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OPERATIONAL FORECASTING USING AUTOMATED GUIDANCE

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Editorial Comment: Mr. L. W. Snellman presented this paper at the American Meteorological Society's 57th Annual Meeting in Tucson, Arizona, on January 18, 1977. A similar version was also presented at the Seventh Military Technical Exchange Conference held in El Paso, Texas, November 30 - December 3, 1976. Our purpose in publishing this paper as a Technical Memorandum is to bring to Western Region forecasters the importance of our MAN/MOS program and how the verification data are being used to promote the importance of the man in operational forecasting today and in the future.

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I. INTRODUCTION

I find myself between the proverbial Rock and a Hard Place these days. On the one hand, I think that persons involved in operational meteorology, like myself, should be strongly promoting the development and use of objective guidance, and on the other hand, I see pursuing this course too far as implied by some top staff people as destroying the meteorologist's significant input into the operational end product.

For a World-War-II-trained meteorologist to talk about the dangers of automation, which is the "in" thing these days, is to ask to be branded as living in the past. Yet, I think that my past meteorological track record does not support that conclusion.

Management decisions now being formulated on operational practices and the effect of these decisions on meteorological education may very well determine whether operational forecasting lives or dies as a satisfying career in the future. I believe man's position in the system must be kept strong and significant if it is to live. In addition, I also believe the quality of meteorological services to our users will be inferior to what the state of the science will support if it dies.

In the next few pages I would like to put my concerns in perspective, and offer some ideas regarding how we can direct operational meteorological practices to capitalize on manual input in an environment of increasing automation.

Certainly using automation to our greatest advantage is the correct path to follow; but, it is not automation, per se, that I am questioning. Rather it is the philosophy espoused by some of how automated guidance should be used.

II. DANGER SIGNS

Some top- and middle-management people of most meteorological organizations are talking about confining forecaster efforts to the first few hours of the forecast period and letting objective guidance like that produced by the National Weather Service (NWS) and Model Output Statistics (MOS) program (Glahn and Lowry, 1972) become the prognosis for the rest of the forecast period. The following danger signs are already showing up that may be attributed to following such a philosophy:

1. Forecasters are relinquishing their meteorological input into the operational product going to the user. Forecasters are operating more as communicators and less as meteorologists. Since this practice is increasing slowly with time, it can be called "meteorological cancer". By this is meant that today's forecaster can, if he chooses, and many do, come to work, accept Numerical Weather Prognoses (NWP) and MOS guidance, put this into words, and go home. Not once does he have to use his meteorological knowledge and experience. This type of practice is taking place more and more across the United States, and it will be made easier to do with Automation of Field Operations and Services (AFOS) (NWS, 1976).

2. Enthusiasm for forecasting and job satisfaction are declining. For one thing, the current trends in the system encourage forecasters to follow guidance blindly, since a forecaster usually is criticized if he departs from guidance and is wrong, but seldom is praised for deviating from guidance and being right.

3. A decrease in the quality of some operational forecasts appear to be showing up in forecast verification data.

As I understand the current philosophy of some, it amounts to calling for current man-machine mix operational forecasts to be replaced by purely machine products except for the early hours of the forecast period. I think this is wrong! But, just because I am skeptical about the future domination of automation, this is not a denial of the recent valuable gains made in dynamic-statistical forecasting. On the contrary, it is my contention that the unique possibilities of the coming technology such as animation and effective use of on-station minicomputers will allow the human forecaster to improve his man-machine mix product in the coming years, and this includes all forecast periods out to 5 days. Management at all levels should therefore not only be encouraging but also assisting forecasters to improve on automated guidance as well as developing better objective guidance.

III. HISTORY

A recent look at history may help to clarify my position. When NWP first made its appearance in the late 1950s, many "wise old forecasters" said, "NWP will never produce a decent forecast!" History has proven these people wrong. It is a well-known fact that the tremendous increase in quality of National Meteorological Center (NMC) guidance and related operational forecasts resulted from use of automation.

Figure I shows the improvement of NMC's 30-hour surface prognoses from 1948 through 1974 when systematic verification of these prognoses was discontinued. The S_1 Score (Teweles and Wobus, 1954) was used as the evaluating scheme and is indicated on the right ordinate. An arbitrary skill percentage is given on the left ordinate. Note that after 1958, the year that automatic data processing made NWP products available in time for NMC forecasters to use them, the product improved dramatically in quality. As NWP models improved, the quality of the man-machine mix product improved.

The lack of improvement after 1969 may be the result of:

1. No significant improvement in NMC guidance after the 6-layer Primitive Euqation (PE) model became operational in 1966 plus man's inability to make more than a given finite improvement on this guidance after 3-years' experience in using it, or

2. forecasters, after 3 years, becoming impressed with the high quality of NWP guidance began decreasing their input into the final product. By 1974 the quality of the man-machine mix product had decreased because "meteorological cancer" had set in causing man's contribution to the final product to decrease. The truth probably includes some of both reasons.

Figure 2 is the verification graph of operational forecasts prepared twice daily for Chicago for three forecast periods covering roughly 36 hours. The verification system evaluates the success of both temperature and precipitation forecasts using one percent-correct figure. The interesting thing in this graph is the slight decrease in the quality of the forecasts over 6 years, then an increase the last two years. The decline may be a sign that Chicago forecasters developed "meteorological cancer", and became more reluctant to deviate from NWP and MOS guidance. The increase could be the result of improved MOS products over the past two years. I am well aware that more information is needed to have confidence in such an interpretation. For example, you can say that the significant improvement in the quality of forecasts after 1951 was due to my leaving the Chicago forecast staff at that time, while I prefer to believe that it was due to the forecast office moving into the department of meteorology building at the University of Chicago where operational forecasters and Dr. Sverre Petterssen and his staff worked in a common environment.

IV. WESTERN REGION PROGRAMS

More convincing may be the results of some new programs now being conducted in the Western Region. A year ago, our Regional Headquarters became concerned over the initial signs of "meteorological cancer" in our forecast offices. Also, talk and statistics being aired across the country in essence said that forecasters were not significantly improving on 24- and 36-hour MOS Probability of Precipitation (PoP) forecasts and MOS terminal forecasts; therefore, they should use their energies elsewhere. We believed strongly and still do that our forecasters could improve significantly on MOS guidance if they were motivated to do so, since MOS PoPs for the western part of the United States leave a lot of room for improvement. Brier Score verification (Brier and Allen, 1951) of Western Region MOS PoPs shows only a 25% improvement over climatology and a less than 20% reduction of variance.

This conviction led to our so-called MAN/MOS program which began December 1, 1975 (MacDonald, 1977). In the precipitation part of this program, we compute on a cumulative weekly basis over 6-month periods the improvement of each forecast office's Probability of Precipitation forecasts over MOS PoP guidance. We stress improvement on MOS and rank the stations against each other using percentage improvement of forecaster Brier Score over MOS Brier Score. MOS PoPs are considered a station normalizer such that it is meaningful to compare wet and dry station forecast performances. To keep the work load within reasonable bounds, forecasts for only two stations in each forecast area of responsibility are used. Results are sent to forecast offices weekly. Figure 3 is an example of the printout distributed and gives the final results of last winter's forecasts. Note that San Francisco is on top and its most significant improvement over MOS and other stations is in the 1st period. I shall refer to this later.

This program immediately promoted greater forecaster interest in MOS guidance and increased application of their own forecasting skills in using available meteorological data and guidance. The element of competition also sharpened their concern for the quality of the product being issued.

This improvement is best illustrated by looking at a comparison of winter season PoP guidance and MAN PoP forecasts using percentage improvement over climatology as our measure of success, see Figure 4. These data are combined yearly averages for all 3 forecast periods, i.e., covering a forecast period of roughly 3 to 40 hours, from 1967-68 to 1975-76. MOS guidance became available routinely in 1972. Note the improvement of MOS since the 1972-73 season, while MAN's improvements for the associated period until 1975-76 season were small. The difference between the quality of the MAN and MOS forecasts as measured by the Brier Score narrowed until December 1975. Figure 5 shows the 3rd-period forecasts made a significant contribution to the 1975-76 improvement. The slight decrease in the quality of MAN's performance in the 1974-75 season shown in this figure and the previous one could be a symptom of "meteorological cancer". However, when the emphasis by management was focused on improving MOS, forecasters were motivated to being better meteorologists and to producing the best public PoP forecasts that had ever been issued before in the Western Region. Also, the improvement over guidance in the 2nd and 3rd periods was greater than any time in the past. There is still plenty of room for improvement and we firmly believe this improvement will continue provided management at all levels including the local Meteorologist in Charge or Detachment Commander acknowledges and supports the significant improvements that MAN can make to the end product.

The other part of the Western Region's current MAN/MOS program involves terminal forecasting, which I would like to touch on briefly. We verify MAN and MOS forecasts on a cumulative monthly basis for forecast periods of 12, 18, and 24 hours. Instead of comparing the MAN forecasts directly with the MOS forecasts, each type of forecast results is displayed in a contingency table. Figure 6 gives the results of this study from March through September 1976. Seven out of nine forecast offices participated. Two or three terminals were included in each station's program with a total of 16 terminals involved. The significance of these results are two-fold:

1. Our forecasters are doing a much better job than MOS in forecasting operationally significant ceilings and visibilities of less than 1000 feet and 3 miles, i.e., the lower 3 categories.

2. The present system used in evaluating these forecasts is not measuring the important differences in the lower 3 categories between the MAN and MOS forecasts.

Looking at just the lower 3 categories of ceiling, i.e., ceilings below 1000 feet as a whole, MOS forecast only 11% of the occurrences correctly while MAN forecast the occurrence of these categories correctly 28% of the time. As for visibility, the comparison is MOS forecast category 3 or less occurrences correctly 13% of the time. MAN on the other hand forecast visibilities less than 3 miles correctly again about 1/3 of the time. If you look at the individual data for each of the 3 categories, the superiority of the MAN forecasts over MOS is even more significant. A desirable bias is near 1.0 as a bias of 1.0 indicates the condition was forecast the same number of times that it occurred. The evaluation of these forecasts according to present National Weather Service procedures (NWS, 1973) scores the MOS forecasts about the same as the MAN forecasts, i.e., they are of equal quality. It is my opinion the MAN forecasts are superior to MOS from an operational point of view.

Figure 7 summarizes where we find ourselves today. MAN alone did some good. Objective guidance alone started out poorer than MAN but gradually improved over purely manual accomplishments over the last 15 - 20 years by 10 - 20%. Our MAN-MACHINE MIX data showed a roughly 10% improvement over objective guidance. But without enlightened management that will encourage the participation of the human element to improve on objective guidance, "meteorological cancer" can be expected to erode the MAN-MACHINE MIX improvement.

V. NEW APPROACH

It seems to me that to capitalize on the great potential of both automation and the meteorologist, we need to take a different approach as to how the man should fit into the forecast system. Figure 8 attempts to summarize the present approach and our suggestion for the needed change in that approach.

Our present forecast program is to produce automated guidance and feed it to the forecaster. He uses it or passes it on to the users depending on how well he is motivated. Within this system the end result seems to me to make the forecaster obsolete. This is depicted in the top half of the figure.

Now let us consider a slightly different role of the forecaster of the future. As Dr. Klein discussed earlier this morning, we are nearing the exciting and new era of AFOS in the NWS (NWS, 1976). To me, the exciting part of AFOS is not the revolutionary change of our communication system, although this will be great help to the forecaster, but the opportunity to process selected information on the local AFOS computer. If this aspect of AFOS is designed into the system, it will open up a whole new realm of information that the forecaster can use in addition to NWP and MOS products. Thus, the forecaster interacts with automation in the process of producing a man-machine mix final operational product. Following this type of philosophy, we think that the quality of the operational product can be much improved over the man-machine mix levels of today as depicted in lower half of Figure 8.

Some of the ideas that have come to mind thus far are:

1. Running local wind or precipitation models for given limited geographical areas, such as river basins. There may be several models available and the forecaster determines which results should be used on a given day.

2. Up-to-date verification statistics of all types that can be available by punching a few buttons. Biases, trends, etc., would be used subjectively in preparing the forecast.

3. Rapid call-up of precedent weather patterns associated with critical weather occurrences.

4. Local studies.

5. Call-up of the sequence of values of significant parameters that make up the MOS forecast, so that these in addition to the final value of the MOS guidance can be evaluated at the forecaster level.

6. Animation of meteorological fields past and forecast. For example, the forecaster worried about thunderstorms might be able to discern certain changes of the surface dew-point field in a motion picture which wouldn't be evident from static chart analyses.

7. Etc.

Also, animation of satellite pictures already a reality at some forecast offices needs to be expanded. We attribute some of San Francisco's success in being the top station in our MAN/MOS program to be the result of having satellite movie loops continually available to the forecaster. (Just last week these movie loops helped the San Francisco forecaster make a spectacular forecast and improvement on 1st-period MOS PoPs.)

All of these suggestions involve the forecaster interacting with the system, not just being the recipient of processed data.

One final thought, if we ask a forecaster to just accept automated guidance until a critical situation arises, can he be expected to perform well? Isn't this analogous to asking an athlete to produce in pressure game situations without ever practicing? In this regard, I want to share with you part of a letter received recently from Mr. J. S. Sawyer, retired member of the British Meteorological Service, and one who made significant contributions to numerical weather prediction.

> *"I sometimes regret that with the coming of numerical weather prediction and a generally greater pressure on time in the forecast room, the daily map discussions have ceased. Although the forecasters are still taught Sutcliffe's thickness theory in training, I wonder whether they acquire the same insight into the way the atmosphere works that we gained from talking it over daily."*

VI. CONCLUSION

In conclusion, I forecast that if the MAN is kept as an integral part of the preparation of operational forecasts for all forecast periods, the improvement of quality of those forecasts will be as depicted schematically in Figures 9 and 10. As MOS improves, the forecaster's end product will improve. When the finer mesh models become operational, NWP products should improve and the forecaster will have better guidance. Finally, AFOS with its great advantages, mostly the local minicomputer, will give the forecaster greater latitude in using his meteorological knowledge thereby resulting in improved operational forecasts. In this regard, the Western Region is already moving in this direction by encouraging and helping our forecasters that are colocated with a minicomputer used for radiosonde computations, to write and use programs that will help them produce operational forecasts.

Should MAN be legislated out of much of the forecasting process or not be continually motivated to stay as an active and important part of the process, "meteorological cancer" can be expected to grow rapidly, and the quality of the final operational forecast to suffer significantly.

There exists tremendous potential for improvement of forecasting in the coming years: certainly much improvement can be expected to come from advances in data collection, modeling, and statistical output. However, to proceed on the assumption that the human element in forecasting is becoming obsolete would be closing our eyes to golden opportunities afforded by new technologies: it is a mistake we cannot afford to make.

VII. ACKNOWLEDGMENTS

The Western Region MAN/MOS program could not have been carried out without the ingenuity of Dr. Alexander MacDonald in designing, writing, and supervising the computer program used. I would like to also recognize the important input of my Scientific Services Division staff, Richard Wagoner, Alexander MacDonald, John Jannuzzi, and James Fors for their suggestions and/or assistance in crystalizing of ideas presented; and to my secretary, Evelyn Allan, for her seemingly endless need to type drafts and manuscripts. David Cook is responsible for the excellent drafting of the figures.

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NMC 30-Hour Surface Prognostic Charts 1948–1974

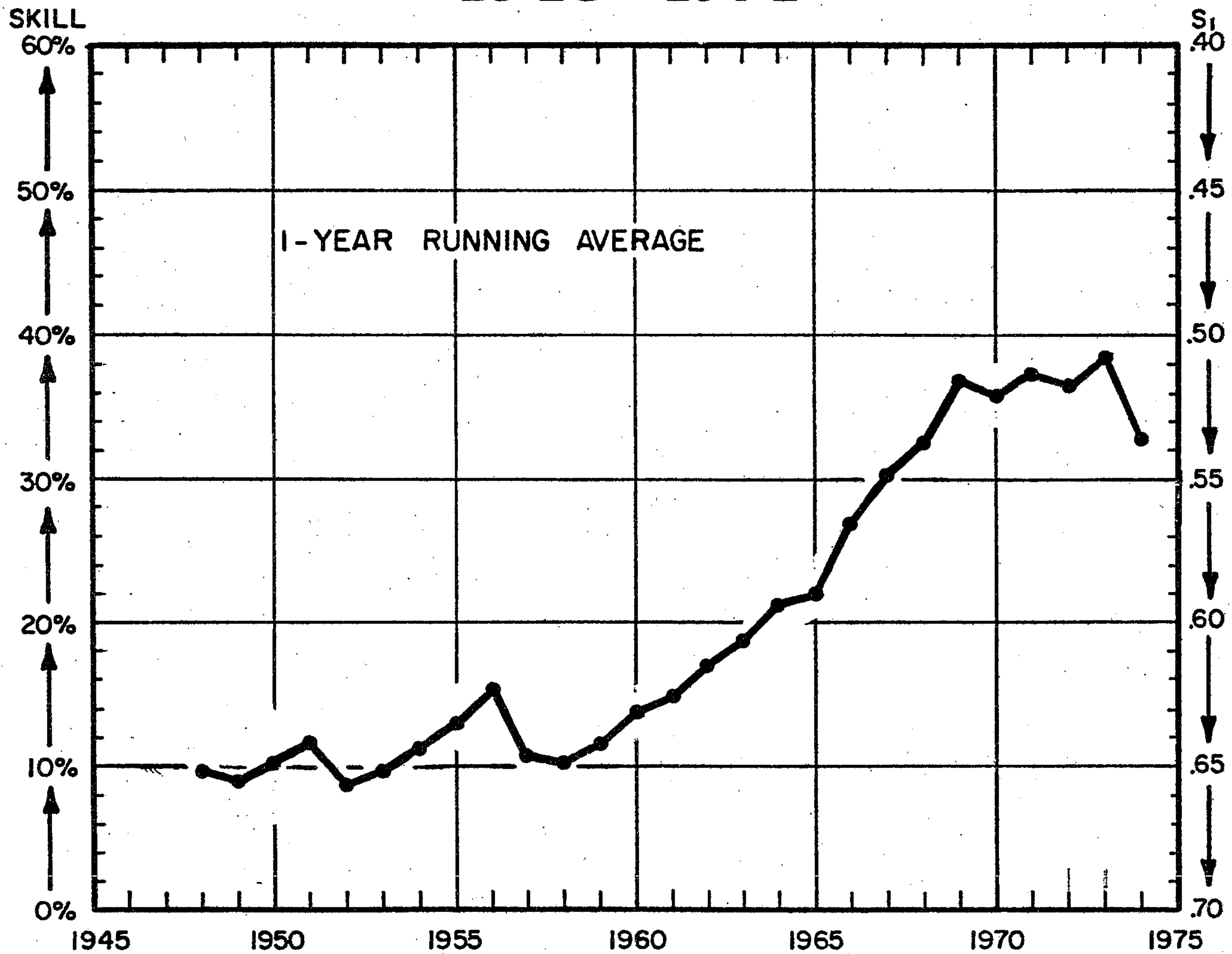

Figure 1. Graph of yearly averaged S| verification scores of NMC 30-hour man-machine mix surface prognostic charts from 1948 through 1974. Skill score on left is based on an S| score of 70 indicating no skill, and S| = 20 as 100% skill. (S| = 70 is average score of 30-hour persistence of surface pressure pattern. S| = 20 is average score when analyses of same data by two different analysts are scored.)

Percentage Of Correct Weather & Temperature Forecasts
Chicago, Illinois
1942-1976

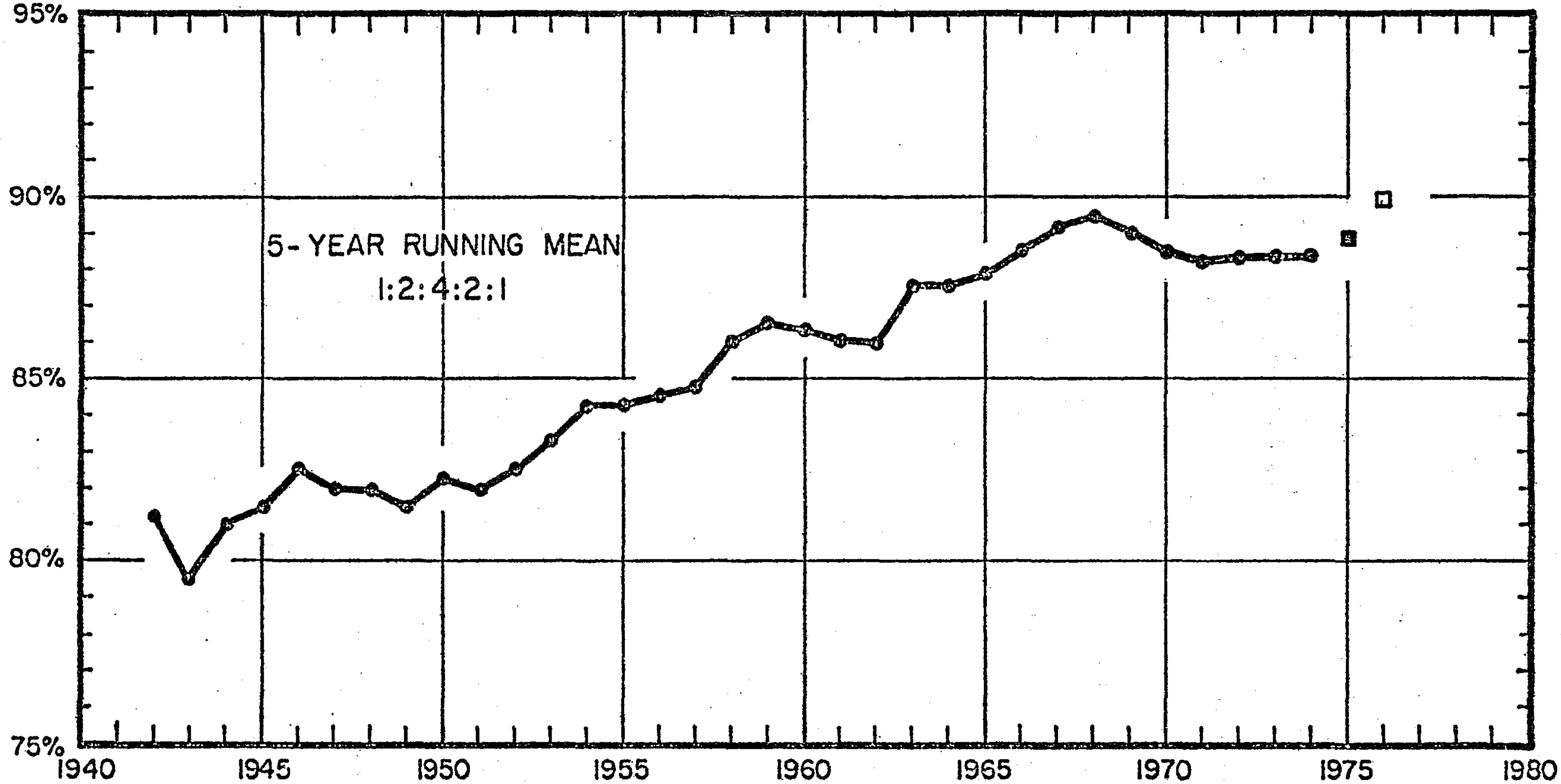

Figure 2. Graph of smoothed annual average of percent-correct forecasts of temperature and precipitation. The black square is a 3-year weighted average (1:2:1) and the open square just 1976 data.

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

Figure 3. Computer printout of final MAN/MOS PoPs verification results for the period December 1975 through March 29, 1976. Modified Brier Score is given in first two columns of each forecast-period data set. FCST is man's score and MOS is objective forecast score. Third column is percentage improvement of FCST over MOS Brier Score. N column is sample size. WSFO standings give ranking of station by forecast period using percent improvement over MOS. The TOTAL table is result when data for all three forecast periods are combined. Period 1 is 0 to 12-hour forecast; Period 2, 12 to 24 hours, and Period 3, 24 to 36 hours.

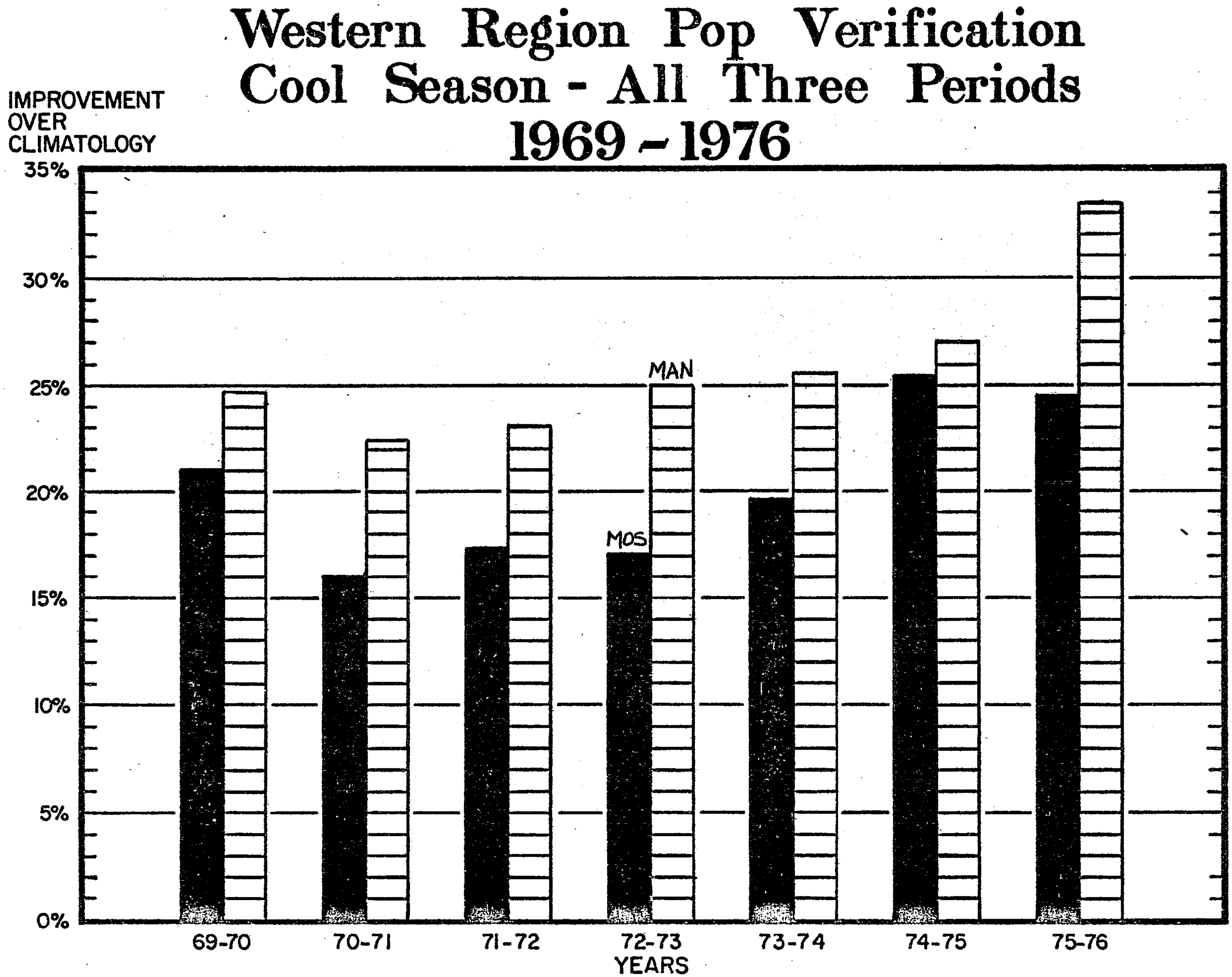

Figure 4. Comparison of December through March averages of NMC PoP guidance and field forecaster PoPs using the Brier Score and percentage over climatology. MOS guidance is indicated from 1972-73 through 1975-76. The data samples for each year are for all three forecast periods but number stations included are not identical for each year. Only the 18 MAN/MOS stations were used to get 1975-76 percentages. However, the comparison is still considered valid.

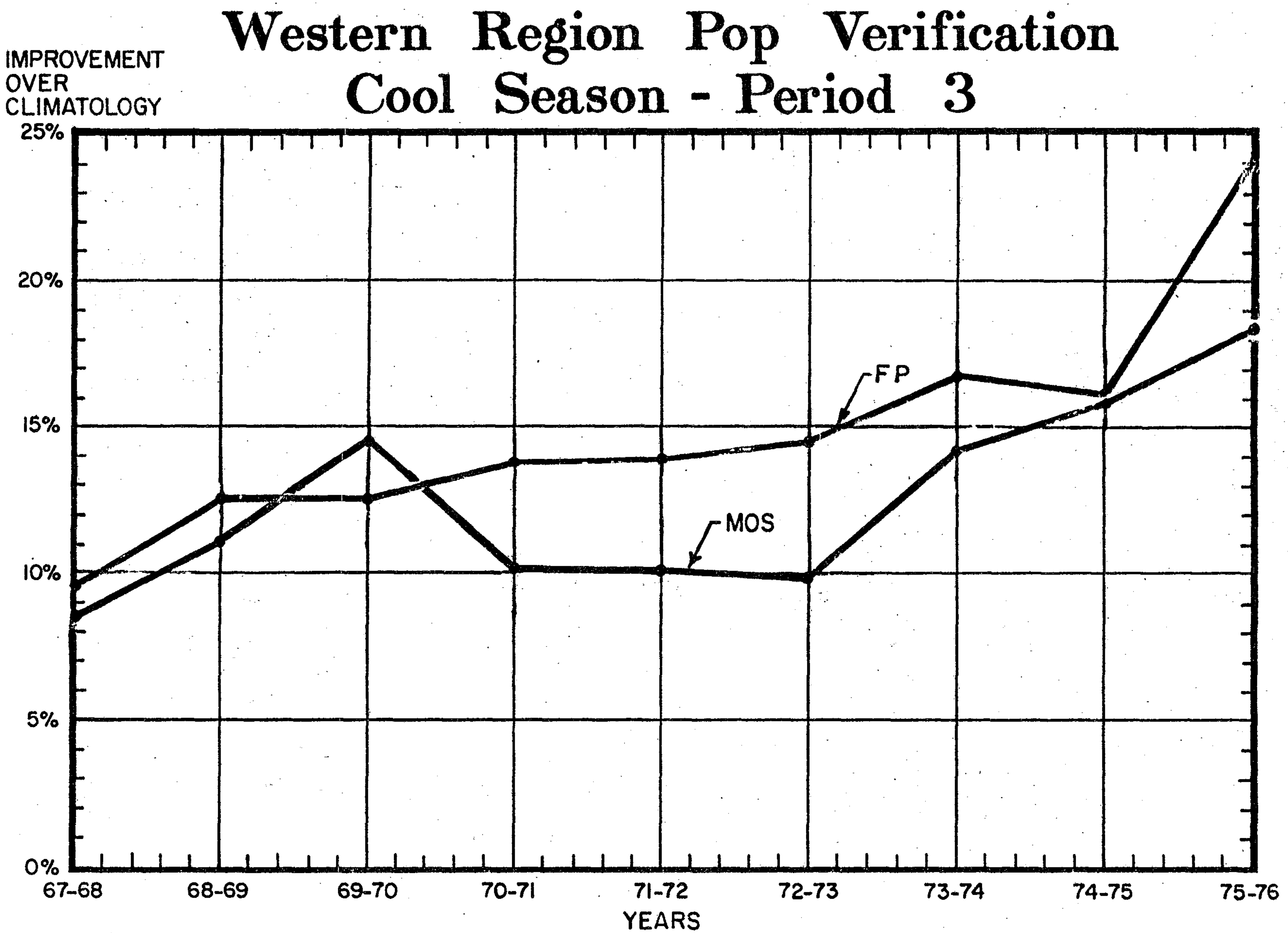

Figure 5. Same as Figure 4, except only 3rd-period data used.

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	138	464
3	8	52	154	181	269	664
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	558	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	26	19	80	162	413	700
4	8	7	33	163	638	849
5	16	25	111	287	25195	25634
TOTAL	159	105	295	692	26620	27871
BIAS	.33	.51	.42	.82	1.04	

PER CENT CORRECT: 91.65

SCORE: 67.13

Figure 6. Computer printout of verification results as contingency tables for MAN and MOS terminal forecasts involving 16 stations and 7 forecast offices. Period March 1st through December 31st, 1976. Forecast verified were for 12, 24, and 36 hours. Categories are: 1 = ≤100 ft.: ≤3/8 mi.; 2 = 200-400 ft.: 1/2-7/8 mi.; 3 = 500-900 ft.: 1 - 2-1/2 mi.; 4 = 1000-1900 ft.: 3 - 4 mi.; 5 = ≥2000 ft.: ≥5 mi. Score is NWS Aviation Verification Score.

Schematic Improvement Of Forecast Products

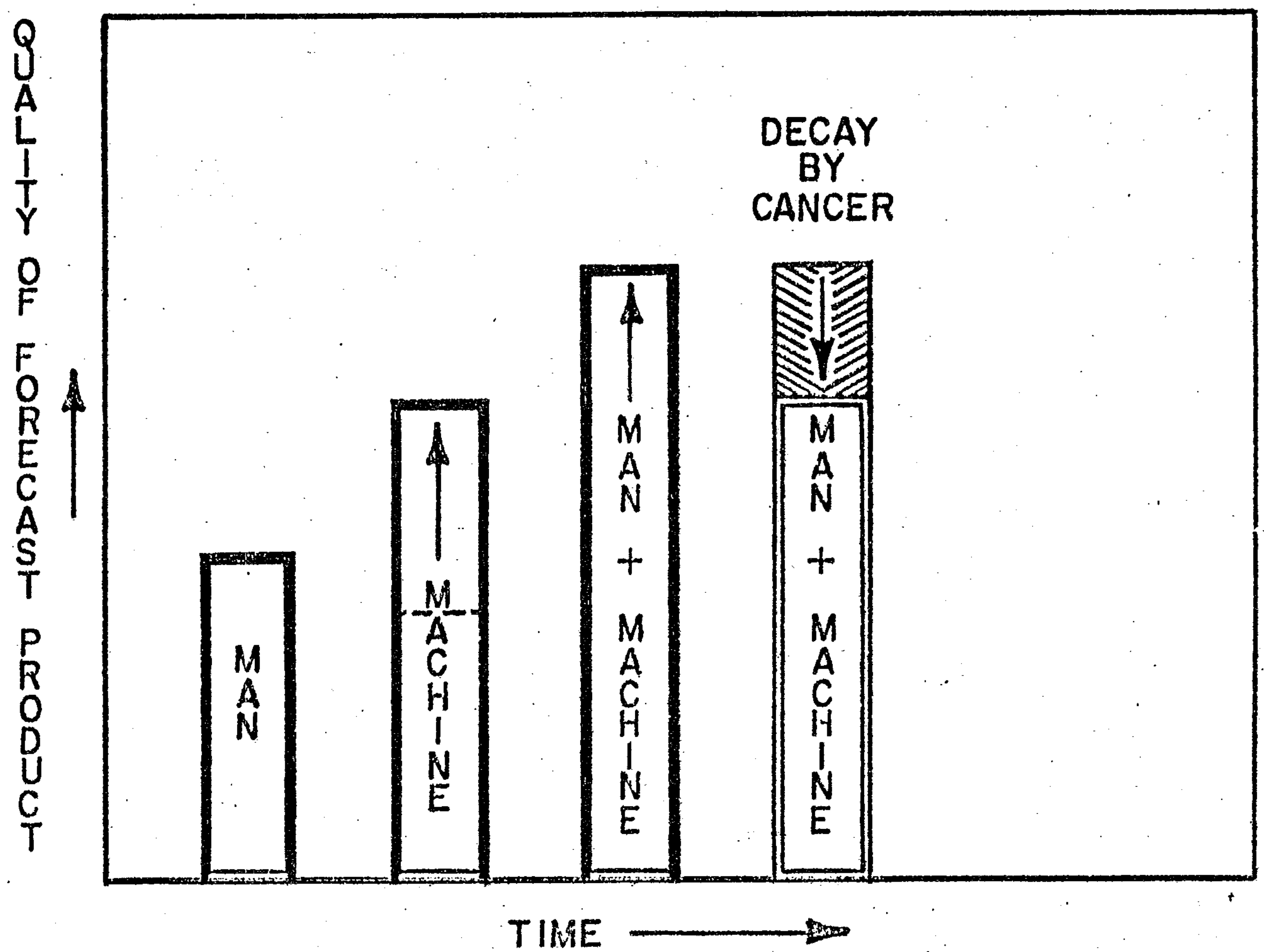

Figure 7. Qualitative graph of skill of operational weather forecasts. Dashed line in machine bar is to indicate quality of pure machine forecasts was initially poorer than pure manual forecasts.

Forecast Production Systems

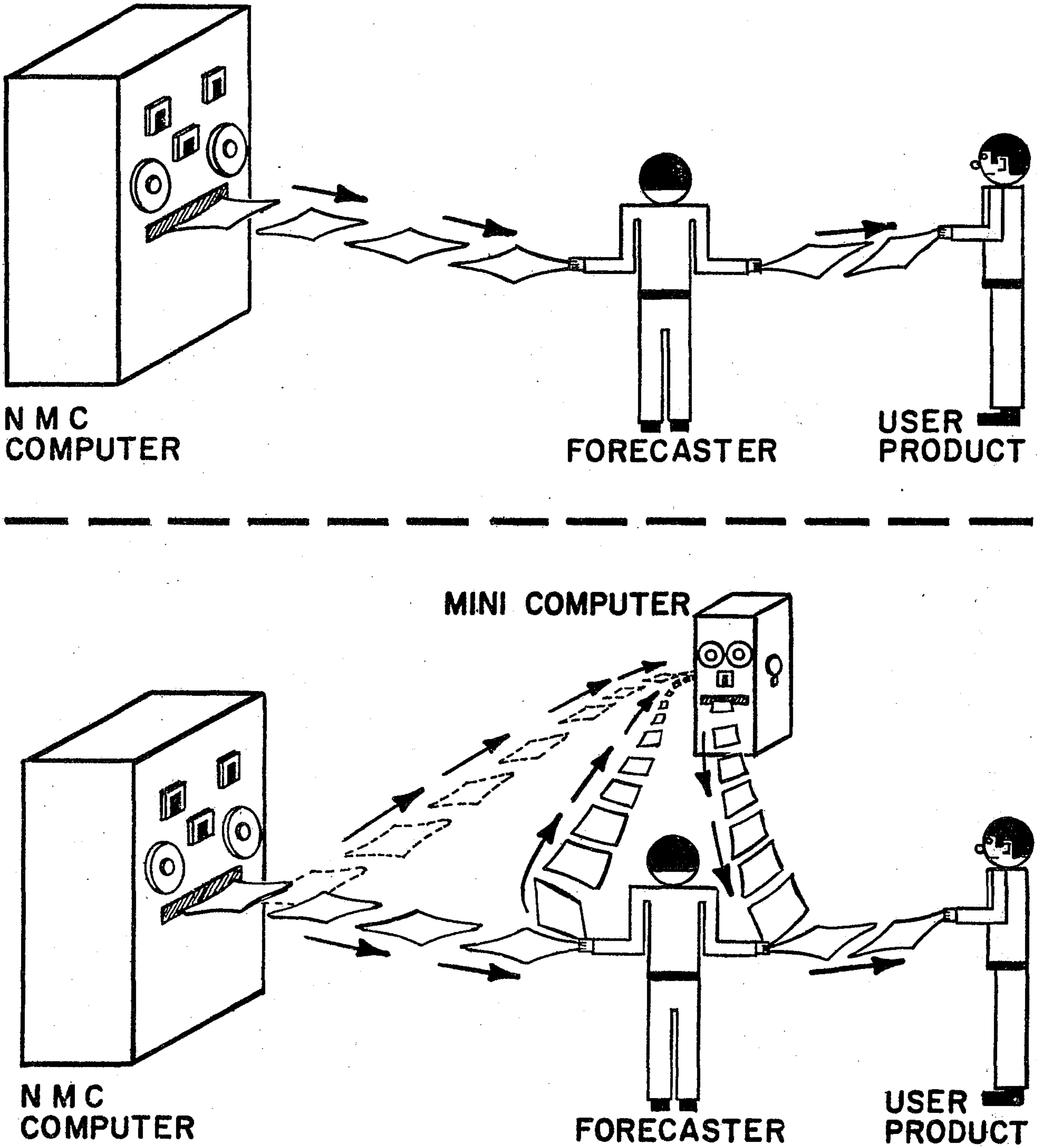

Figure 8. Schematic diagram representing the flow of forecast and guidance information from the NMC computer to the user.

Schematic Improvement Of Forecast Products

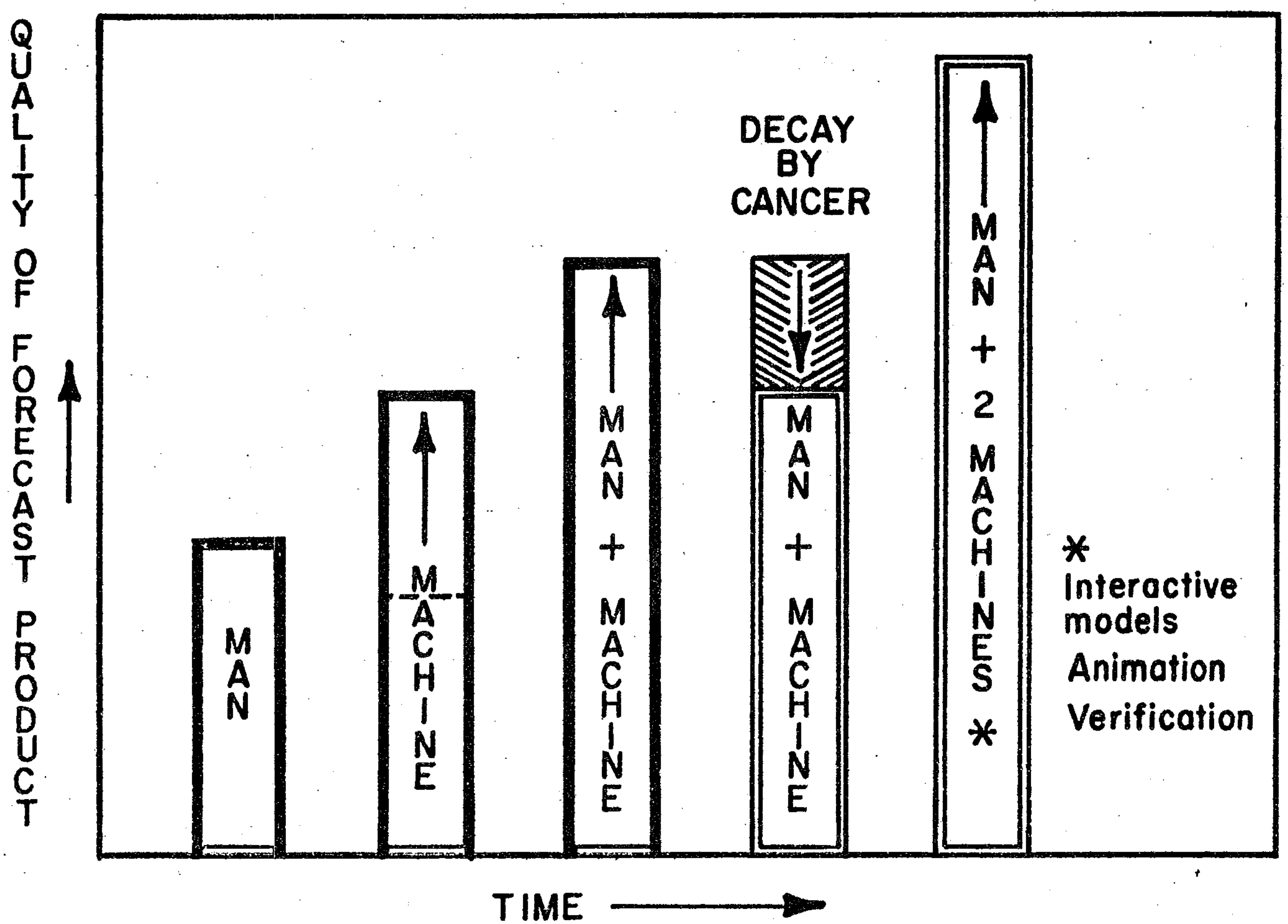

Figure 9. Same as Figure 7, with an added bar giving quality of forecasts expected when the production system given in bottom of Figure 8 is used.

Schematic Diagram of Improvement in Applied Forecasting 1954 - 1990

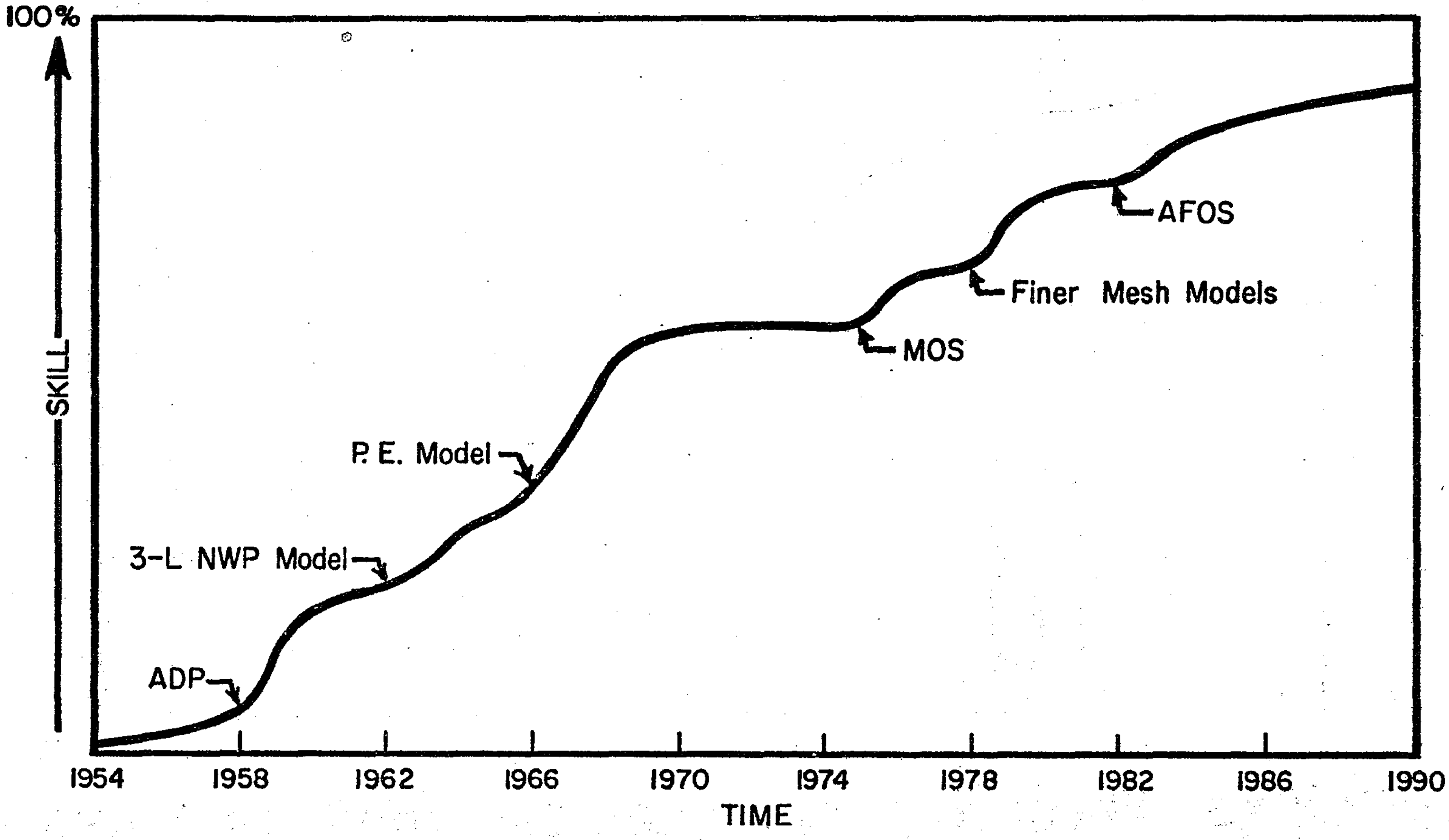

Figure 10. Schematic graph of observed (1954-1976) and forecast (1977-1990) improvement of operational weather forecasts. Suggested reasons for improvement are indicated.

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