NOAA Technical Memorandum NWS WR-112

THE MAN/MOS PROGRAM

Alexander E. MacDonald
Scientific Services Division
Western Region Headquarters
Salt Lake City, Utah

February 1977

UNITED STATES
DEPARTMENT OF COMMERCE
Juanita Kreps, Secretary /

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION
Robert M. White, Administrator /

NATIONAL WEATHER
SERVICE
George P. Cressman, Director

CONTENTS

TABLES AND FIGURES

THE MAN/MOS PROGRAM

Alexander E. MacDonald
Scientific Services Division
National Weather Service Western Region

ABSTRACT. The MAN/MOS Program was instituted in late 1975 to improve forecasting by making more effective use of MOS and to determine if WSFOs could significantly improve on MOS guidance. A complete description of the methods and results of the program through the end of 1976 is given. Methods used included (1) encouraging more meteorological reasoning, (2) more careful use of MOS, (3) fostering competition among WSFOs for improvements over MOS, and (4) rapid feedback techniques. Two seasons of PoP verifications are presented which show substantial improvements over MOS for Western Region WSFOs, and increased skill in comparison with previous years. A ceiling and visibility verification is presented which shows WSFOs producing a much more useful product than MOS. It is concluded that the methods of the program were successful in improving forecasting, and that WSFOs can still make substantial improvements on currently available statistical forecasts.

I. INTRODUCTION

The genesis of the MAN/MOS Program was to answer the question, "Can WSFOs make significant improvements on computer produced statistical guidance?" In recent years statistical forecast schemes developed by Techniques Development Laboratory (TDL) have shown significant improvement. For example, in Figure 1 it can be seen that statistical precipitation probabilities scored by the Brier P score (Brier, 1950) (solid bars) improved from about 17% over climatology in the period from 1970 to 1973, to over a 25% improvement in the winter of 1974-1975. Forecasts issued by Western Region WSFOs in the same period showed less of an improvement; by cool season 74-75 the WSFOs showed negligible improvement over the statistical technique. This is quite surprising since the forecasters have the statistical forecast in hand when they make their forecasts; it raised the question of whether the human forecaster should be devoting time to make such marginal improvements. The idea had particular force in the second (12 to 24 hours) and third (24 to 36 hours) period forecasts where MOS (Model Output Statistics; henceforth, used synonimously with the "statistical techniques") did even better vis-a-vis the WSFO forecasts. Forecasters, it was contended, should concentrate on their warning responsibilities and the first period (0 to 12 hours), accepting the MOS forecasts without modification in the later periods.

Conversely, there were others who contended that the meteorologists can and should make significant improvements over MOS, even in the later periods. A study done in late 1975 by Scientific Services Division (SSD) indicated that Western Region forecasters, while generally deviating from MOS in the right direction, tended to go too far; it suggested the forecasters were not using MOS to maximum advantage. A program, which became known as the MAN/MOS Program, was instituted with two major purposes in mind:

1. To improve forecasting by stimulating more effective use of MOS guidance.

2. To determine if WSFOs can significantly improve on MOS guidance.

This Technical Memorandum presents the methods and results of the two main components of the program: Sections II and III discuss the methods and results of the PoP verification, and Section IV discusses the program to verify aviation forecasting (i.e., ceilings and visibilities).

II. METHODS OF THE PoP VERIFICATION PROGRAM

Probabilities of precipitation are generally the most significant of the numbers routinely issued by forecast offices. The verification system used for PoPs, the Brier P score (Brier, 1950), is excellent because it can't be "played" (Brier, 1950; Hughes, 1967) and has been shown to be "proper" (Murphy and Epstein, 1967). Therefore, although the thrust of the program was directed toward PoPs, it is felt the results would have been similar had temperature or some other forecast parameter been chosen.

It is clear from the stated purposes of the program that its essential goal was to improve PoP forecasting. The methods used can be separated into meteorological and administrative aspects:

A. Meteorological Methods.

The first question to be answered was, "Have the WSFOs been deviating from MOS in the right direction (on the average)?"

1. The Progressive Truncation Study.

To answer this question, a study was undertaken of PoP data from the winter of 1974-1975. The study involved a Brier score verification, comparing WSFO PoP forecasts with MOS PoP forecasts. They were initially verified as given by the WSFO; and then they were progressively truncated such that their absolute difference from MOS was smaller and smaller. For example, suppose that the MOS PoP for a certain period was 80% and the WSFO PoP was 20%. For an "allowed variation" of 60 or greater the WSFO PoP would not be modified (80% - 20% = 60%); but for an allowed variation of 50, the WSFO PoP would be scored as if it were issued as a 30% (80% - 30% = 50%).

A graph of this Progressive Truncation is shown in Figure 2; the results of the study are shown on the line labeled 1975. The ordinate of the graph is given in terms of percent improvement over MOS. For large values of the allowed variation (right portion of the abscissa), such as 60 and 70, the score can be interpreted as the actual (unmodified) comparison between WSFO and MOS scores. This is because it was quite rare for a WSFO to deviate as much as 60 or 70% from MOS. Averaged over the three periods, the Western Region WSFOs had only a very slight improvement over MOS. As the aggregate of forecasts are modified toward MOS, it is evident that the maximum improvement over MOS occurred for a truncation of all forecasts greater than 20% from MOS. In other words, if there had been a rule which said, "Western Region forecasters will not differ more than 20% from MOS", the WSFO PoPs would have verified substantially better than they did. The maxima is "The score the WSFOs could have had by more effective use of MOS". As the WSFO PoPs are truncated closer to MOS their score decreases; for an allowed variation of 0% the score must be the same as MOS.

The 1975 lines on Figures 3a, 3b, and 3c show the same information stratified into the first, second, and third periods. Figure 3a shows the first period to have maximal improvement with allowed variation of 20%, with about the same improvement for allowed variation of 30%. In the second period (Figure 3b) there was maximal improvement for variations of 10 and 20%, and in the third period the improvement would have been greatest if the WSFO forecasters had limited themselves to 10% deviation from MOS. These results show that the ability of the forecasters to deviate successfully was limited to 30% the first period, 20% the second period, and 10% in the third period. It became known as the 30-20-10 rule.

The Progressive Truncation Study identified two important characteristics of the PoPs being issued by WSFOs. First, as demonstrated above, the ability of the forecasters to deviate successfully from MOS decreased with longer forecasts. Secondly, and of more significance, was that the WSFOs were deviating in the proper direction; they just tended to go too far. It strongly suggested that if MOS was used more effectively, the improvement over MOS made by WSFO forecasters would improve substantially.

2. The Forecast Process.

The Progressive Truncation Study gave evidence of a certain type of forecast process. The forecaster looks at the situation, with MOS considered as just one piece of data to be assessed along with other factors. He arrives at his PoP with MOS considered, but not necessarily a dominant factor. However, the Progressive Truncation Study clearly identified this type of forecast process deficient--MOS was not accorded the significance it deserved.

Thus, as part of the MAN/MOS Program, SSD suggested that the WSFO forecasters take a new approach to their PoP forecasting: the forecast process should begin with the MOS PoP. Only in cases where the forecaster had very good reasons should he depart significantly from MOS; when he was unsure, he should "cozy-up" to MOS.

Although initially it was though unwise to deviate more than allowed by the 30-20-10 rule, it soon became apparent that there were situations which warranted drastic differences from MOS. The results (discussed in Section III) supported this idea.

3. Methods for Improving on MOS.

Beginning before, and ultimately as an integral part of the MAN/MOS Program, SSD conducted a program to help forecasters better understand the weaknesses of MOS. For example, if the numerical model which MOS uses was seriously in error due to poor initialization, then the associated MOS PoPs should be modified accordingly. This and other ideas were promulgated through a series of Technical Attachments, station visits and a videotape (Use of MOS PoPs, produced by Carl Bullock of SSD).

4. Meteorological Basis.

It should not have been surprising that the meteorologist could on the average deviate successfully from the statistical forecast scheme. He is privy to much information which is not available to the statistical forecast. A notable example of this is satellite pictures. The appearance, development, and movement of cloud systems are types of information which are very useful to the human brain, but which are difficult to quantify for use in numerical models. Similarly, strong local effects can be advantageously used when the meteorologist is cognizant of deficiencies in the developmental sample.

In the future, developments, such as animation of satellite pictures and prognoses, as well as other applications of advanced technology (e.g., use of on-station minicomputers) should continue to give WSFO forecasters an edge over statistical techniques.

B. Administrative Methods.

Administrative methods were also used in the MAN/MOS Program. Chief among these was the communication through the organization to the operational forecasters the objectives of the program. Parallel to this other methods were used:

I. Computer Scoring System.

The most important administrative innovation of the program was a computerized system for rating the WSFOs competitively in terms of improvement over MOS. Forecasts for two stations were scored for both the 9 GMT and 21 GTM forecasts at each WSFO. Table I is a list of the stations scored; one station is the WSFO location, and the other was chosen to represent a different weather regime within the WSFO forecast area. The data compilation and computer program were accomplished by SSD.

TABLE I

WSFO	IDENTIFIER	SECOND STATION
Portland	PDX	Medford, Oregon
Phoenix	PHX	Flagstaff, Arizona
Salt Lake City	SLC	Cedar City, Utah
Seattle	SEA	Spokane, Washington
Los Angeles	LAX	San Diego, California
San Francisco	SFO	Red Bluff, California
Reno	RNO	Las Vegas, Nevada
Boise	BOI	Pocatello, Idaho
Great Falls	GTF	*Missoula, Montana

*Kalispell, Montana, was used in cool season.

Table I. The stations used in the MAN/MOS PoP Program were the WSFO listed, plus a second station in each WSFO's area of responsibility.

Table 2 is a copy of the rating form which was updated and sent to all WSFOs weekly. In the upper section each WSFO is listed, along with the Brier scores for WSFO (column labeled FCST) and MOS (column labeled MOS) forecasts, the improvement of the WSFO over MOS (column labeled IMPR/MOS; units are percent) and the number of forecasts (N) for each period.

In the middle section the WSFOs are ranked according to improvement over MOS for each period, and in the bottom section the total Brier scores and improvement over MOS for all three periods are shown, with the WSFOs listed by rank.

MAN/MOS SCIENTIFIC SERVICES OCT 4 1976 THRU JAN 30 1977 DATE

	PERIOD 1				PERIOD 2				PERIOD 3			
	* FCST	MOS	IMPR/MOS	N	* FCST	MOS	IMPR/MOS	N	* FCST	MOS	IMPR/MOS	N
SEA	.096	.105	8.7	476	.109	.123	11.6	476	.117	.132	11.9	476
BOI	.044	.046	5.1	476	.061	.063	3.0	476	.061	.064	4.8	476
GTF	.080	.089	10.4	476	.097	.099	2.3	476	.103	.104	1.8	476
PDX	.075	.091	19.0	476	.093	.098	4.9	476	.100	.112	10.2	476
SFO	.027	.033	20.1	476	.030	.034	9.7	476	.045	.053	14.7	476
LAX	.046	.053	13.9	476	.060	.067	10.3	476	.064	.070	7.9	476
RNO	.018	.022	18.2	476	.024	.025	3.1	476	.028	.026	-10.0	476
SLC	.028	.031	7.8	476	.035	.037	6.2	476	.038	.039	1.4	476
PHX	.041	.045	9.3	476	.051	.052	1.5	476	.053	.059	9.5	476
TOTAL	.050	.057	12.0	4284	.062	.066	6.2	4284	.068	.073	7.4	4284

WSFO STANDINGS

PERIOD 1	PERIOD 2	PERIOD 3
1 SFO	1 SEA	1 SFO
2 RNO	2 LAX	2 SEA
3 PDX	3 SFO	3 PDX
4 LAX	4 SLC	4 PHX
5 GTF	5 PDX	5 LAX
6 PHX	6 RNO	6 BOI
7 SEA	7 BOI	7 GTF
8 SLC	8 GTF	8 SLC
9 BOI	9 PHX	9 RNO

WSFO STANDINGS (TOTAL)

RANK	STA	FP	MOS	IM/MOS	N
1	SFO	.034	.040	14.8	1428
2	SEA	.107	.120	10.8	1428
3	PDX	.089	.100	10.8	1428
4	LAX	.057	.063	10.4	1428
5	PHX	.048	.052	6.8	1428
6	SLC	.034	.036	4.9	1428
7	GTF	.093	.098	4.6	1428
8	BOI	.055	.057	4.2	1428
9	RNO	.023	.024	2.9	1428
	TOTAL	.060	.066	8.4	12852

Table 2. Example of MAN/MOS verification update which was sent weekly to WSFOs.

2. Competition.

The weekly ranking system fostered competition among WSFOs to improve over MOS. The primary competition was with MOS: A runner generally makes better time against another runner than he does running alone.

As stated in the Introduction, a major purpose of the program was to encourage more effective use of MOS; it was to be the first and most important item considered in the forecast process. The realization by a forecaster that his product would be measured with reference to MOS accomplished this end: After the competition began, forecasters didn't always agree with MOS, but it was evident they were looking at it much more carefully.

3. Feedback.

It has long been known by psychologists that feedback is useful in improving performance; the more rapid the feedback, the more effective it is.

The MAN/MOS Program made use of this in two ways. First, all WSFOs were encouraged to develop forms to tabulate their forecasts and those of MOS on a running basis. In addition, SSD mailed each WSFO a tabulation of their forecasts and errors along with those of MOS every week. Figure 4 is an example of this form. In addition to being useful as feedback, it allowed a check on the data by the WSFOs.

III. RESULTS OF PoP VERIFICATION

Though the MAN/MOS PoP verification is continuing, this Technical Memorandum will limit discussion to the two complete forecast terms available: cool season 75-76 consisting of 12,833 PoP forecasts between December 1, 1975, and March 29, 1976; and warm season 76, with 20,229 forecasts verified between March 29 and October 3, 1976. Since the results of the two seasons are quite similar, most of the discussion will be limited to the cool season results.

Tables 3 and 4 present the final results of the cool- and warm-season verifications. In the upper section of the Tables, it can be seen that every WSFO improved on MOS in every period for both seasons. The average improvement over MOS was about 12% in the cool season and 7% in the warm season.

Note that the maximum improvement over MOS in both seasons is in the first period (18.7% for the cool season and 11.5% for the warm season). For the cool season the trend continues, with a 10.7% second-period improvement, and a 7.3% first-period improvement. In the warm season, the third period showed a greater improvement over MOS than the second period (5.3% to 4.9%). It is reasonable to infer from the above that improvements over MOS are more difficult to make in longer range forecasts.

A. Comparison With Previous Years.

Figure 1 is a bar graph of the cool season PoP verification for the Western Region for the years 1969 to 1976. The solid bars represent NMC guidance (MOS after 1972) and the horizontally hatched bars represent the WSFOs' improvements over climatology. Use of improvement over climatology gives a fixed standard of comparison; MOS is not a fixed standard because it has been improving with time.

The data from previous years were obtained from a series of Technical Memoranda (Derouin and Cobb, 1970, 1971, 1972; Sadowski and Cobb, 1973, 1974) issued by Technical Procedures

MAN/MOS Final Results, Dec. 1 Thru Mar. 29, 1976

	PERIOD 1				PERIOD 2				PERIOD 3			
	* FCST	MOS	IMPR/MOS	N	* FCST	MOS	IMPR/MOS	N	* FCST	MOS	IMPR/MOS	N
SEA	.139	.160	13.4	476	.168	.183	8.1	476	.180	.202	11.0	476
BOI	.107	.117	8.8	476	.127	.142	10.1	476	.136	.148	7.9	476
GTF	.108	.126	14.0	476	.126	.139	9.0	476	.143	.145	1.1	476
PDX	.121	.149	19.3	473	.145	.164	11.9	476	.169	.181	6.6	476
SFO	.065	.100	35.1	476	.077	.096	19.7	476	.087	.099	12.7	476
LAX	.033	.044	24.5	475	.044	.050	12.1	476	.049	.056	12.3	476
RNO	.042	.053	20.1	474	.047	.055	14.1	474	.058	.059	1.3	474
SLC	.071	.092	22.6	473	.096	.101	5.2	473	.099	.107	7.1	473
PHX	.055	.069	20.8	476	.069	.077	10.6	476	.079	.082	3.6	476
TOTAL	.082	.101	18.7	4275	.100	.112	10.7	4279	.111	.120	7.3	4279

WSFO STANDINGS

PERIOD 1	PERIOD 2	PERIOD 3
1 SFO	1 SFO	1 SFO
2 LAX	2 RNO	2 LAX
3 SLC	3 LAX	3 SEA
4 PHX	4 PDX	4 BOI
5 RNO	5 PHX	5 SLC
6 PDX	6 BOI	6 PDX
7 GTF	7 GTF	7 PHX
8 SEA	8 SEA	8 RNO
9 BOI	9 SLC	9 GTF

WSFO STANDINGS (TOTAL)

RANK	STA	FP	MOS	IM/MOS	N
1	SFO	.076	.098	22.6	1428
2	LAX	.042	.050	15.8	1427
3	PDX	.145	.165	12.2	1425
4	RNO	.049	.056	11.5	1422
5	PHX	.068	.076	11.2	1428
6	SLC	.089	.100	11.2	1419
7	SEA	.162	.182	10.8	1428
8	BOI	.124	.136	8.9	1428
9	GTF	.126	.137	7.8	1428
	TOTAL	.098	.111	11.9	12833

Table 3. Final results of the MAN/MOS Program for the cool season, 1975-76.

MAN/MOS SCIENTIFIC SERVICES MAR 29 THRU OCT 3 1976 -FINAL- DATE 10/06/76

	PERIOD 1				PERIOD 2				PERIOD 3			
	* FCST	MOS	IMPR/MOS	N	* FCST	MOS	IMPR/MOS	N	* FCST	MOS	IMPR/MOS	N
SEA	.103	.119	13.2	748	.120	.123	3.1	747	.132	.139	5.0	746
BOI	.086	.098	12.5	749	.098	.108	9.1	749	.106	.110	4.0	746
GTF.	.115	.129	11.3	750	.133	.140	5.0	750	.146	.150	2.7	748
PDX	.094	.102	7.4	752	.109	.112	2.6	750	.118	.125	5.3	750
SFO	.039	.046	15.0	752	.042	.044	5.3	751	.047	.054	11.6	750
LAX	.044	.050	13.5	751	.045	.049	9.0	749	.049	.054	8.4	749
RNO	.048	.058	17.3	750	.053	.059	9.0	749	.056	.062	10.7	748
SLC	.077	.080	4.5	750	.082	.084	1.7	750	.088	.092	4.4	748
PHX	.073	.083	12.9	750	.078	.081	2.7	749	.088	.091	3.4	748
TOTAL	.075	.085	11.5	6752	.084	.089	4.9	6744	.092	.097	5.3	6733

****

WSFO STANDINGS

PERIOD 1	PERIOD 2	PERIOD 3
1 RNO	1 BOI	1 SFO
2 SFO	2 RNO	2 RNO
3 LAX	3 LAX	3 LAX
4 SEA	4 SFO	4 PDX
5 PHX	5 GTF	5 SEA
6 BOI	6 SEA	6 SLC
7 GTF	7 PHX	7 BOI
8 PDX	8 PDX	8 PHX
9 SLC	9 SLC	9 GTF

****

WSFO STANDINGS (TOTAL)

RANK	STA	FP	MOS	IM/MOS	N
1	RNO	.052	.060	12.3	2247
2	SFO	.043	.048	10.8	2253
3	LAX	.046	.051	10.2	2249
4	BOI	.097	.105	8.3	2244
5	SEA	.118	.127	6.9	2241
6	PHX	.079	.085	6.3	2247
7	GTF	.131	.139	6.1	2248
8	PDX	.107	.113	5.0	2252
9	SLC	.082	.085	3.6	2248
	TOTAL	.084	.090	7.1	20229

Table 4. Final results of the MAN/MOS Program for the warm season - 1976.

Branch (TPB) of NWS. The data for 1973-1975 were obtained directly from magnetic tape from TPB. There is a difference in data between that obtained from TPB and that collected in the MAN/MOS Program (the TPB data had more stations for some WSFOs) but the large data sample and geographic balance in the MAN/MOS data selection makes the two samples comparable.

The WSFOs have always done better than MOS, running about 25% over climatology. By 74-75 MOS is also up to 25% improvement, with the WSFOs only slightly better.

The effect of the MAN/MOS Program is evident in the 75-76 season. Although MOS stayed near 25%, the WSFOs jumped to nearly 34% over climatology. This represents a significant jump in the accuracy of WSFO forecasting, as can be seen by comparison with previous years.

The situation is similar for all three periods. Figure 5a is a graph of the improvement over climatology for the second period, and 5b shows the same for the third period. Both show a significant improvement in PoP forecasting in cool season 75-76.

The ability of WSFOs to improve over MOS in the third period is considered quite significant. Notice that in cool season 75-76 the WSFOs had a greater improvement over climatology in the third period than MOS had in the second period.

B. Results of 1976 Progressive Truncation Study.

The Progressive Truncation Study done for the cool season 75-76 is labeled 1976 in Figure 2. Notice that large values of allowed variation the improvement over MOS is about 12%, and as the WSFO PoPs are modified toward MOS they decrease monotonically. This means that, on the average, when the WSFOs departed significantly from MOS they were successful. There is a sharp contrast between 1975, when the WSFO forecasts could be improved by modification toward MOS, and 1976, when any modification toward MOS results in poorer forecasts. It is clear from the graph that the WSFOs were making much more effective use of MOS in 1976.

The Progressive Truncation Study for Period 3 is given in Figure 3c. There is a slight improvement in the scores as they are modified toward MOS. Again, the comparison with the previous year is striking, indicating much more effective use and improvement on MOS.

IV. THE AVIATION VERIFICATION PROGRAM

A. Description of Program.

In addition to the PoPs verification, a program was also conducted to verify and compare terminal forecasts (FTs) for ceilings and visibilities with MOS. The program was voluntary for WSFOs; Table 5 is a list of the seven (out of nine) WSFOs participating, and the stations verified at each WSFO. An example of the verification form used is presented in Figure 6. The 10 GMT and 22 GMT forecasts are each verified three times daily for both ceilings and visibilities. Because six-hour multiples are used, it allowed direct comparison with MOS, unlike the National verification program. In this section the results of the complete program, which lasted from March 1 to December 31, 1976, are presented.

TABLE 5

WSFO	OTHER STATION(S)
Seattle	Olympia, Washington
Los Angeles	San Diego, California
San Francisco	Fresno, California
Reno	Ely, Nevada
Boise	Pocatello, Idaho
Great Falls	Missoula, Montana
Portland	Pendleton, Oregon Medford, Oregon Eugene, Oregon

Table 5. The stations used in the MAN/MOS Aviation Verification.

B. Results.

Table 6 presents a complete tabulation of the results. It consists of four forecast and observed contingency tables; one each for the ceiling and visibility forecasts of MOS and the FTs. The total number of forecasts verified for both MOS and FTs is 55,575, a large enough sample to lend credence to the results.

1. Discussion of Contingency Tables.

The superiority of FTs over MOS is evident in the contingency tables. Consider, for example, the occurrences of Category 1. When the ceiling verified in Category 1, it was forecast correctly 99 times versus 58 for MOS; more noteworthy is the fact that the FTs observed Category 1 on 46 of their Category 5 forecasts versus 155 for MOS. In visibility the FTs hit Category 1 correctly 229 times

MAN/MOS FT Verification, Mar. 1 Thru Dec. 31, 1976

WESTERN REGION SUMMARY PERIOD: 1976

FT CEILING

OBSERVED \ FORECAST	1	2	3	4	5	TOTAL
1	99	86	19	4	46	254
2	57	138	85	46	130	454
3	8	52	154	181	269	654
4	1	29	78	521	675	1304
5	61	184	176	712	24065	25198
TOTAL	226	489	512	1464	25193	27884
BIAS	.89	1.05	.77	1.12	1.00	

PER CENT CORRECT: 89.57

SCORE: 67.30

IMPROVEMENT OVER MOS (PER CENT): 1.05

MOS CEILING

OBSERVED \ FORECAST	1	2	3	4	5	TOTAL
1	58	29	4	8	155	254
2	27	47	25	42	323	464
3	4	23	45	137	455	664
4	2	18	49	298	937	1304
5	34	41	82	511	24530	25198
TOTAL	125	158	205	996	26400	27884
BIAS	.49	.34	.31	.76	1.05	

PER CENT CORRECT: 89.58

SCORE: 65.60

FT VISIBILITY

OBSERVED \ FORECAST	1	2	3	4	5	TOTAL
1	229	59	63	39	91	481
2	31	30	47	35	64	207
3	53	53	151	183	260	700
4	27	21	76	294	431	849
5	66	80	180	556	24750	25634
TOTAL	406	243	517	1109	25596	27871
BIAS	.84	1.17	.74	1.31	1.00	

PER CENT CORRECT: 91.33

SCORE: 67.65

IMPROVEMENT OVER MOS (PER CENT): .79

MOS VISIBILITY

OBSERVED \ FORECAST	1	2	3	4	5	TOTAL
1	99	46	47	52	237	481
2	10	8	24	28	137	207
3	25	19	80	162	413	700
4	8	7	33	163	638	849
5	16	25	111	287	25195	25634
TOTAL	159	105	295	692	26520	27871
BIAS	.33	.51	.42	.82	1.04	

PER CENT CORRECT: 91.65

SCORE: 67.13

Table 6. Final results of the Aviation MOS Verification. "SCORE" is the NWS Matrix Score as defined in Chapter C-73 of the NWS Operations Manual.

versus 99 for MOS; MOS had 237 five-category-busts, with only 91 such busts for the FTs. In the lowest three categories the FTs had 801 correct forecasts versus 337 for MOS.

2. Bias Characteristics.

The biases of each forecast category are shown at the bottom of the columns in Table 6. Techniques Development Laboratory has recognized a problem with the bias characteristics of the MOS ceiling and visibility forecasts (Crisci, 1976), and the problem is evident in this set. All the MOS biases for the lower three categories are around .5 or less. In contrast, the lower category biases of the FTs are closer to 1. A comparison of the 10 biases shows that only in one case (Category 4 of visibility) does MOS have a bias closer to 1 than the FTs.

3. Score and Percent Correct.

The "SCORE" listed in Table 6 is the NWS Matrix Score as defined in Chapter C-73 of the NWS Operations Manual. This score shows that FTs were a little over 1% better than MOS in ceiling forecasting and .8% better in visibility forecasting. It is felt that the clear superiority of the FTs shown in the contingency table, with only a negligible improvement in the NWS Matrix Score, implies a weakness in the scoring system.

For both ceilings and visibilities MOS had a slightly greater percent correct. These figures are not considered too significant, however, because an exclusive forecast of Category 5 would have given 90.37% correct for ceilings and 91.8% correct for visibilities; both of these are better than MOS.

V. CONCLUSIONS

A. PoP Verification.

The results of the MAN/MOS PoP verification support the following conclusions:

1. The MAN/MOS Program was instrumental in bringing about a significant improvement in Western Region PoP forecasting.

2. The WSFOs were able to use MOS more effectively as a result of the program.

3. The methods of the program, such as the suggested forecast process and competition, were effective in bringing about improvements.

4. The WSFOs can significantly improve on MOS in all three periods.

5. MOS' future role should continue to be guidance.

6. With MOS PoPs running only 25% over climatology, there is still much room for improvement.

B. Aviation Verification.

The results of the ceiling and visibility verification support these conclusions:

1. The FTs verified significantly better than MOS.

2. The NWS Matrix Score is a poor standard of comparison. Similarly, percent correct was not very meaningful due to the preponderance of Category 5.

3. The five-category MOS ceiling and visibility forecasts were only marginally useful to aviation forecasters.

The differences between the conclusions of the PoP verification and the Aviation verification are substantial. In PoP forecasting, the improvement of the WSFOs was made possible by more effective use of an excellent product: the MOS PoPs. In contrast, the poor bias and generally poor performance of the MOS ceiling and visibility forecasts implies they were not useful to help improve WSFO forecasts.

In recognition of these problems, NWS has now switched to a six-category forecast system which has been derived in a manner to improve bias characteristics (Crisci, 1976; TPB #180, 1977).

C. General Conclusions.

The important conclusions of the MAN/MOS Program are that it was effective in improving forecasting, and that WSFOs can still make substantial improvements over MOS.

VI. ACKNOWLEDGMENT

My deepest thanks is to Len Snellman, Chief, Scientific Services Division, National Weather Service Western Region Headquarters, for his leadership and guidance on all aspects of the MAN/MOS Program. I would also like to thank Ira Brenner, Phoenix Weather Service Forecast Office, for programming help, and Carl Bullock, John Jannuzzi, and Jim Fors, of Scientific Services Division, Western Region Headquarters, for help with data collection.

VII. REFERENCES

Brier, G. W., 1950: Verification of Forecasts Expressed in Terms of Probability. Monthly Weather Review, 78, 1-3.

Crisci, R. L., 1976: Improving the Bias in MOS Ceiling and Visibility Forecasts. TDL Office Note 76-4, Techniques Development Laboratory, National Weather Service, National Oceanic and Atmospheric Administration, U. S. Department of Commerce, Washington, D. C.

Derouin, R., and G. Cobb, 1970: Weather Bureau Forecast Verification Scores 1968-69 and Some Performance Trends from 1966. NOAA WBTM FCST 15, National Oceanic and Atmospheric Administration, U. S. Department of Commerce, Washington, D. C.

Derouin, R., and G. Cobb, 1971: Weather Bureau April 1969 - March 1970 Verification Report with Special Emphasis on Performance Scores within Echelons. NOAA NWS FCST 16, National Oceanic and Atmospheric Administration, U. S. Department of Commerce, Washington, D. C.

Derouin, R., and G. Cobb, 1972: Public Forecast Verification Summary. NOAA NWS FCST 17, National Oceanic and Atmospheric Administration, U. S. Department of Commerce, Washington, D. C.

Hughes, L. A., 1967: On the Use and Misuse of the Brier Verification Score. Weather Bureau Technical Memorandum CR-18, ESSA, U. S. Department of Commerce, Washington, D. C.

Murphy, A. H., and E. S. Epstein, 1967: A Note on Probability Forecasts and "Hedging". Journal of Applied Meteorology, 6, 1002 - 1005.

Sadowski, A., and G. Cobb, 1973: Public Forecast Verification Summary. NOAA NWS FCST 19, National Oceanic and Atmospheric Administration, U. S. Department of Commerce, Washington, D. C.

Sadowski, A., and G. Cobb, 1974: National Weather Service April 1972 to March 1973 Public Forecast Verification Summary. NOAA NWS FCST 21, National Oceanic and Atmospheric Administration, U. S. Department of Commerce, Washington, D. C.

Technical Procedures Bulletin No. 180, 1977: The Use of Model Output Statistics for Predicting Ceiling, Visibility and Cloud Amount. National Weather Service, National Oceanic and Atmospheric Administration, U. S. Department of Commerce, Washington, D. C.

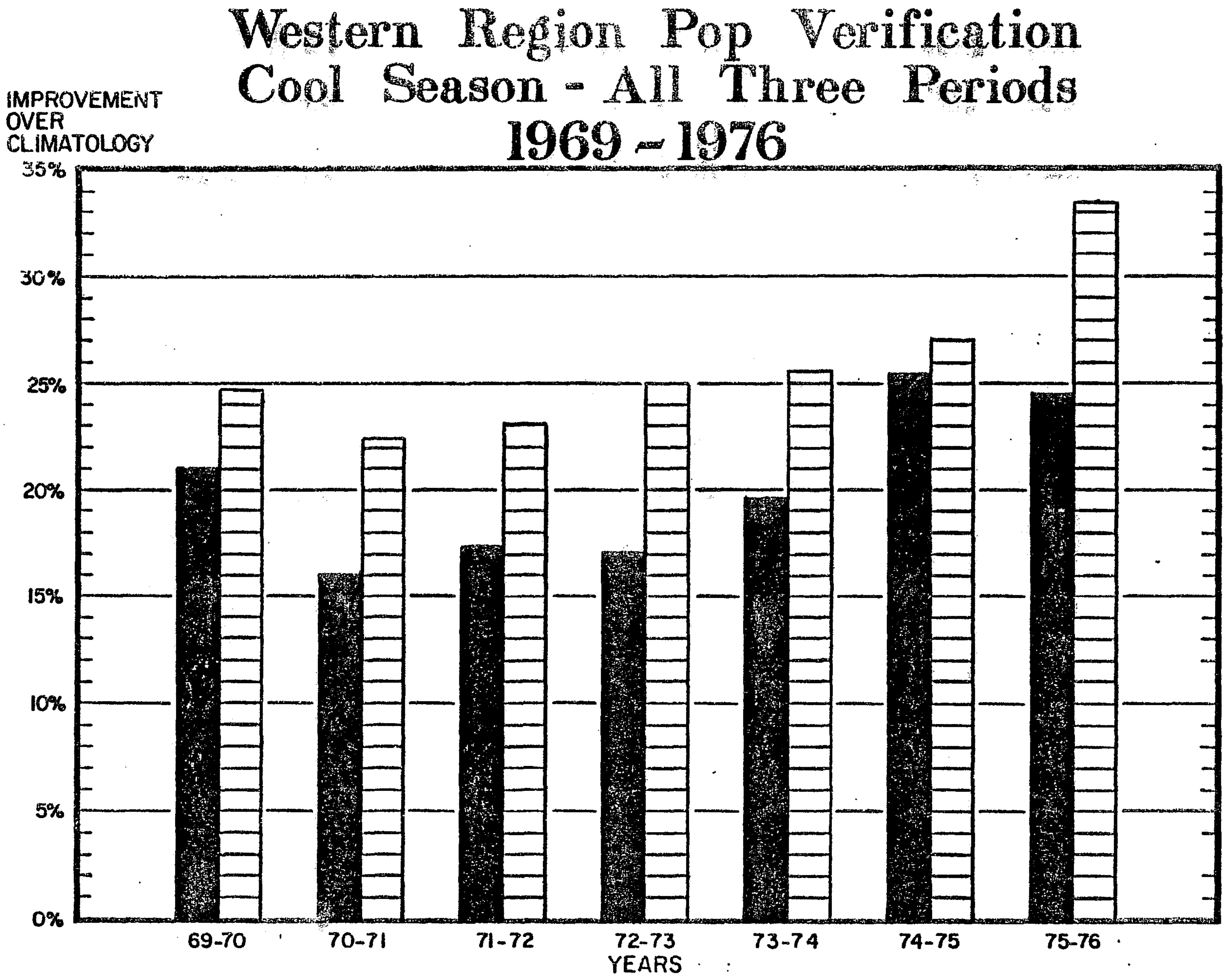


Figure I. A Comparison of Brier Score Improvement Over Climatology for PoP Forecasts Issued by Western Region WSFOs.

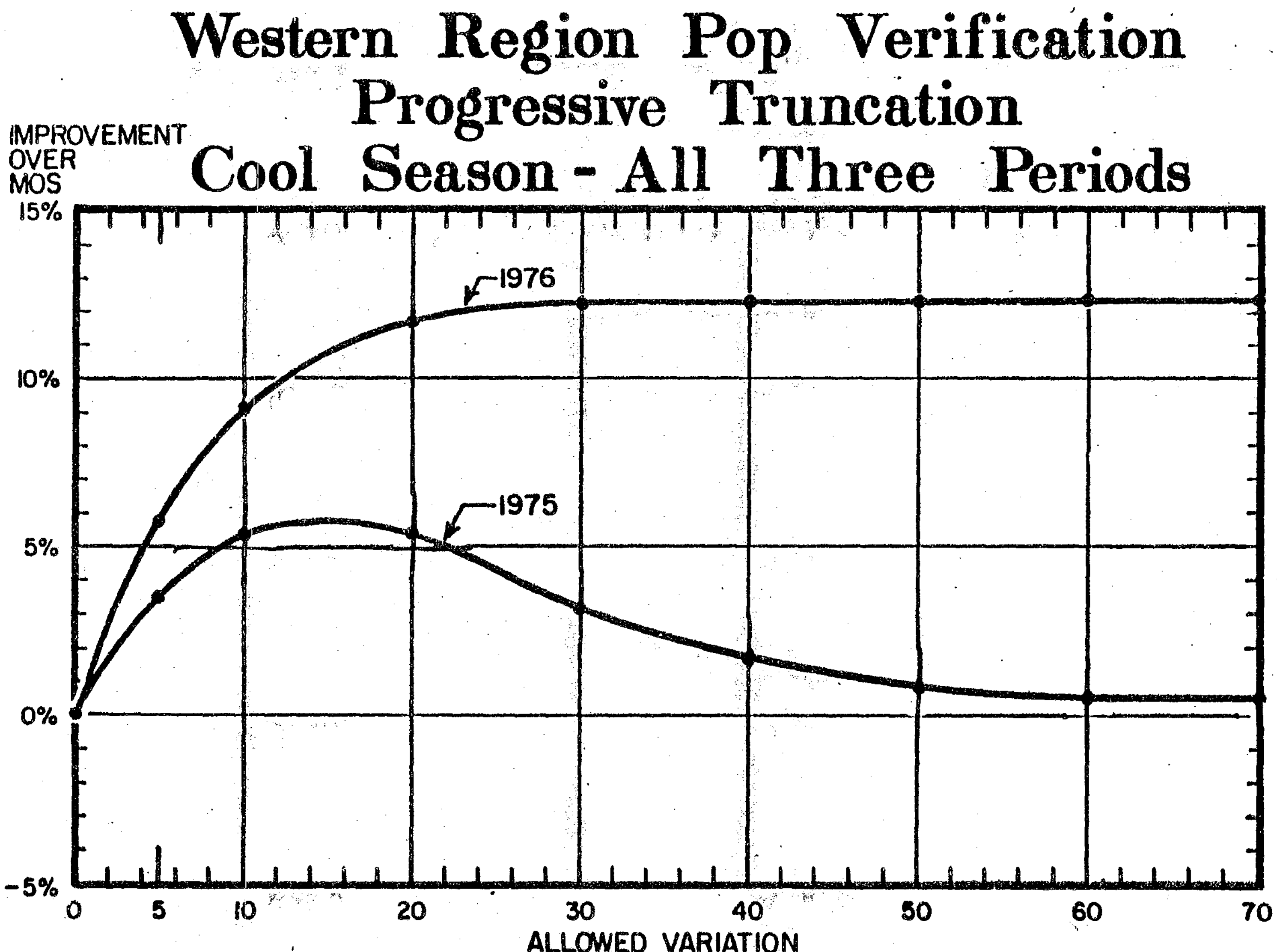
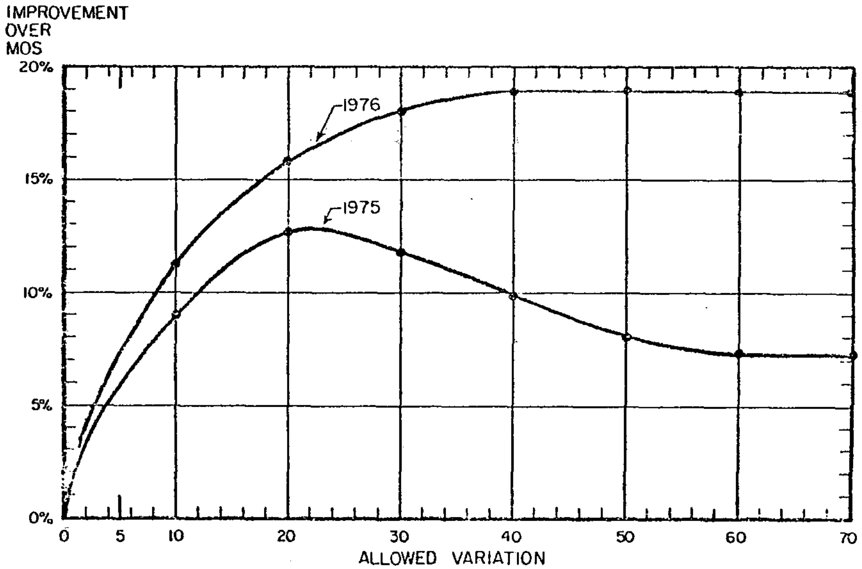
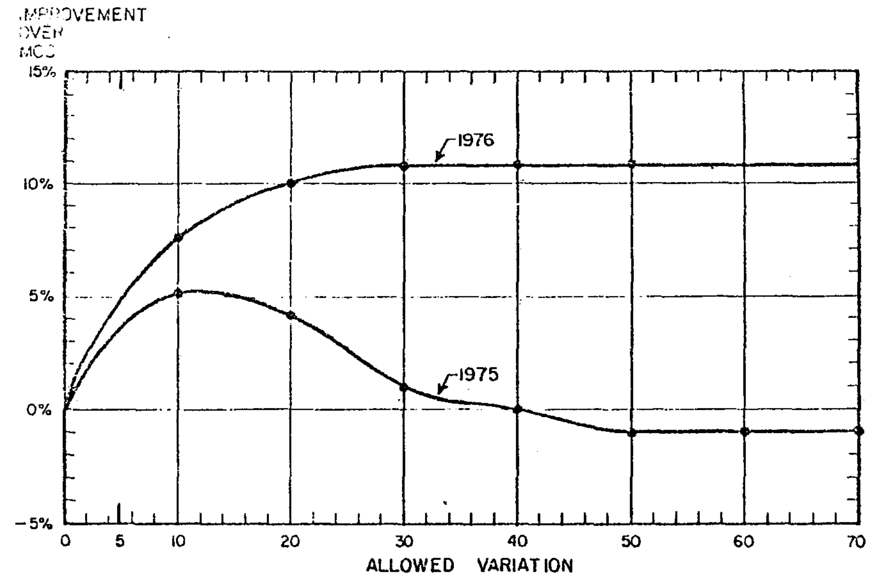


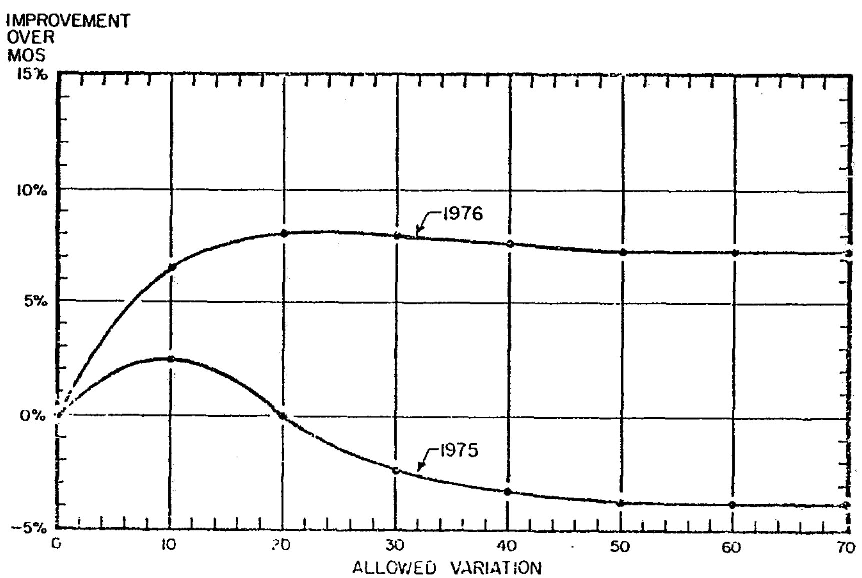
Figure 2. Graph of Percentage Improvement of Progressively Truncated PoP Forecasts of Western Region WSFOs Over MOS PoP Forecasts Using the Brier Score.



(a) First Period



(b) Second Period



(c) Third Period

Figure 3. Progressive Truncation Study with Results Stratified into the Three Forecast Periods: (a) Period 1, 0 - 12 hours; (b) Period 2, 12 - 24 hours; (c) Period 3, 24 - 36 hours.

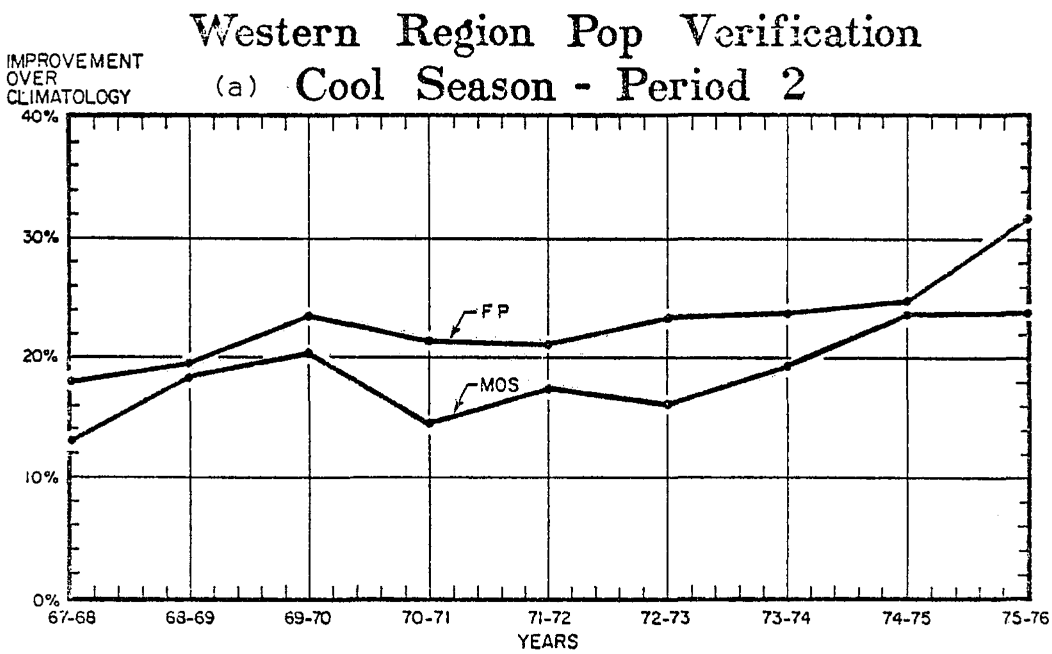
MAN/MOS SCIENTIFIC SERVICES OCT 4 1976 THRU JAN 30 1977 DATE 02/01/77

FORECAST CONTEST VERIFICATION

SEA YEAR 1977

FORECAST ISSUED				PERIOD 1					PERIOD 2					PERIOD 3				
DAY	HR	STA	*	PRECIP	FP	ERR	MOS	ERR*	PRECIP	FP	ERR	MOS	ERR*	PRECIP	FP	ERR	MOS	ERR*
JAN 24	6	SEA	*	NO	0	0	0	0*	NO	0	0	0	0*	NO	0	0	0	0*
JAN 24	18	SEA	*	NO	5	0	0	0*	NO	5	0	0	0*	NO	5	0	0	0*
JAN 25	6	SEA	*	NO	0	0	0	0*	NO	0	0	0	0*	NO	0	0	0	0*
JAN 25	18	SEA	*	NO	0	0	0	0*	NO	0	0	5	0*	NO	5	0	0	0*
JAN 26	6	SEA	*	NO	0	0	0	0*	NO	0	0	0	0*	NO	0	0	0	0*
JAN 26	18	SEA	*	NO	0	0	5	0*	NO	5	0	10	1*	NO	10	1	20	4*
JAN 27	6	SEA	*	NO	0	0	20	4*	NO	5	0	10	1*	NO	20	4	20	4*
JAN 27	18	SEA	*	NO	5	0	10	1*	NO	10	1	20	4*	NO	10	1	30	9*
JAN 28	6	SEA	*	NO	0	0	0	0*	NO	5	0	10	1*	NO	10	1	10	1*
JAN 28	18	SEA	*	NO	10	1	10	1*	NO	10	1	20	4*	NO	20	4	20	4*
JAN 29	6	SEA	*	NO	5	0	0	0*	NO	10	1	10	1*	NO	20	4	20	4*
JAN 29	18	SEA	*	NO	5	0	5	0*	NO	10	1	20	4*	YES	30	49	30	49*
JAN 30	6	SEA	*	NO	0	0	0	0*	YES	10	81	10	81*	YES	40	36	60	16*
JAN 30	18	SEA	*	YES	30	49	30	49*	YES	40	36	40	36*	YES	20	64	50	25*
JAN 24	6	GEG	*	NO	0	0	5	0*	NO	5	0	10	1*	NO	5	0	0	0*
JAN 24	18	GEG	*	NO	5	0	10	1*	NO	5	0	0	0*	NO	5	0	0	0*
JAN 25	6	GEG	*	NO	5	0	5	0*	NO	5	0	5	0*	NO	5	0	10	1*
JAN 25	18	GEG	*	NO	5	0	10	1*	NO	5	0	5	0*	NO	5	0	0	0*
JAN 26	6	GEG	*	NO	0	0	10	1*	NO	0	0	5	0*	NO	0	0	10	1*
JAN 26	18	GEG	*	NO	5	0	10	1*	NO	5	0	0	0*	NO	5	0	10	1*
JAN 27	6	GEG	*	NO	0	0	20	4*	NO	5	0	20	4*	NO	10	1	10	1*
JAN 27	18	GEG	*	NO	10	1	10	1*	NO	5	0	5	0*	NO	10	1	10	1*
JAN 28	6	GEG	*	NO	0	0	0	0*	NO	5	0	5	0*	NO	5	0	10	1*
JAN 28	18	GEG	*	NO	10	1	10	1*	NO	10	1	0	0*	NO	10	1	5	0*
JAN 29	6	GEG	*	NO	5	0	0	0*	NO	5	0	10	1*	NO	10	1	10	1*
JAN 29	18	GEG	*	NO	5	0	0	0*	NO	5	0	5	0*	NO	5	0	5	0*
JAN 30	6	GEG	*	NO	0	0	0	0*	NO	5	0	5	0*	NO	10	1	5	0*
JAN 30	18	GEG	*	NO	5	0	5	0*	NO	20	4	20	4*	NO	20	4	30	9*

Figure 4. Example of the Forecast Tabulation Which Was Mailed to WSFOs Weekly.



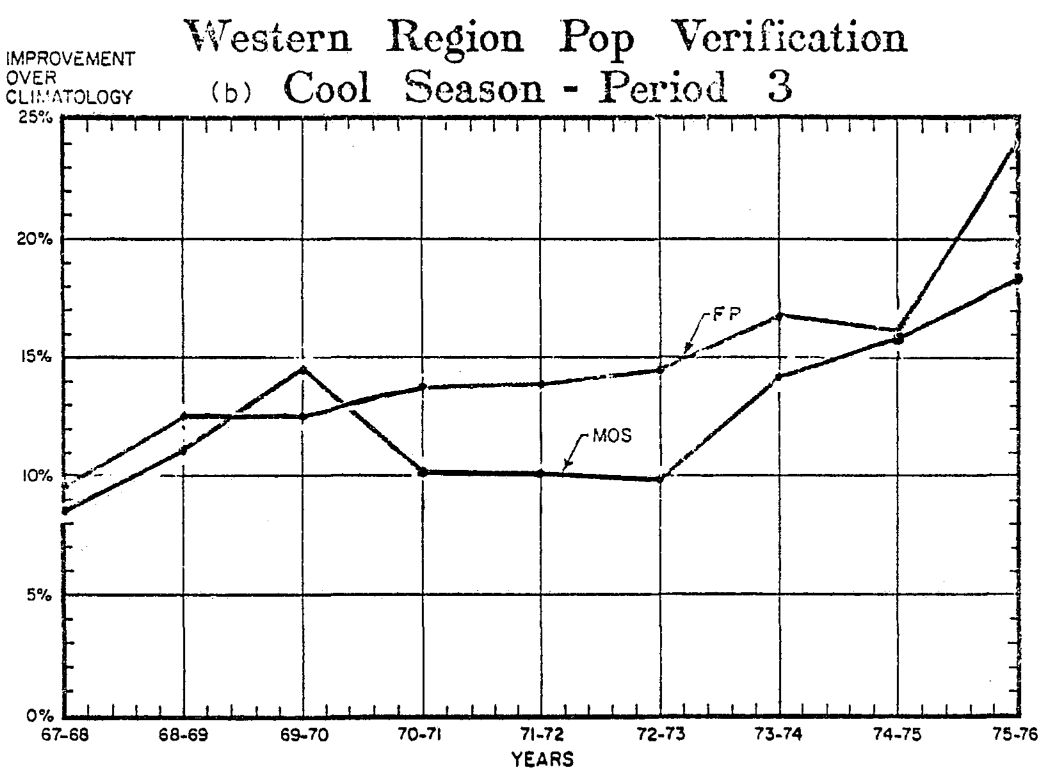


Figure 5. Brier Score PoP Verification in Terms of Improvement Over Climatology for Western Region WSFOs.

AVIATION WEATHER VERIFICATION FORM

NATIONAL WEATHER SERVICE — WESTERN REGION

06Z MOS 10Z FT	WSFO NUMBER			STATION NUMBER			DATE						CODE	CEILING									VISIBILITY									FORECASTER	
							YEAR		MONTH		DAY			12Z			18Z			00Z			12Z			18Z			00Z			Number	
														FT	OBS	MOS	FT	OBS	MOS	FT	OBS	MOS	FT	OBS	MOS	FT	OBS	MOS	FT	OBS	MOS		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1.	7	7	5	7	7	3																											
2.	7	7	5	7	7	3																											
3.	7	7	5	7	7	3																											
4.	7	7	5	7	7	3																											
5.	7	7	5	7	7	3																											
6.	7	7	5	7	7	3																											
7.	7	7	5	7	7	3																											

MSO

Category	Ceiling (Ft)	Visibility (Mi)
1	≤100	≤3/8
2	200–400	1/2–7/8
3	500–900	1–2 1/2
4	1000–1900	3–4
5	≥2000	≥5

Note: Missing Data = 9

Remarks

18Z MOS 23Z FT	CODE	CEILING									VISIBILITY									FORECASTER	
		00Z			06Z			12Z			00Z			06Z			12Z			Number	
		FT	OBS	MOS	FT	OBS	MOS	FT	OBS	MOS	FT	OBS	MOS	FT	OBS	MOS	FT	OBS	MOS		
	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
1.																					
2.																					
3.																					
4.																					
5.																					
6.																					
7.																					

Figure 6. An Example of the Data Collection Form Used in the Aviation Verification Program.

No. 45/2 Precipitation Probabilities in the Western Region Associated with Spring 500-mb Map Types. Richard P. Augulis. January 1970. (Out of print.) (PB-189434)
No. 45/3 Precipitation Probabilities in the Western Region Associated with Summer 500-mb Map Types. Richard P. Augulis, January 1970. (Out of print.) (PB-189414)
No. 45/4 Precipitation Probabilities in the Western Region Associated with Fall 500-mb Map Types. Richard P. Augulis, January 1970. (Out of print.) (PB-189435)
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-190476)
No. 47 Statistical Analysis as a Flood Routing Tool. Robert J. C. Burnash, December 1969. (PB-188744)
No. 48 Tsunami. Richard P. Augulis, February 1970. (PB-190157)
No. 49 Predicting Precipitation Type. Robert J. C. Burnash and Floyd E. Hug, March 1970. (PB-190962)
No. 50 Statistical Report on Aeroallergens (Pollens and Molds) Fort Huachuca, Arizona, 1969. Wayne S. Johnson, April 1970. (PB-191743)
No. 51 Western Region Sea State and Surf Forecaster's Manual. Gordon C. Shields and Gerald B. Burdwell, July 1970. (PB-193102)
No. 52 Sacramento Weather Radar Climatology. R. G. Pappas and C. M. Veliquette, July 1970. (PB-193347)
No. 53 Experimental Air Quality Forecasts in the Sacramento Valley. Norman S. Benes, August 1970. (Out of print.) (PB-194128)
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-194394)
No. 56 Areal Coverage of Precipitation in Northwestern Utah. Philip Williams, Jr., and Werner J. Heck, September 1970. (PB-194389)
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. (PB-194710)
No. 58 Air Pollution by Jet Aircraft at Seattle-Tacoma Airport. Wallace R. Donaldson, October 1970. (COM-71-00017)
No. 59 Application of P.E. Model Forecast Parameters to Local-Area Forecasting. Leonard W. Snellman, October 1970. (COM-71-00016)

NOAA Technical Memoranda NWS

No. 60 An Aid for Forecasting the Minimum Temperature at Medford, Oregon. Arthur W. Fritz, October 1970. (COM-71-00120)
No. 61 Relationship of Wind Velocity and Stability to SO_2 Concentrations at Salt Lake City, Utah. Werner J. Heck, January 1971. (COM-71-00232)
No. 62 Forecasting the Catalina Eddy. Arthur L. Eichelberger, February 1971. (COM-71-00223)
No. 63 700-mb Warm Air Advection as a Forecasting Tool for Montana and Northern Idaho. Norris E. Woerner, February 1971. (COM-71-00349)
No. 64 Wind and Weather Regimes at Great Falls, Montana. Warren B. Price, March 1971.
No. 65 Climate of Sacramento, California. Wilbur E. Figgins, June 1971. (COM-71-00764)
No. 66 A Preliminary Report on Correlation of ARTCC Radar Echoes and Precipitation. Wilbur K. Hall, June 1971. (COM-71-00829)
No. 67 Precipitation Detection Probabilities by Los Angeles ARTC Radars. Dennis E. Ronne, July 1971. (Out of print.) (COM-71-00925)
No. 68 A Survey of Marine Weather Requirements. Herbert P. Benner, July 1971. (Out of print.) (COM-71-00889)
No. 69 National Weather Service Support to Soaring Activities. Ellis Burton, August 1971. (Out of print.) (COM-71-00956)
No. 70 Predicting Inversion Depths and Temperature Influences in the Helena Valley. David E. Olsen, October 1971. (Out of print.) (COM-71-01037)
No. 71 Western Region Synoptic Analysis-Problems and Methods. Philip Williams, Jr., February 1972. (COM-72-10433)
No. 72 A Paradox Principle in the Prediction of Precipitation Type. Thomas J. Weitz, February 1972. (Out of print.) (COM-72-10432)
No. 73 A Synoptic Climatology for Snowstorms in Northwestern Nevada. Bert L. Nelson, Paul M. Fransioli, and Clarence M. Sakamoto, February 1972. (Out of print.) (COM-72-10338)
No. 74 Thunderstorms and Hail Days Probabilities in Nevada. Clarence M. Sakamoto, April 1972. (COM-72-10554)
No. 75 A Study of the Low Level Jet Stream of the San Joaquin Valley. Ronald A. Willis and Philip Williams, Jr., May 1972. (COM-72-10707)
No. 76 Monthly Climatological Charts of the Behavior of Fog and Low Stratus at Los Angeles International Airport. Donald M. Gales, July 1972. (COM-72-11140)
No. 77 A Study of Radar Echo Distribution in Arizona During July and August. John E. Hales, Jr., July 1972. (COM-72-11136)
No. 78 Forecasting Precipitation at Bakersfield, California, Using Pressure Gradient Vectors. Earl T. Riddiough, July 1972. (COM-72-11146)
No. 79 Climate of Stockton, California. Robert C. Nelson, July 1972. (COM-72-10920)
No. 80 Estimation of Number of Days Above or Below Selected Temperatures. Clarence M. Sakamoto, October 1972. (COM-72-10021)
No. 81 An Aid for Forecasting Summer Maximum Temperatures at Seattle, Washington. Edgar G. Johnson, November 1972. (COM-73-10150)
No. 82 Flash Flood Forecasting and Warning Program in the Western Region. Philip Williams, Jr., Chester L. Glenn, and Roland L. Raetz, December 1972. (COM-73-10251)
No. 83 A Comparison of Manual and Semiautomatic Methods of Digitizing Analog Wind Records. Glenn E. Rasch, March 1973. (COM-73-10669)
No. 84 Southwestern United States Summer Monsoon Source--Gulf of Mexico or Pacific Ocean? John E. Hales, Jr., March 1973. (COM-73-10769)
No. 85 Range of Radar Detection Associated with Precipitation Echoes of Given Heights by the WSR-57 at Missoula, Montana. Raymond Granger, April 1973. (COM-73-11030)
No. 86 Conditional Probabilities for Sequences of Wet Days at Phoenix, Arizona. Paul C. Kangieser, June 1973. (COM-73-11264)
No. 87 A Refinement of the Use of K-Values in Forecasting Thunderstorms in Washington and Oregon. Robert Y. G. Lee, June 1973. (COM-73-11276)
No. 88 A Surge of Maritime Tropical Air--Gulf of California to the Southwestern United States. Ira S. Brenner, July 1973.
No. 89 Objective Forecast of Precipitation Over the Western Region of the United States. Julia N. Paegle and Larry P. Kierulff, September 1973. (COM-73-11946/3AS)
No. 90 A Thunderstorm "Warm Wake" at Midland, Texas. Richard A. Wood, September 1973. (COM-73-11845/AS)
No. 91 Arizona "Eddy" Tornadoes. Robert S. Ingram, October 1973. (COM-74-10465)

NOAA Technical Memoranda NWSWR: (Continued)

No. 92 Smoke Management in the Willamette Valley. Earl M. Bates, May 1974. (COM-74-11277/AS)
No. 93 An Operational Evaluation of 500-mb Type Stratified Regression Equations. Alexander E. MacDonald, June 1974. (COM-74-11407/AS)
No. 94 Conditional Probability of Visibility Less than One-half Mile in Radiation Fog at Fresno, California. John D. Thomas, August 1974. (COM-74-11555/AS)
No. 95 Climate of Flagstaff, Arizona. Paul W. Sorenson, August 1974. (COM-74-11678/AS)
No. 96 Map Type Precipitation Probabilities for the Western Region. Glenn E. Rasch and Alexander E. MacDonald, February 1975. (COM-75-10428/AS)
No. 97 Eastern Pacific Cut-off Low of April 21-28, 1974. William J. Alder and George R. Miller, January 1976. (PB-250-711/AS)
No. 98 Study on a Significant Precipitation Episode in the Western United States. Ira S. Brenner, April 1975. (COM-75-10719/AS)
No. 99 A Study of Flash Flood Susceptibility--A Basin in Southern Arizona. Gerald Williams, August 1975. (COM-75-11360/AS)
No. 100 A Study of Flash-flood Occurrences at a Site versus Over a Forecast Zone. Gerald Williams, August 1975. (COM-75-11404/AS)
No. 101 Digitized Eastern Pacific Tropical Cyclone Tracks. Robert A. Baum and Glenn E. Rasch, September 1975. (COM-75-11479/AS)
No. 102 A Set of Rules for Forecasting Temperatures in Napa and Sonoma Counties. Wesley L. Tuft, October 1975. (PB-246-902/AS)
No. 103 Application of the National Weather Service Flash-flood Program in the Western Region. Gerald Williams, January 1976. (PB-253-053/AS)
No. 104 Objective Aids for Forecasting Minimum Temperatures at Reno, Nevada, During the Summer Months. Christopher D. Hill, January 1976. (PB252866/AS)
No. 105 Forecasting the Mono Wind. Charles P. Ruscha, Jr., February 1976. (PB254650)
No. 106 Use of MOS Forecast Parameters in Temperature Forecasting. John C. Plankinton, Jr., March 1976. (PB254649)
No. 107 Map Types as Aid in Using MOS PoPs in Western U. S. Ira S. Brenner, August 1976. (PB259594)
No. 108 Other Kinds of Wind Shear. Christopher D. Hill, August 1976. (PB260437/AS)
No. 109 Forecasting North Winds in the Upper Sacramento Valley and Adjoining Forests. Christopher E. Fontana, September 1976.
No. 110 Cool Inflow as a Weakening Influence on Eastern Pacific Tropical Cyclones. William J. Denney, November 1976.
No. 111 Operational Forecasting Using Automated Guidance. Leonard W. Snellman, February 1977.