasts, and the cross-hatched areas locate scores of less than 20, or rather poor forecasts. Note that the good (stippled) areas decreased and the poor (cross-hatched) areas increased from 1968-69 to last winter. The charts on the right of the figure give the bias of the PEP forecasts. One hundred percent signifies no under- or overforecasting of the frequency of precipitation. The stippling shows areas where the PEP model forecast precipitation more frequently than was observed. Note how dry the 1969-70 P.E. model was east of the Rockies with most biases less than 60%.

The slip in accuracy of the P.E. model last winter also shows up in both local temperature and precipitation forecasts. Figure 3 shows the temperature forecast verification for October-March (winter) 1968-69 (solid line), and 1969-70 (dashed), for the Western Region of the Weather Bureau (8 most western states of contiguous 48 states). The periods refer to essentially 12-, 24-, and 36-hour forecasts of maximum and minimum temperatures. The right graph gives the verification of NMC forecasts. These NMC forecasts were man-machine mix products with the objective temperature-forecast guidance being the so-called Klein temperature [4]. The middle graph is the verification of Weather Bureau forecast office temperature predictions and the left graph shows the verification of locally prepared local forecasts. Note that these data show better performance in 1968-69 than last year. They also show that field offices considerably improved the guidance that they received from NMC.

Figure 4 is a similar verification of measurable precipitation forecasts using the threat score. The same things are evident although the improvement over NMC guidance by regional and local forecasts is much less. However, the best forecast for all three periods is still the locally prepared forecast.

Dr. Stackpole indicated that the slip in performance of the P.E. model probably resulted from changing the handling of moisture in the model. Of course part of the deterioration could have been the result of a recurrence of synoptic regimes last winter that are not well handled by the current P.E. model. Nonetheless, the close tie between local forecasts and P.E.-model forecasts suggests that changes in the model should be made only after careful, albeit limited, testing to be reasonably certain that there will be no deterioration in operational output. If we are to promote maximum utilization of P.E. products by operational forecasters, model changes must be made with more discretion in the future. This is in contrast to the situation that existed five years ago when model changes could be made without too much regard for the operational forecaster. In those days his final forecast output was not so closely tied to the NWP output as it is today.

II. USE OF P.E. MODEL OUTPUT

The present P.E. model output is used in essentially three ways in producing operational forecasts:

1) Directly. A few P.E. forecast parameters are given directly to the user. These are mostly upper-air parameters used by aviation interests. To my knowledge, there are no P.E. forecasts given directly to the public in local forecasts.

2) As Guidance. Some P.E. products are available in final user form but the forecaster uses them only as guidance in preparing his forecast. Examples are QPF, boundary-layer winds, etc. Probably the most useful form in which this P.E. forecast guidance reaches the field forecaster is in the so-called FOUS teletype bulletin, i.e., the 48-hour forecast of selected P.E. parameters printed out at 6-hourly intervals for about 100 cities.

3) As Forecast Aids. Some P.E. forecast parameters are used both qualitatively and quantitatively in preparing the local forecast; but in contrast to the uses just mentioned, the parameters are not explicitly a part of the final forecast. Examples are vertical motion, lifted-index, etc.

The general high quality of the forecast of these parameters has resulted in a significant increase over the past two years in the development and use of statistical studies that tie these P.E. forecast parameters to local weather conditions. Development of such studies is still in the ascendent and I think it will continue that way for many years.

The resulting local-area forecasting scheme that is evolving could be called a dynamic-statistical-manual scheme — a man-machine mix where the only manual input into the process is the local forecaster.

This means that local forecasters are looking to the P.E. model to provide the general meteorological prognosis and statistical studies, or as I prefer to call them conditional climatology studies, to refine the P.E. products to their particular local area. Therefore, our most productive use of P.E. data will be the dynamic-statistical approach, and we should probably judge the models in terms of its contribution to this type of forecast rather than the categorical indication of precipitation.

There is some controversy regarding the best technique to use in developing conditional climatologies when P.E. model forecast parameters are used. One approach is to develop the statistics using observed parameters, i.e., the perfect-prog technique. The other is to develop them using P.E. forecast parameters, i.e., the imperfect-prog technique. I lean toward the use of the perfect-prog technique, because the results of such studies improve as the P.E. forecasts are improved. In any case there are merits to both approaches, and we are encouraging the development of both types of studies. Appendix I gives some interesting ideas by Larry Hughes on the use of statistical studies.

III. EXAMPLES OF STATISTICAL STUDIES

At this point, it might be good to look at a few examples of these approaches now in operational use. Many forecasters are using P.E. mean relative humidity forecasts as input variables to their precipitation forecast studies. Figure 5 gives the start of a study for Astoria, Oregon, using 12- and 24-hour P.E. forecasts of relative humidity and vertical motion to get the probability of precipitation. The area above the heavy line indicates over 50% occurrence of precipitation [5].

Another example is this study (Figure 6) developed by the Southern Region of the Weather Bureau for stations in the southeastern part of the country. P.E. forecasts of relative humidity, vertical motion, and lifted index are related to frequencies of measurable precipitation occurrence within the next 6 hours.

An example of a perfect prog study is that which we have developed for our region using a set of 500-mb flow types and the conditional climatologies of measurable precipitation occurring at each of our stations [6]. By this technique we are trying to add objectively a measure of detail to the weather implications of the P.E. 500-mb forecast. Figure 7 shows the probability of precipitation over Western United States associated with this particular flow pattern. This program is now operational in that 500-mb P.E. initial, 12-, 24-, 36-, 48-, and 72-hour prognoses are typed by computer at NMC twice per day and the types are transmitted over teletype Service "C" for use by our forecasters. The end result is conditional climatological expectancies of precipitation for each 12-hour period of the 72-hour forecast for specific stations. Because the types are aimed at relating the probability of precipitation to the large-scale forecast flow, our next step in this study is to refine these probabilities using other P.E. forecast parameters within types. Since the history tape of the P.E. prognosis is used in the typing, we look for NMC to do the computer work, rather than doing it locally. I think most studies will eventually be based on P.E. forecast parameters and computed routinely at NMC with the end results sent to the field.

Another example of an operational dynamical-statistical program based on the perfect-prog technique is the so-called Klein max/min temperature forecasts. This is the temperature forecast guidance produced totally by machine using P.E. model forecast parameters in regression equations [4]. NMC now transmits these temperatures to the field twice daily via teletype and facsimile.

It is interesting to note that many field forecasters are much happier with this totally machine-produced guidance, than the previous man-machine mix temperature guidance that was transmitted. Forecasters prefer the machine output because they can learn and take into account the biases and systematic errors in objectively derived guidance for their particular area. When a centrally prepared man-machine mix product is used, the biases, etc., of the manual input are unknown. The success of P.E. model forecasts is resulting in forecasters giving less weight to NMC man-machine mix forecast guidance and more to purely machine products.

IV. PROBLEMS WITH COMPUTER FORECASTS

This is not to say that I am advocating machine-produced local-area forecasts--far from it. There are too many unacceptable aspects of a pure machine product of this type. For example:

> 1) Insensitivity. Insensitivity to critical values that may exist on a given day. For example, if fruit is in a certain stage of development, a temperature of 26 may be more significant than a temperature of 28. It is true that such critical temperatures could be put into a central computer program, but the local and changing character of such critical values makes this impractical. A man can do jobs of this type much better than a computer.
>
> A forecaster often takes the existing and recent past local weather into account in preparing and packaging his temperature and/or precipitation forecasts. The computer can't do this because significant local data will not usually be available. For example, he may

highlight or play down a changing trend after a rainy spell depending on the state of local rivers or farms.

Objective forecasts as well as centrally prepared man-machine mix products can change the forecast for a specific location significantly every 12 hours such that "yo-yo" forecasts result much more frequently than they do now. "yo-yo" forecasting is very disturbing to users and erodes confidence the user has in weather forecasts.

2) Time Lag. Computer-produced forecasts based on the P.E. model have a large lag time (over 6 hours after data time) before reception in the field. For example we don't get the 12-hour P.E. forecast until 6 hours of that 12-hour peroid have passed. Twice each day the only P.E. guidance available is 18 hours old!

3) Detailed Information Missing. It is difficult to see how important detailed information such as radar and GOES-type satellite observations can get into the computer in time to be incorporated into short-range (<18 hours) forecasts. Many important weather changes that require warnings are the result of rapidly developing situations.

4) Computer Failure. A big problem at times is missing NWP products due to computer failure. As models become more sophisticated and computers get bigger, the use of back-up will be more difficult.

5) Normal Input Data Missing. Missing input data can cause important forecast errors. Once a procedure is automated, the time period for accepting input data becomes very rigid. Should these data be only slightly delayed, they may not be used in the forecast computations.

A dramatic example of what can happen when there are data input problems occurred last May. Important input temperatures for the Klein temperature equations were missing causing serious forecast errors for several days. Table 1 shows 48 hours of this period. Note that Klein temperatures for New York City were consistently in error 10 to 20 degrees. See Appendix II for further explanation of the forecast failure.

Therefore, there is now and will continue to be a need for the machine product to be processed by man before giving it to the public. This manual massage can best be done by the local or regional forecaster rather than by a distant forecast central. The local forecaster is often in the best position to take into account shortcomings in the physics of the model that affect his area. History shows that in large scale at least, manual adjustments to the NWP forecasts are decreasing and the time is only a few years away when operational forecasters will be able to accept NWP upper-air flow prognoses without modification. I believe other P.E. outputs, however, will continue to be modified by forecasters applying known systematic errors or biases of the forecasts for their local areas. Modification by intuition is no longer acceptable. This may still be done on occasion but it is not justified. Explicit P.E. forecasts in user format can best be tailored to local uses locally. For example the NWP meteorological input to air-pollution forecasts, soil temperature forecasts, QPFs for water supply regulation need local adaptation, especially in western United States.

And lastly, the local forecaster can take into account the latest local data to improve the machine forecast, which may be based on data as much as 18 hours old. The importance of use of the latest data was indicated by Mr. Roberts' discussion [7].

V. EXAMPLES OF MANUAL MASSAGE

An example of the type of physical reasoning that can be done locally is illustrated in Figure 8. At times there are strong diurnal changes of relative humidity (RH) that the model doesn't take into account. The solid line is the observed mean 1000-500 mb RH; the broken lines are three consecutive P.E. FOUS forecasts. Note that the 00Z input data are low and remain low; the 1200Z input data are high and the forecasts in general remain high. This could cause quite different objectively determined probabilities of precipitation. However, a man knowing of this diurnal change would modify the machine forecast accordingly. Also since the trend of the FOUS forecasts are more useful than the absolute forecast values, the forecaster can easily consider these trends in his massaging of the machine product.

History shows that manual massage by local forecasters is justified with regard to temperatures. Table 2 shows two recent verifications which support this point.

During a two weeks' period last February, forecasters at 19 stations in the Weather Bureau's Southern Region, from Phoenix in the west to Atlanta and Miami in the east, improved on objective temperature forecasts by significant amounts. The left side of the table gives the mean forecast errors for both types of forecast. The right side of the table shows verification data for Missoula, Montana for last winter. The local forecasters, several of whom are meteorological technicians, through manual massage made significant improvements in both maximum and minimum temperature forecasts.

When discussing the need for manual override, there is one factor that must be considered, but which has never really been documented; namely, exactly what are the desired accuracies and lead times for the many forecasts which are issued? Obviously these will vary from place to place and with the season and type of weather. But it is difficult to know how or what to automate until the limits of the results are defined.

VI. SUMMARY

Operational forecasters are very much pleased with the substantial improvements in forecast accuracy over the last several years of P.E. model forecast guidance. However, many forecasters, like myself, are not very optimistic about significant breakthroughs in accuracy of machine products in the future even with the use of finer-mesh and global P.E. models. Rather it looks like slow steady progress for the next decade. Therefore I would like to revise the forecast of NWP improvement which I made at last year's conference [9], as shown in Figure 9. The dot-dash line is the original forecast and the dashed line the revision showing steady but much slower progress. Certainly finer mesh and global models should increase the accuracy of many parts of the P.E. model forecast output. However significant progress in forecasting such parameters as temperature and moisture in the detail needed will probably be much slower. As Russell Younkin, Chief of the Quantitative Precipitation Forecast Branch of NMC, and one of the most knowledgeable and capable precipitation forecaster in the country, pointed out in a recent consultant visit, *"We usually make a significant step forward when we first incorporate gross features of the atmosphere into dynamic models, but we run into trouble and progress is much slower when we start introducing details."* This certainly appears to have been the case when the P.E. model was modified from a single to multi-layered moisture model.

Therefore, the answer to the role of automation in production of local-area forecasts, at least for the next decade or so, seems to be through the use of dynamically forecast parameters used in conditional climatologies (statistical studies) to produce more specific guidance. This guidance can then be used to provide high quality local forecasts by manual adaptation. The statistical studies can be automated for operational use at either a central location like NMC or a regional forecast center or locally. Some type of computer link between the NMC computer and small regional center computer appears to be most desirable. Also, the use of such studies gets away from categorical forecasts of dynamic prediction and gives us forecast guidance in probabilistic terms if we want it. Figure 10 depicts this idea graphically.

I would like to close by strongly endorsing Captain Kotch's statements which said to me, *"Let's centralize the computer facilities and decentralize the manual effort. Let's transmit machine-produced meteorological products to the man on the forecast firing line for adaptation, packaging and deliver to the user."* [8] This type of man-machine mix will make the 1970s the golden decade for the operational forecaster. He will be close enough to the user to feel the pressure of his weather service needs, but so well supported by machine products that his productivity and job satisfaction will be increased and occasions of poor meteorological advice will be limited.

VII. ACKNOWLEDGMENTS

I gratefully acknowledge the generous response of my Weather Bureau colleagues, Dr. Ed Diemer, Alaskan Region; Mr. Ed Carlstead, Pacific Region; Mr. Carlos Dunn, Eastern Region; Mr. Larry Hughes, Central Region; and Mr. Paul Moore, Southern Region, to a request for their ideas on the subject of this paper.

I also appreciate the Weather Bureau's giving me the privilege of accepting the invitation to participate in this conference. However, the ideas expressed are my own, and should not be considered as Weather Bureau policy.

VIII. REFERENCES

[1] Glahn, H. R., "Computer-Produced Worded Forecasts". ESSA Technical Memorandum WBTM TDL 32, June 1970.

[2] Numerical Weather Prediction Activities, National Meteorological Center, First Half 1969, July 1969, pages 26-31.

[3] Numerical Weather Prediction Activities, National Meteorological Center, First Half 1970, July 1970, pages 25-29.

[4] Klein, W. H., Lewis, F., and Casely, G. P., "Automated Nationwide Forecasts of Maximum and Minimum Temperature", Journal of Applied Meteorology, Vol. 6, No. 2, April 1967, pages 216-228.

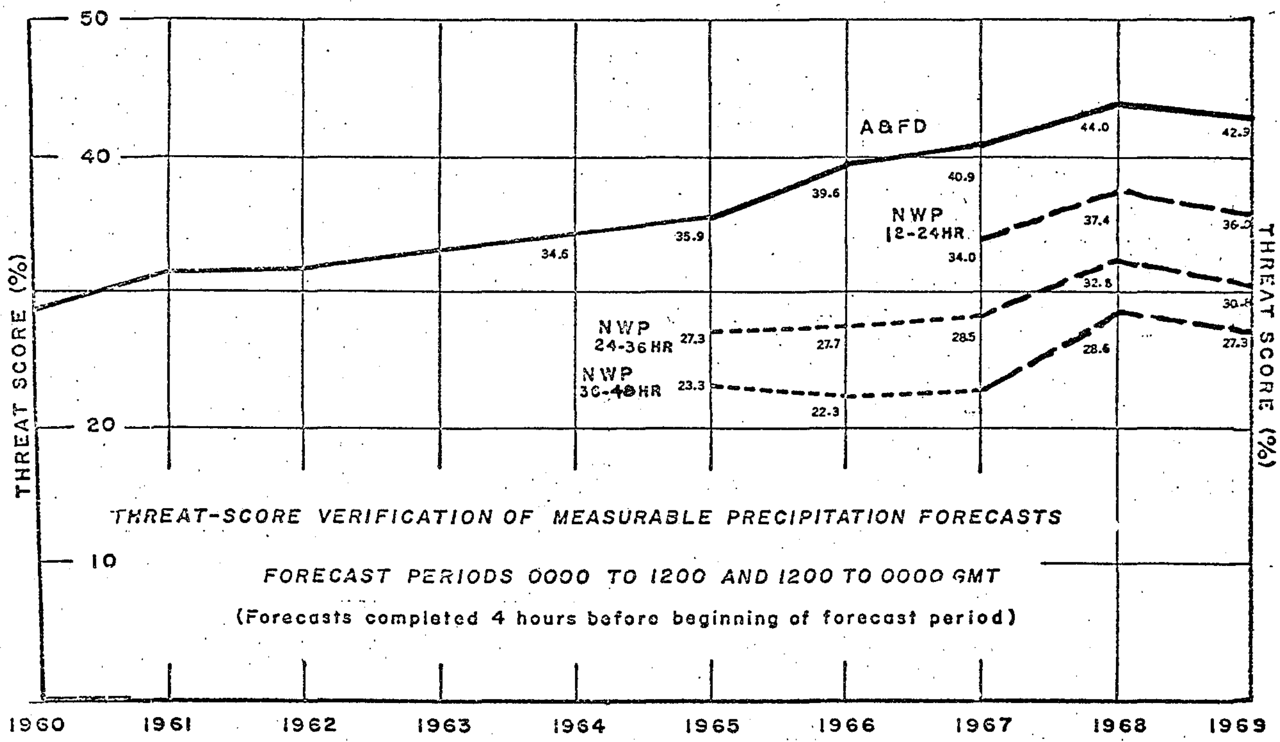
[5] Williams, P., "Objective Forecasts from P.E. Output", Western Regional Technical Attachment No. 70-11, March 24, 1970, (U. S. Weather Bureau Manuscript).

[6] Augulis, R. P., "Precipitation Probabilities in the Western Region Associated with 500-mb Map Types", ESSA Technical Memorandum WBTM WR 45, Parts 1, 2, 3, and 4, December 1969.

[7] Roberts, C. F., "Predictability of Local Area Weather". October 1970 (to be published).

[8] Kotsch, W. J., "Keynote Address for the 1970 Meteorological Technical Exchange Conference". October 1970 (to be published).

[9] Snellman, L. W., "Man-Machine Mix in Applied Weather Forecasting in the 1970s". ESSA Technical Memorandum WBTM WR-40, August 1969.



THREAT-SCORE VERIFICATION OF MEASURABLE PRECIPITATION FORECASTS

FORECAST PERIODS 0000 TO 1200 AND 1200 TO 0000 GMT

(Forecasts completed 4 hours before beginning of forecast period)

FIGURE 1. THREAT SCORE VERIFICATION OF MEASURABLE PRECIPITATION FORECASTS 1960 THROUGH 1969. A&FD CURVE REFERENCE TO SUBJECTIVE MAN-MACHINE MIX FORECAST PREPARED BY ANALYSIS AND FORECAST DIVISION OF NMC.

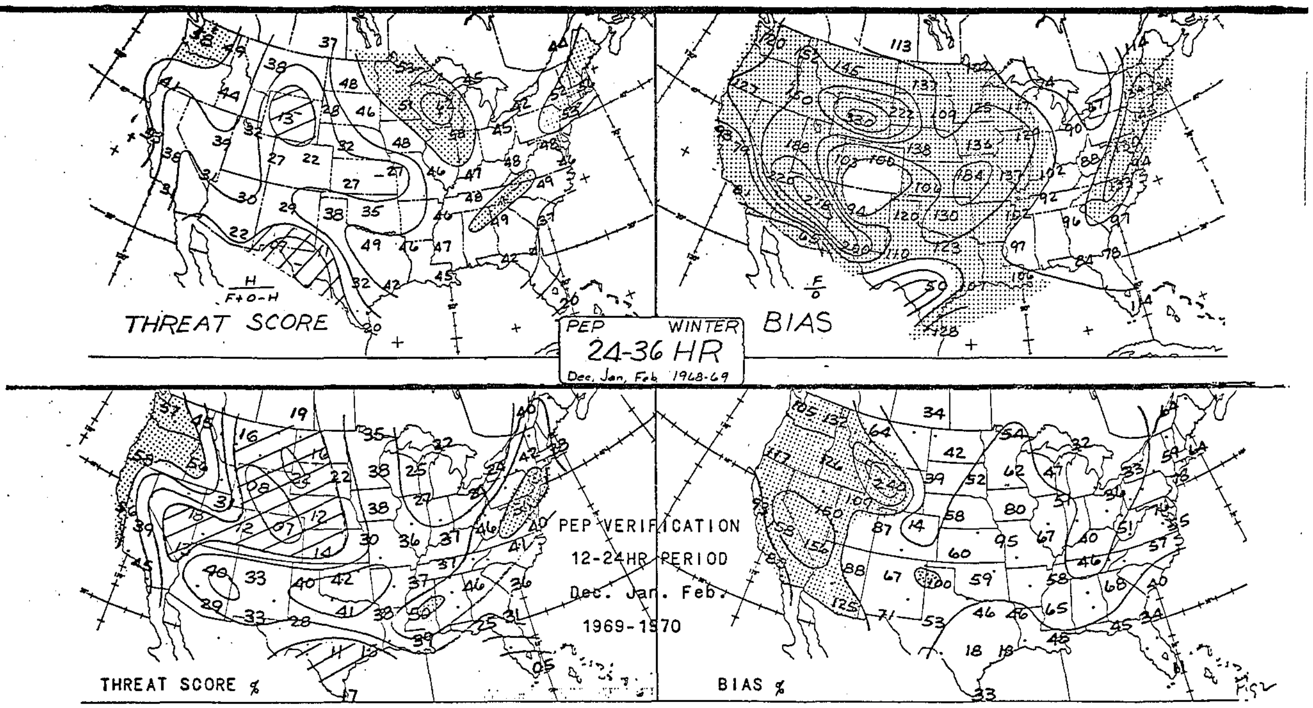


FIGURE 2. P.E. PRECIPITATION VERIFICATION FOR FORECASTS OF MEASURABLE PRECIPITATION (≥.01") FOR 1968-69 AND 1969-70 WINTER MONTHS (DEC., JAN., FEB.). THREAT SCORE IS:

$$\frac{\text{HITS}}{\text{FCST + OBS - HITS}} \times 100;$$ SCORES >50% ARE STIPPLED; SCORES <20% CROSS HATCHED.

BIAS IS $$\frac{\text{NO. OF FCST OCCURRENCES}}{\text{NO. OF OBSERVED EVENTS}} \times 100;$$ >100% IS STIPPLED.

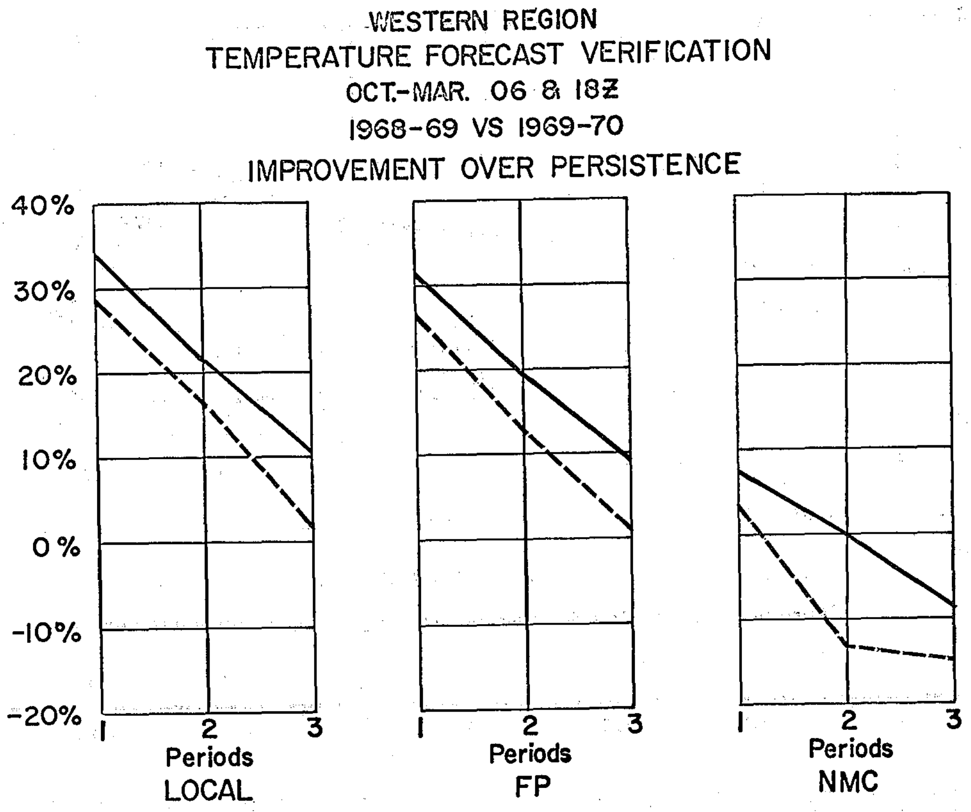


FIGURE 3. VERIFICATION OF WESTERN REGION LOCAL MAXIMUM AND MINIMUM 12-, 24-, AND 36-HOUR TEMPERATURE FORECAST AS IMPROVEMENT OVER 24-HOUR PERSISTENCE FOR 1968-69 (SOLID) AND 1969-70 (DASHED) WINTERS (OCTOBER-MARCH).

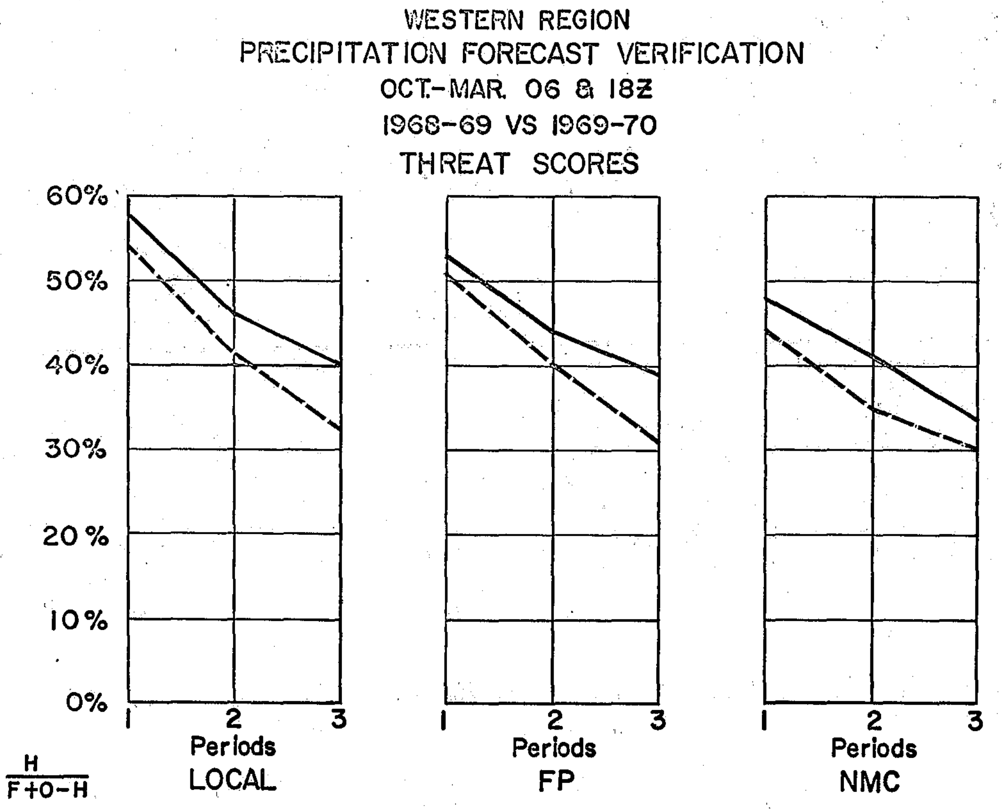


FIGURE 4. VERIFICATION OF WESTERN REGION 12-, 24-, AND 36-HOUR PRECIPITATION FORECASTS BY THREAT SCORE FOR 1968-69 (SOLID) AND 1969-70 (DASHED) WINTERS.

Relative Humidity

Vertical Velocity	< 70%	70% - 79%	80 - 94%	≥ 95%	Total
+2	$\frac{1}{1}$ = 100%		$\frac{29}{35}$ = 83%	$\frac{18}{18}$ = 100%	$\frac{48}{54}$ = 89%
+1.0 to +1.9	$\frac{1}{6}$ = 17%	$\frac{5}{10}$ = 50%	$\frac{34}{43}$ = 79%	$\frac{3}{3}$ = 100%	$\frac{43}{62}$ = 69%
0 to +0.9	$\frac{4}{26}$ = 15%	$\frac{5}{11}$ = 45%	$\frac{7}{11}$ = 64%	$\frac{1}{1}$ = 100%	$\frac{17}{49}$ = 35%
< 0	$\frac{1}{6}$ = 17%	$\frac{0}{2}$ = 0	$\frac{1}{1}$ = 100%		$\frac{2}{11}$ = 18%
Total	$\frac{7}{41}$ = 17%	$\frac{10}{23}$ = 43%	$\frac{71}{90\%}$ = 79%	$\frac{22}{22}$ = 100%	$\frac{110}{176}$ = 63%

	P.F.	P.A.	T.S.
RH and VV combined	.90	.81	.74
RH alone	.85	.83	.72
VV alone	.83	.79	.67

FIGURE 5. RELATIONSHIP OF RH AND VV TO OCCURRENCE OF PRECIPITATION AT ASTORIA, OREGON (12- TO 24-HOUR FORECAST).

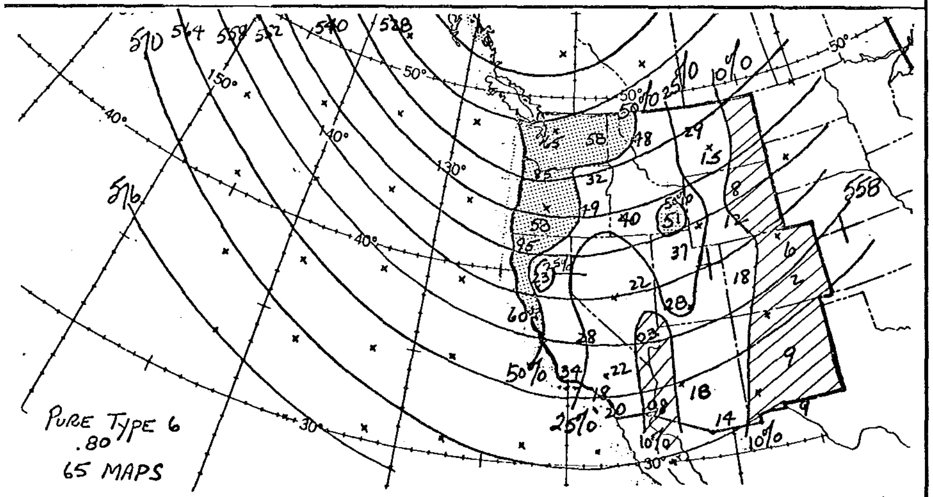


FIGURE 7. WESTERN REGION 500-MB WINTER TYPE MAP 6, WITH PROBABILITIES OF PRECIPITATION FOR 12-HOUR PERIOD AFTER MAP TIME. STIPPLING INDICATES PROBABILITIES ≥50%; CROSS HATCHING INDICATES <10%.

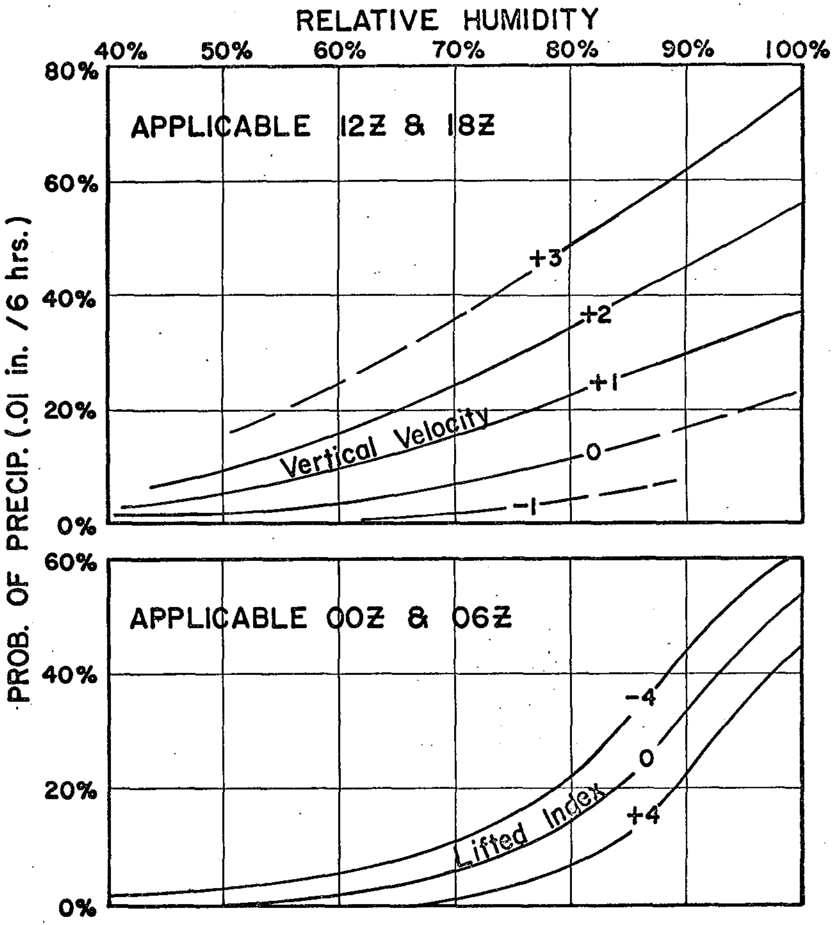


FIGURE 6. SOUTHERN REGION STATISTICAL FORECAST AID FOR SUMMER USING P.E. PARAMETERS AS INPUT. TOP GRAPH IS FOR PREDICTION OF PRECIPITATION OCCURRING IN [redacted] 6-HOUR PERIODS ENDING AT 1200Z AND 1800Z. BOTTOM GRAPH IS FOR THE 6-HOUR PERIODS ENDING 0000Z AND 0600Z.

DIURNAL RELATIVE HUMIDITY CHANGES

(Data from NAFAX NOS. 23 & 85 and Fous-2 Forecast Bulletins)

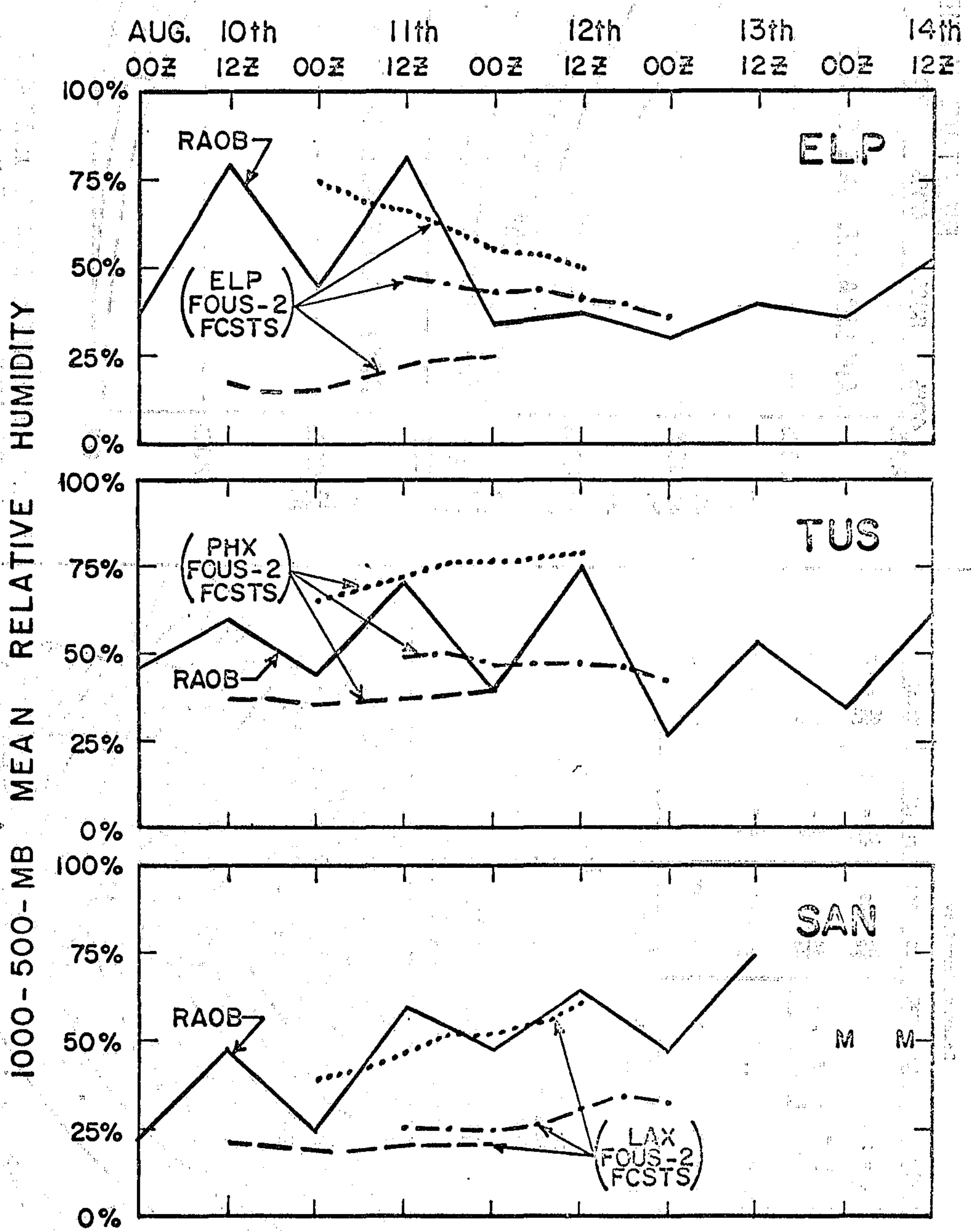


FIGURE 8. PLOT OF MEAN 1000-500 MB RELATIVE HUMIDITY FOR EL PASO (ELP), TEXAS; TUCSON (TUS), AND SAN DIEGO (SAN) AUGUST 11-14, 1970 AND RELATED FOUS-2 MEAN RELATIVE HUMIDITY FORECASTS FOR EL PASO, PHOENIX (PHX), ARIZONA, AND LOS ANGELES (LAX), CALIFORNIA. FOUS FORECAST STARTS WITH 12-HOUR FORECAST. FORECASTS BASED ON 0000Z P.E. FORECAST RUNS ARE DASH AND DOT-DASH LINES.

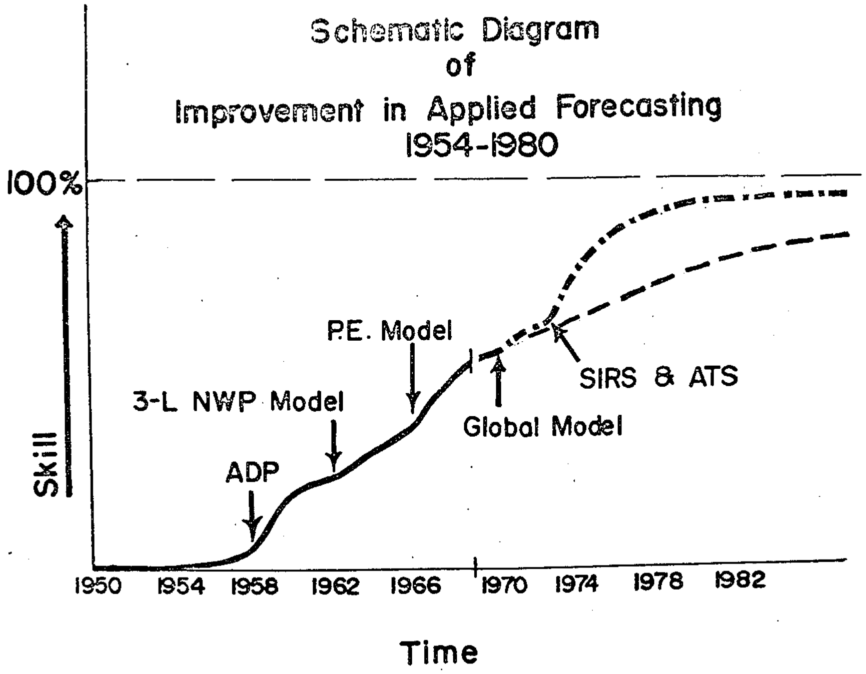


FIGURE 9. SCHEMATIC TREND OF IMPROVEMENT IN APPLIED FORECASTING, 1954-1982 REVISED. DASHED CURVE IS REVISION OF ORIGINAL FORECAST (DASH-DOT) FROM AWS TR 217, PAGE 162.

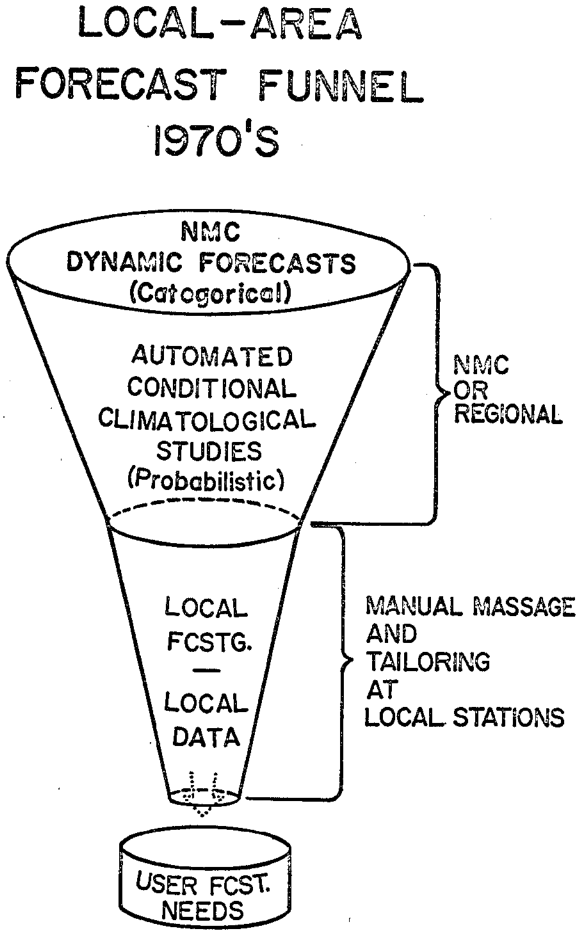


FIGURE 10. GRAPHICAL SUMMARY OF MACHINE-STATISTICAL-MANUAL SCHEME OF PREPARING LOCAL FORECASTS.

TABLE 1

NEW YORK CITY MAY 1970

INITIAL DATA	KLEIN FORECAST	OBSERVED MAX/MIN
May 8 00Z	66-48-68	72-56-90
May 8 12Z	48-69-50	56-90-70
May 9 00Z	73-52-69	90-70-93
May 9 12Z	52-69-52	70-93-69
May 10 00Z	73-56-74	93-69-88

TABLE 2

KLEIN TEMPERATURE FORECASTS

Avg. 24-Hr. Fcst. Errors (°F)
19 SR Stations
10-28 February 1970

	Max	Min
Obj.	5.3	5.8
Lcl.	3.5	3.6

Avg. 24-, 36-, 48-Hr. Fcst Errors (°F)
Missoula, Montana
December 1969 - February 1970

	Max-Min-Max	Min-Max-Min
Obj.	5.0 5.9 6.3	5.0 5.8 5.8
Lcl.	2.7 4.4 4.3	3.7 3.8 5.3

APPENDIX I

The following is excerpts from a Central Region Technical Attachment, "A Discourse On Objective Forecasting Schemes," February 1969:

> "An objective forecast scheme as used here means a statistical relationship derived from past events. An objective forecast scheme can serve a variety of purposes. It can provide instant experience, since any forecaster, regardless of his experience, gets the same result, and its design is usually based on experience and physical principles. It can provide understanding, since it will show the significance of the parameters chosen for examination. It can provide a quantitative result, such as the temperature or probability."

* * *

> "Let us say that you have made or obtained an objective scheme derived from PE products. How do you use such a scheme? That is, how do you decide to use the value given by the scheme rather than your own estimate, or vice versa? In many cases, there is no scientific way to make the decision, especially for a categorical forecast. This is a major weakness of objective schemes, and it could be a significant factor in schemes being put into disuse.
>
> "There are three ways to use a scheme in other than a chaotic way. One is to use the scheme 100% of the time (this will come more and more, and it is now here for some things--the 500-mb flow pattern); another way would be to compromise on every forecast (this is easy in probabilistic forecasts but not with categorical forecasts); a third way is to try some orderly modification method, such as that suggested below. It would seem that only by extensive verification data will one be able to tell which is the best method. The best method would depend on the quality of the forecaster and the scheme, and thus could vary among forecasters even using the same scheme; and it would vary with time if the scheme is undergoing continual improvement, such as could be the case with dynamical-statistical techniques if produced routinely."

* * *

> "...if we are to use an objective scheme based on complex models like the PE model, we need to show that the scheme can do at least as well as the forecaster on independent data. If it is better than the forecaster, he can use the scheme all the time for that element and shift his efforts to other elements of the forecast. However, if the scheme

is a probabilistic one, it may be possible for the forecaster to improve on it even if it can do better than he can by itself. Consider the following way of modifying an objective scheme:

1. The forecaster makes his own forecast before obtaining the result of the objective scheme.

2. When the objective scheme and the forecaster both have values on the same side of climatology (including the climatic value), use the higher (lower) if they are above (below) the climatic frequency.

3. When the scheme and the forecaster have values on opposite sides of the climatic frequency, use the average of the two forecasts or some other compromise.

"This system has the advantage of trying to maximize resolution, although possibly at the loss of some reliability. However, it is hoped that the scheme will be reliable for those cases when it is selected in preference to the forecaster's value, and that the unmodified forecasts remaining will still be reliable. Let us look at the validity of this desire.

"Let us assume that both the forecaster and the scheme are perfectly reliable by themselves (a fairly realistic assumption). Now take a group of forecasts placed in the same probability by the forecaster--say 40%. If the scheme is to be used according to the above rules, some of these 40% values will be shifted to a higher value, if the objective scheme is of value. After such a shift, we want the shifted set and all the remaining forecasts to still be reliable. That means that the set shifted upward must have a higher precipitation frequency than 40%, to be reliable. This also means that those forecasts remaining at 40% must have a lowered precipitation frequency--not be reliable--unless some cases are also shifted to lower probabilities as well.

"As to the set shifted upward. There is no way to be certain that it will be reliable. It would be if it were a random selection, but the extent to which it approaches randomness is unknown. The hope here is that the gain in resolution will more than offset any loss in reliability.

"If the climatic frequency is below 40%, step 3 is the way to get some of the 40% forecasts to lower probabilities and thus possibly keep the 40% set reliable, although the reliability of the set shifted downward is also unknown. This same procedure will apply to any probability value, so it would be possible for all systems to remain reliable throughout. Only verification can tell.

"Forecasters may have difficulty accepting step 2 above, as they would probably tend to compromise here as well as in step 3. However, there is no assurance that a compromise will yield a more reliable set, and it could reduce resolution. It certainly would reduce resolution if one had a near-perfect scheme. Thus, one should overcome the natural tendency to compromise in Step 2, especially when the difference between the scheme's and the forecaster's probability is large. Compromise or use of the forecaster's probability would be appropriate only when the input data to the scheme can be conclusively shown to be significantly in error, and this is difficult to ascertain in most cases.

"As far as step 3 is concerned, compromise may not be the best course of action all the time, for the same reason as above. If there are large differences, it should alert the forecaster to the possibility that he overlooked something in his forecast preparation. On the other hand, if there is a good probability that the PE progs (or other base for the scheme) are wrong in a known way, its probability should be changed accordingly.

"The above system says something about the quality of an objective scheme that is to see continued use. It must be able to predict the high and low values a reasonable number of times when the forecaster is not so extreme in his forecasts. This probably means that the system needs to be able to score as well or better than the forecaster on independent data. In addition, and probably necessary to the above, the scheme most likely will have about the same or more cases in the high and low values than the forecaster."

* * *

"In SUMMARY, we believe that we are now entering the age when regionalized objective schemes, created on a central computer with development data taken from the prog material of dynamical or statistical numerical models, and with a probabilistic output based on past occurrences, are the final product of numerical models. We also feel that the probability concept will be extended into other aspects of our forecast output, especially to the extent of defining the probabilistic threshold of categorical forecasts, e.g., warnings, so the forecaster will know what sort of precision is desired, and so more uniformity in the decision to issue is achieved. The concept of the watch preceding the warning is a step in this direction. Finally, once a good objective probability scheme is available, it probably should be used in the manner discussed above."

APPENDIX II

The following explanation of the large errors in the Klein maximum and minimum temperature forecasts for New York City during the period May 8-11, 1970 was given by Mr. Gordon A Hammons of the Techniques Development Laboratory of Weather Bureau Headquarters:

> "Study of the observed and forecast temperature data during the period in question indicates that the large forecast errors are mainly due to missing computer runs, missing reports from New York City, and a large temperature increase in the same time interval.
>
> "There were three cases when no computer run was made: 12Z/9th, 12Z/11th and 00Z/12th. In addition to the missing runs, the NYC observation was missing on 12Z/8th and on 12Z/12th. So, in this four-day period, there were five cases out of ten in which the latest min was not available to the system.
>
> "The May-June equations for New York City use the min temperature as a predictor for both the max and min forecast. The weight on this term is .44 for the min forecast and .88 for the max forecast. The large weights on the NYC min term will give a tendency to forecast persistence. Now, during the period in question, the temperatures warmed up considerably. The max went from the 60s to around 90, and the mins had about ten-degree increase.
>
> "It seems that the problem is a combination of a large temperature change at a time when runs were missed and reports were missing. The result is that, in these cases, the most current min was not used in an equation in which the min is an important factor. The unfortunate part is that the field does not know when a guess is used instead of a report. However, in the case of a backup transmission, NYC should be made aware of the hazards of using the backup transmission if the air mass at NYC has just changed."

(Above information extracted from the Technical Attachment to the Weather Bureau's Eastern Region Staff Minutes dated July 6, 1970.)

Western Region Technical Memoranda: (Continued)

No. 28** Weather Extremes. R. J. Schmidli. April 1968. (PB-178 928)
No. 29 Small-Scale Analysis and Prediction. Philip Williams, Jr. May 1968. (PB-178 425)
No. 30 Numerical Weather Prediction and Synoptic Meteorology. Capt. Thomas D. Murphy, U.S.A.F. May 1968. (AD-673 365)
No. 31* Precipitation Detection Probabilities by Salt Lake ARTC Radars. Robert K. Belesky. July 1968. (PB-179 084)
No. 32 Probability Forecasting in the Portland Fire Weather District. Harold S. Ayer. July 1968. (PB-179 289)
No. 33 Objective Forecasting. Philip Williams, Jr. August 1968. (AD-680 425)
No. 34 The WSR-57 Radar Program at Missoula, Montana. R. Granger. October 1968. (PB-180 292)
No. 35** Joint ESSA/FAA ARTC Radar Weather Surveillance Program. Herbert P. Benner and DeVon B. Smith. December 1968. (AD-681 857)
No. 36* Temperature Trends in Sacramento--Another Heat Island. Anthony D. Lentini. February 1969. (PB0183 055)
No. 37 Disposal of Logging Residues Without Damage to Air Quality. Owen P. Cramer. March 1969. (PB-183 057)
No. 38 Climate of Phoenix, Arizona. R. J. Schmidli, P. C. Kangieser, and R. S. Ingram. April 1969. (PB-184 295)
No. 39 Upper-Air Lows Over Northwestern United States. A. L. Jacobson. April 1969. (PB-184 296)
No. 40 The Man-Machine Mix in Applied Weather Forecasting in the 1970s. L. W. Snellman. August 1969. (PB-185 068)
No. 41 High Resolution Radiosonde Observations. W. W. Johnson. August 1969. (PB-185 673)
No. 42 Analysis of the Southern California Santa Ana of January 15-17, 1966. Barry B. Aronovitch. August 1969. (PB-185 670)
No. 43 Forecasting Maximum Temperatures at Helena, Montana. David E. Olsen. October 1969. (PB-185 762)
No. 44* Estimated Return Periods for Short-Duration Precipitation in Arizona. Paul C. Kangieser. October 1969. (PB-187 763)
No. 45/1 Precipitation Probabilities in the Western Region Associated with Winter 500-mb Map Types. Richard P. Augulis. December 1969. (PB-188 248)
No. 45/2 Precipitation Probabilities in the Western Region Associated with Spring 500-mb Map Types. Richard P. Augulis. January 1970. (PB-189 434)
No. 45/3 Precipitation Probabilities in the Western Region Associated with Summer 500-mb Map Types. Richard P. Augulis. January 1970. (PB-189 414)
No. 45/4 Precipitation Probabilities in the Western Region Associated with Fall 500-mb Map Types. Richard P. Augulis. January 1970. (PB-189 435)
No. 46 Applications of the Net Radiometer to Short-Range Fog and Stratus Forecasting at Eugene, Oregon. L. Yee and E. Bates. December 1969. (PB-190 476)
No. 47 Statistical Analysis as a Flood Routing Tool. Robert J. C. Burnash. December 1969. (PB-188 744)
No. 48 Tsunami. Richard P. Augulis. February 1970. (PB-190 157)
No. 49 Predicting Precipitation Type. Robert J. C. Burnash and Floyd E. Hug. March 1970. (PB-190 962)
No. 50 Statistical Report of Aeroallergens (Pollens and Molds) Fort Huachuca, Arizona 1969. Wayne S. Johnson. April 1970. (PB-191 743)
No. 51 Western Region Sea State and Surf Forecaster's Manual. Gordon C. Shields and Gerald B. Burdwell. July 1970. (PB-193 102)
No. 52 Sacramento Weather Radar Climatology. R. G. Pappas and C. M. Veliquette. July 1970. (PB-193 347)
No. 53 Experimental Air Quality Forecasts in the Sacramento Valley. Norman S. Benes. August 1970. (PB-194 128)
No. 54 A Refinement of the Vorticity Field to Delineate Areas of Significant Precipitation. Barry B. Aronovitch. August 1970.
No. 55 Application of the SSARR Model to a Basin Without Discharge Record. Vail Schermerhorn and Donald W. Kuehl. August 1970. (PB-194 394)
No. 56 Areal Coverage of Precipitation in Northwestern Utah. Philip Williams, Jr. and Werner J. Heck. September 1970. (PB-194 389)
No. 57 Preliminary Report on Agricultural Field Burning vs. Atmospheric Visibility in the Willamette Valley of Oregon. Earl M. Bates and David O. Chilcote. September 1970.
No. 58 Air Pollution by Jet Aircraft at Seattle-Tacoma Airport. Wallace R. Donaldson. October 1970.

* Out of Print
**Revised