UNITED STATES DEPARTMENT OF COMMERCE PUBLICATION

NOAA Technical Memorandum NWS ER -49

U. S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service

A PROCEDURE FOR IMPROVING NATIONAL METEOROLOGICAL CENTER OBJECTIVE PRECIPITATION FORECASTS.

Joseph A. Ronco, Jr.

Eastern Region
Garden City, NY

November 1972

NOAA TECHNICAL MEMORANDA
National Weather Service, Eastern Region Subseries

The National Weather Service Eastern Region (ER) Subseries provides an informal medium for the documentation and quick dissemination of results not appropriate, or not yet ready, for formal publication. The series is used to report on work in progress, to describe technical procedures and practices, or to relate progress to a limited audience. These Technical Memoranda will report on investigations devoted primarily to regional and local problems of interest mainly to ER personnel, and hence will not be widely distributed.

Papers 1 to 22 are in the former series, ESSA Technical Memoranda, Eastern Region Technical Memoranda (ERTM); papers 23 to 37 are in the former series, ESSA Technical Memoranda, Weather Bureau Technical Memoranda (WBTM). Beginning with 38, the papers are now part of the series, NOAA Technical Memoranda NWS.

Papers 1 to 22 are available from the National Weather Service Eastern Region, Scientific Services Division, 585 Stewart Avenue, Garden City, N.Y. 11530. Beginning with 23, the papers are available from the National Technical Information Service, U.S. Department of Commerce, Sills Bldg., 5285 Port Royal Road, Springfield, Va. 22151. Price: $3.00 paper copy; $0.95 microfilm. Order by accession number shown in parentheses at end of each entry.

ESSA Technical Memoranda

ERTM 1 Local Uses of Vorticity Prognoses in Weather Prediction. Carlos R. Dunn. April 1965

ERTM 2 Application of the Barotropic Vorticity Prognostic Field to the Surface Forecast Problem. Silvio G. Simplicio. July 1965

ERTM 3 A Technique for Deriving an Objective Precipitation Forecast Scheme for Columbus, Ohio. Robert Kuessner. September 1965

ERTM 4 Stepwise Procedures for Developing Objective Aids for Forecasting the Probability of Precipitation. Carlos R. Dunn. November 1965

ERTM 5 A Comparative Verification of 300 mb. Winds and Temperatures Based on NMC Computer Products Before and After Manual Processing. Silvio G. Simplicio. March 1966

ERTM 6 Evaluation of OFDEV Technical Note No. 17. Richard M. DeAngelis. March 1966

ERTM 7 Verification of Probability Forecasts at Hartford, Connecticut, for the Period 1963-1965. Robert B. Wassall. March 1966

ERTM 8 Forest-Fire Pollution Episode in West Virginia November 8-12, 1964. Robert O. Weedfall. April 1966

ERTM 9 The Utilization of Radar in Meso-Scale Synoptic Analysis and Forecasting. Jerry D. Hill. March 1966

ERTM 10 Preliminary Evaluation of Probability of Precipitation Experiment. Carlos R. Dunn. May 1966

ERTM 11 Final Report. A Comparative Verification of 300 mb. Winds and Temperatures Based on NMC Computer Products Before and After Manual Processing. Silvio G. Simplicio. May 1966

ERTM 12 Summary of Scientific Services Division Development Work in Sub-Synoptic Scale Analysis and Prediction - Fiscal Year 1966. Fred L. Zuckerberg. July 1966

ERTM 13 A Survey of the Role of Non-Adiabatic Heating and Cooling in Relation to the Development of Mid-Latitude Synoptic Systems. Constantine Zois. July 1966

ERTM 14 The Forecasting of Extratropical Onshore Gales at the Virginia Capes. Glen V. Sachse. August 1966

ERTM 15 Solar Radiation and Clover Temperature. Alex J. Kish. September 1966

ERTM 16 The Effects of Dams, Reservoirs and Levees on River Forecasting. Richard M. Greening. September 1966

ERTM 17 Use of Reflectivity Measurements and Reflectivity Profiles for Determining Severe Storms. Robert E. Hamilton. October 1966

ERTM 18 Procedure for Developing a Nomograph for Use in Forecasting Phenological Events from Growing Degree Days. John C. Purvis and Milton Brown. December 1966

ERTM 19 Snowfall Statistics for Williamsport, Pa. Jack Hummel. January 1967

ERTM 20 Forecasting Maturity Date of Snap Beans in South Carolina. Alex J. Kish. March 1967

ERTM 21 New England Coastal Fog. Richard Fay. April 1967

ERTM 22 Rainfall Probability at Five Stations Near Pickens, South Carolina, 1957-1963. John C. Purvis. April 1967

WBTM ER 23 A Study of the Effect of Sea Surface Temperature on the Areal Distribution of Radar Detected Precipitation Over the South Carolina Coastal Waters. Edward Paquet. June 1967 (PB-180-612)

WBTM ER 24 An Example of Radar as a Tool in Forecasting Tidal Flooding. Edward P. Johnson. August 1967 (PB-180-613)

WBTM ER 25 Average Mixing Depths and Transport Wind Speeds over Eastern United States in 1965. Marvin E. Miller. August 1967 (PB-180-614)

WBTM ER 26 The Sleet Bright Band. Donald Marier. October 1967 (PB-180-615)

WBTM ER 27 A Study of Areas of Maximum Echo Tops in the Washington, D.C. Area During the Spring and Fall Months. Marie D. Fellechner. April 1968 (PB-179-339)

WBTM ER 28 Washington Metropolitan Area Precipitation and Temperature Patterns. C. A. Woollum and N. L. Canfield. June 1968 (PB-179-340)

WBTM ER 29 Climatological Regime of Rainfall Associated with Hurricanes after Landfall. Robert W. Schoner. June 1968 (PB-179-341)

WBTM ER 30 Monthly Precipitation - Amount Probabilities for Selected Stations in Virginia. M. H. Bailey. June 1968 (PB-179-342)

WBTM ER 31 A Study of the Areal Distribution of Radar Detected Precipitation at Charleston, S. C. S. K. Parrish and M. A. Lopez. October 1968 (PB-180-480)

WBTM ER 32 The Meteorological and Hydrological Aspects of the May 1968 New Jersey Floods. Albert S. Kachic and William Long. February 1969 (Revised July 1970) (PB-194-222)

WBTM ER 33 A Climatology of Weather that Affects Prescribed Burning Operations at Columbia, South Carolina. S. E. Wasserman and J. D. Kanupp. December 1968 (COM-71-00194)

WBTM ER 34 A Review of Use of Radar in Detection of Tornadoes and Hail. R. E. Hamilton. December 1969 (PB-188-315)

WBTM ER 35 Objective Forecasts of Precipitation Using PE Model Output. Stanley E. Wasserman. July 1970 (PB-193-378)

WBTM ER 36 Summary of Radar Echoes in 1967 Near Buffalo, N.Y. Richard K. Sheffield. September 1970 (COM-71-00310)

WBTM ER 37 Objective Mesoscale Temperature Forecasts. Joseph P. Sobel. September 1970. (COM-71-0074)

NOAA Technical Memoranda NWS

NWS ER 38 Use of Primitive Equation Model Output to Forecast Winter Precipitation in the Northeast Coastal Sections of the United States. Stanley E. Wasserman and Harvey Rosenblum. December 1970 (COM-71-00138)

NWS ER 39 A Preliminary Climatology of Air Quality in Ohio. Marvin E. Miller. January 1971 (COM-71-00204)

(Continued On Inside Rear Cover)

UNITED STATES DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE EASTERN REGION
Garden City, New York

NOAA TECHNICAL MEMORANDUM NWS ER-49

A PROCEDURE FOR IMPROVING NATIONAL METEOROLOGICAL CENTER OBJECTIVE PRECIPITATION FORECASTS

Joseph A. Ronco, Jr.
WSFO Portland, Maine

SCIENTIFIC SERVICES DIVISION
Eastern Region Headquarters
November 1972

A PROCEDURE FOR IMPROVING NATIONAL METEOROLOGICAL CENTER OBJECTIVE PRECIPITATION FORECASTS

ABSTRACT

The National Meteorological Center's Limited-Area Fine-Mesh Model (LFM) predictions of precipitation are found to be skillful in northern New England. A technique is presented for using 12 to 24-hour LFM predictions of precipitation to modify precipitation probability forecasts prepared at the National Meteorological Center from Primitive Equation and Trajectory Model Output Statistics (PEATMOS).

INTRODUCTION

The Techniques Development Laboratory of the National Weather Service has developed a statistical method of using Primitive Equation and Trajectory Model Output Statistics (PEATMOS) for objectively determining the probability of precipitation (PoP)(1). Verification figures have shown these PEATMOS PoP forecasts to be competitive with the subjectively determined PoP forecasts formerly made at the National Meteorological Center (NMC). In January 1972, the PEATMOS PoP guidance replaced the NMC subjective PoP guidance.

The field forecaster could improve upon the PEATMOS PoP guidance forecasts if he could find some other skillful predictor of precipitation not already considered in the development of the PEATMOS PoP equations. In a number of Eastern Region Technical Attachments to the Staff Notes (2), (3), (4), it was shown that the Limited-Area Fine-Mesh Model (LFM) is skillful in predicting the occurrence of precipitation. This suggested a project to examine the feasibility of using LFM quantitative precipitation forecasts (QPF) to modify the PEATMOS PoP guidance issued from NMC.

PROCEDURE

The relative frequency of measurable precipitation ($\geq$ .01 inch) was determined for cases with similar PEATMOS PoP values; for cases within a specified range of LFM QPF, and for cases with similar PEATMOS PoP values stratified further according to LFM QPF. The PEATMOS PoP and LFM QPF were obtained from facsimile maps. These forecasts were for a 12-hour period ending 24 hours after the time of initial data used to prepare the forecasts. This 12-hour period is identical to the first 12 hours covered in the public weather forecasts released near 5 a.m. and 5 p.m. local time. Forecasts and observations valid for the 12-hour night period 0000Z to 1200Z were evaluated together with forecasts and observations valid for the 12-hour day period 1200Z to 0000Z. This combining of data could mask out any diurnal effects that may exist, but a preliminary evaluation of the data indicates that diurnal variations are small.

Combined data for six stations located in New Hampshire and Maine were used to preserve geographic homogeneity and at the same time yield sufficient cases from which to arrive at conclusions. The six stations chosen were Concord, New Hampshire; and Portland, Rumford, Bangor, Eastport and Caribou, Maine.

Dependent data were initially for the period April 20, 1972, to July 31, 1972. A test was conducted on independent data for August and September 1972. All the data were then combined for the period April 20, 1972 through September 30, 1972 to arrive at a final procedure for modifying the PEATMOS PoP.

RESULTS

Table 1 presents results for the initial dependent data period of April 20, 1972 to July 31, 1972. LFM QPF and PEATMOS PoP were each independently well related to the frequency of occurrence of measurable precipitation. PEATMOS PoP without stratification for LFM QPF performed well in the low range of 0% to 30% and also in the high range of 80% or greater. In the middle range of 40% to 70%, however, the PEATMOS PoP values were too high and had poor reliability. When it forecast no precipitation, the LFM was correct in 88% of 714 cases (Table 1, bottom line). Measurable precipitation occurred in 66% of 220 cases when the LFM QPF was in the range .01 to .49 inches and, most interesting, measurable precipitation occurred in all 38 cases in which the LFM forecast .50 inches or more.

What improvement can be made to PEATMOS PoP if we consider the LFM QPF as an additional predictor? First, note in Table 1 that for all PEATMOS PoP values the frequency of precipitation increases with increasing values of LFM QPF. The PEATMOS PoP can be changed by only 10% or less when it is in the low range of 0% to 30% and the LFM QPF is equal to zero. Note that the LFM QPF is generally zero when the PEATMOS PoP is $\leq$ 30%. Little improvement is also possible for PEATMOS PoP in the high range of $\geq$ 50% when the LFM QPF is between .01 and .49 inches. For all other combinations of PEATMOS PoP and LFM QPF, we find that the PEATMOS PoP values should be lowered when the LFM QPF is zero, should be raised when the LFM QPF is between .01 and .49 inches, and should be raised significantly to 100% when the LFM QPF is $\geq$ .50 inches. The only area where the data does not support these generalizations is with PEATMOS PoP 60% and LFM QPF between .01 and .49 inches. This disagreement

is considered to be a function of the small data sample, and for a larger data sample this disagreement probably would not exist. Table 2 presents a modified PoP as a function of the original PEATMOS PoP and LFM QPF. Some subjectivity was necessary in developing Table 2 from the data presented in Table 1, especially where little or no data were available.

The modified PoP was tested and compared to unmodified PEATMOS PoP using the dependent data and then later the independent data for the months of August and September 1972 (Table 3). The results were quite good. On independent data the modified PoP had a 29% improvement in Brier score over the PEATMOS PoP and a 22% improvement over the 0.088 Brier score determined for PoP forecasts that were actually released to the public by forecasters on those days when the modified PoP was available but not necessarily referred to by the forecasters. The PoP forecasts were converted into categorical forecasts and verified (Table 3). A PoP of $\geq$ 50% was treated as a categorical forecast of precipitation and a PoP of $\leq$ 40% was considered as a categorical forecast of no precipitation. Regardless of the score used, the modified PoP was superior to PEATMOS PoP. For instance, the modified PoP led to categorical forecasts that were correct 10% more often than the PEATMOS PoP.

The independent data were combined with the dependent data to produce a larger data sample that could then be used to modify the results presented in Tables 1 and 2. Table 4 is the relative frequency of observed measurable precipitation as a function of PEATMOS PoP and LFM QPF for the period April 20, 1972 to September 30, 1972. Table 5 gives the modified PoPs as a function of PEATMOS PoP and LFM QPF, and is based on results presented in Table 4. The results obtained for the entire period, April 20, 1972 to September 30, 1972 (Tables 4 and 5) were not much different than the results obtained for the shorter period, April 20, 1972 to July 31, 1972 (Tables 1 and 2). Statistics in Table 6 show the skill of the unmodified PEATMOS PoP compared to the PoP modified using LFM QPF and Table 5 for the larger dependent data sample period of April 20, 1972 to September 30, 1972.

CONCLUSION

This study has developed a technique for improving precipitation forecasts by objectively using LFM 12 to 24-hour QPF to modify PEATMOS PoP. It is a pilot study which found a predictor that possessed independent information and improved upon the PEATMOS PoP. Even though the sample is small and for a particular area and season, it clearly points the way toward further studies. There is no a priori reason why this approach shouldn't show skill for other areas and seasons. The major contribution of the LFM QPF is in improving the resolution of the PEATMOS PoPs. Because numerical models and the PEATMOS PoP equations change and because the sample used in this study is small, the modified PoP should be continually verified to assure that they remain superior to the PEATMOS PoPs.

PEATMOS PoP	Without Stratification For LFM QPF	With Stratification for LFM QPF: LFM QPF = 0	LFM QPF .01" to .49"	LFM QPF ≥ .50"
0%	.02(2/128)	.02(2/128)	X	X
10%	.04(7/182)	.03(6/180)	.50(1/2)	X
20%	.16(23/146)	.14(21/141)	.40(2/5)	X
30%	.26(25/99)	.22(18/82)	.43(6/14)	1.00(1/1)
40%	.30(37/124)	.16(14/90)	.67(22/33)	1.00(1/1)
50%	.32(7/54)	.22(8/36)	.44(7/16)	1.00(2/2)
60%	.30(15/50)	.15(4/26)	.38(8/21)	1.00(3/3)
70%	.52(26/50)	.15(2/13)	.63(22/35)	1.00(2/2)
80%	.78(60/77)	.59(10/17)	.79(37/47)	1.00(13/13)
90%	.89(57/64)	.00(0/1)	.87(41/47)	1.00(16/16)
100%	X	X	X	X
All Cases	.28(269/972)	.12(85/714)	.66(146/220)	1.00(38/38)

Relative Frequency of Precipitation

Table 1. *Relative frequency of observed measurable precipitation as a function of PEATMOS PoP and LFM QPF. Results are for the period April 20 - July 31, 1972. Numbers in parenthesis are number of precipitation cases over total cases. X indicates no cases.*

PEATMOS PoP	PEATMOS PoP Modified for LFM QPF LFM QPF = 0	 LFM QPF .01" to 49"	 LFM QPF ≥ 50"
0%	0%	30%	100%
10%	0%	40%	100%
20%	10%	50%	100%
30%	20%	60%	100%
40%	20%	60%	100%
50%	20%	60%	100%
60%	20%	60%	100%
70%	20%	70%	100%
80%	60%	80%	100%
90%	60%	90%	100%
100%	60%	100%	100%

Table 2. *Modified PoP as a function of PEATMOS PoP and LFM QPF. Period of data sample is April 20 to July 31, 1972.*

Scores	PEATMOS PoP		MODIFIED PoP	
	Dependent Data	Independent Data	Dependent Data	Independent Data
Brier Score	0.141	0.097	0.110	0.069
Bias	1.1	1.1	1.0	1.0
Prefigurance	0.65	0.56	0.72	0.72
Post Agreement	0.59	0.53	0.70	0.72
Threat Score	0.45	0.37	0.55	0.56
Percent Correct	78%	86%	84%	92%
Number of Cases	972	638	972	638

Table 3. *Comparison of skill of PEATMOS PoP and modified PoP forecasts for the dependent (April 20 - July 31, 1972) and independent (August 1 - September 30, 1972) data periods.*

Definitions of scores are as follows:

Brier Score $1/N[\sum_{1}^{N}(F-O)^2]$ *F = Forecast Probability for each case.*
O = 1 (Rain) or 0 (No Rain) observed for each case.
N = Total number of cases.

Bias $\frac{\text{Number of precipitation forecasts}}{\text{Number of precipitation cases}}$

Prefigurance *Fraction of Precipitation cases correctly forecast.*

Post Agreement *Fraction of Precipitation forecasts which were correct.*

Threat Score *Fraction of "expected" and observed precipitation cases which were correctly forecast.*

Percent Correct $100\% \times \frac{\text{Number of correct forecasts}}{\text{Number of forecasts}}$

PEATMOS PoP	Relative Frequency of Precipitation: Without Stratification For LFM QPF	With Stratification for LFM QPF: LFM QPF = 0	LFM QPF .01" to .49"	LFM QPF ≥ .50"
0%	.01(2/296)	.01(2/296)	X	X
10%	.04(14/359)	.03(10/352)	.57(4/7)	X
20%	.15(35/239)	.12(28/227)	.58(7/12)	X
30%	.23(33/144)	.18(22/121)	.45(10/22)	1.00(1/1)
40%	.33(55/167)	.18(22/119)	.67(31/46)	1.00(2/2)
50%	.33(30/90)	.18(10/55)	.53(17/32)	1.00(3/3)
60%	.34(23/68)	.12(4/34)	.48(14/29)	1.00(5/5)
70%	.46(31/67)	.14(3/22)	.59(25/42)	1.00(3/3)
80%	.79(79/101)	.55(11/20)	.80(52/65)	1.00(16/16)
90%	.89(70/79)	.00(0/2)	.88(50/57)	1.00(20/20)
100%	X	X	X	X
All Cases	.23(372/1610)	.09(112/1208)	.67(210/312)	1.00(50/50)

Table 4. *Relative frequency of observed measurable precipitation as a function of PEATMOS PoP and LFM QPF. Results are for the period April 20, 1972 to September 30, 1972. Numbers in parentheses are the number of precipitation cases over total cases. X indicates no cases.*

PEATMOS PoP	PEATMOS PoP Modified for LFM QPF: LFM QPF = 0	LFM QPF .01" to .49"	LFM QPF ≥ 50"
0%	0%	40%	100%
10%	0%	50%	100%
20%	10%	50%	100%
30%	20%	50%	100%
40%	20%	60%	100%
50%	20%	60%	100%
60%	20%	60%	100%
70%	20%	70%	100%
80%	50%	80%	100%
90%	50%	90%	100%
100%	50%	100%	100%

Table 5. *Modified PoP as a function of PEATMOS PoP and LFM QPF. Data sample is for April 20 to September 30, 1972, for locations in Maine and New Hampshire.*

	PEATMOS PoP	Modified PoP
Brier Score	0.121	0.098
Bias	1.1	1.0
Prefigurance	0.63	0.72
Post Agreement	0.58	0.71
Threat Score	0.43	0.55
Percent Correct	81%	87%
Number of Cases	1610	1610

Table 6. *Skill of PEATMOS PoP and PoP modified for LFM QPF using Table 5. In converting a PoP to a categorical forecast, PoP ≥ 50% is a precipitation forecast. Results are for the dependent data period of April 20, 1972 to September 30, 1972.*

REFERENCES

1. National Weather Service: "Operational Forecasts Derived From Primitive Equation And Trajectory Model Output Statistics (PEATMOS)," Technical Procedures Bulletin No. 68, December 3, 1971.

2. Nagler, L. H., Jr., and Quadros, J. D.: "Preliminary Statistics Relating to Winter Performance of LFM Forecasts for Selected Eastern Region Stations," Eastern Region Technical Attachment No. 72-2-28, February 1972.

3. WSFO Washington, DC: "Preliminary Evaluation of LFM Predictions of Thickness and Precipitation," Eastern Region Technical Attachment No. 72-3-20, March 1972.

4. Case, S. D., Jr.: "Performance of the Limited Area Fine Mesh (LFM) Model in the Forecasting of Precipitation at Charleston, WV," Eastern Region Technical Attachment No. 72-7-31, July 1972.

LIST OF EASTERN REGION TECHNICAL MEMORANDA

(Continued from inside front cover)

NWS ER 40 Use of Detailed Radar Intensity Data in Mesoscale Surface Analysis. Robert E. Hamilton. March 1971 (COM-71-00573)

NWS ER 41 A Relationship Between Snow Accumulation and Snow Intensity as Determined from Visibility. Stanley E. Wasserman and Daniel J. Monte. May 1971 (COM-71-00763)

NWS ER 42 A Case Study of Radar Determined Rainfall as Compared to Rain Gage Measurements. Martin Ross. July 1971 (COM-71-00897)

NWS ER 43 Snow Squalls in the Lee of Lake Erie and Lake Ontario. Jerry D. Hill. August 1971 (COM-71-00959)

NWS ER 44 Forecasting Precipitation Type at Greer, South Carolina. John C. Purvis. December 1971 (COM-72-10332)

NWS ER 45 Forecasting Type of Precipitation. Stanley E. Wasserman. January 1972 (COM-72-10316)

NWS ER 46 An Objective Method of Forecasting Summertime Thunderstorms. John F. Townsend and Russell J. Younkin. May 1972 (COM-72-10765)

NWS ER 47 Forecast Cloud Cover Study. James R. Sims. August 1972

NWS ER 48 Accuracy of Automated Temperature Forecasts for Philadelphia as Related to Sky Condition and Wind Direction. Robert B. Wassall. September 1972