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Western Region

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Man-Machine Mix in Applied Weather Forecasting in the 1970's

L. W. SNELLMAN

Technical Memorandum WBTM WR-40

U.S. DEPARTMENT OF COMMERCE / ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION

WESTERN REGION TECHNICAL MEMORANDA

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

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

Weather Bureau Technical Memorandum WR-40

THE MAN-MACHINE MIX IN APPLIED WEATHER FORECASTING IN THE 1970S

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PREFACE

This paper was presented at the USAF Air Weather Service 1969 Meteorological Technical Exchange Conference at the U. S. Air Force Academy, July 16, 1969, as one of four invited papers on "Automation and Applied Weather Forecasting". We are publishing it as a Technical Memorandum because of the interest, and in some cases concern, of forecasters over the roles of man and machine in operational forecasting in the next decade.

L. W. Snellman

L. W. Snellman, Chief
Scientific Services Division

THE MAN-MACHINE MIX IN APPLIED WEATHER FORECASTING IN THE 1970S

ABSTRACT

Significant improvement in some phases of operational forecasting over the past several years is demonstrated and is attributed to the transition from a totally manual to a "man-machine-mix" operation. This is used as the departure point in discussing expected changes in current forecasting practice over the next several years. The "man-machine mix" has been replaced by a machine product only if the quality of this end product is comparable or better than the "man-machine-mix" product. The number of machine-produced products which are directly suitable for users is rather limited, and it is difficult to see how this number will increase significantly in the next several years. Therefore, the conclusion is reached that while most centrally prepared forecast guidance for field forecasters may soon be a purely machine product, man will provide an important input into improved weather services in the preparation of short-period general public forecasts, specialized user forecasts, and warnings. This conclusion is discussed in light of recent atmospheric predictability studies and the lack of success to date of machine aviation terminal forecasting.

I. INTRODUCTION

In approaching this very challenging topic of man-machine mix, I decided to touch base with my counterparts in other regions of the Weather Bureau* as well as with Mr. Charles Roberts at Weather Bureau Headquarters and Mr. Beckwith of United Airlines. I was pleasantly surprised to see the more or less unanimity of opinion of their ideas of the role of man and machine in applied weather forecasting in the 1970s. The surprise was pleasant because their ideas were in close consonance with mine. However, the views expressed in this paper are mine and should not be considered as representing Weather Bureau policy.

To explore these ideas, I shall look back briefly into history to show the effects of machines (computers) on applied weather forecasting. From this history we can glean some ideas on which to base a projection of operations in the 1970s.

*Responses from the regions came from Mr. Carlstead in Hawaii, Dr. Diemer in Alaska, and Mr. Dunn in New York.

II. PREPARATION OF A FORECAST

Preparation of applied weather forecasts went through a large change during the 1960s. At the beginning of this decade, forecast preparation was mainly a one-man effort, with most forecasters using the analytic rather than prognostic NMC facsimile output. As prognostic charts from the computer improved, forecasters gradually shifted their attention to prognostic charts. Today the final forecast is the result of a team effort of the National Meteorological Center and field forecaster. Since a large percentage of present prognostic guidance from NMC is a man-machine-mix product, we can represent today's applied forecast procedure as:

$$(\text{Man})^2 + \text{Machine} = \text{Final Forecast}.$$

It might be better to change the plus sign to a times sign to give the machine term due weight. But the important point here is that the final weather forecast of today is prepared manually, based to a large extent on man-machine-mix centralized guidance material.

Certainly this team, consisting of a major forecast center (i.e., NMC) and the local station, will continue to be the combination that produces our weather service throughout most, if not all, of the 1970s. Figure 1 attempts to give a graphic summarization of this conclusion.

III. CONTRIBUTION OF COMPUTERS TO APPLIED WEATHER FORECASTING

The computer made strong inroads into this team operation with the establishment of JNWP in 1954. Figure 2 summarizes the change from a purely manual team operation to today's man-machine mix. It really wasn't until after automatic data processing (ADP) became operational in 1958 that the computer had much impact on the operational forecast. By the advent of 1969 both upper-air analyses and prognoses issued by NMC were largely computer-produced, with the main manual production being surface analysis and prediction and "weather" forecast guidance.

Machine techniques are not yet being used in field forecast offices to any significant extent, i.e. $<10\%$. Two of the major drawbacks to more automated field operations at present are economic limitations and lack of appropriate automated techniques. However, there are tests now under way and plans on the drawing board which suggest that this situation will change rather soon; and I shall speak to this point later. Nonetheless, incorporating the machine into centralized operational forecasting procedures during the 1960s significantly increased the quality of forecasts issued by local stations.

Figure 3 shows the dramatic improvement in accuracy after 1958 in NMC's man-machine-mix 30-hour surface prognostic charts. Prior to 1958 this NMC product was based on subjective techniques and forecaster experience. Today it is based largely on machine prognoses.

Figure 4 shows the improvement that NMC makes on the machine-produced P.E. surface prognostic chart. The first point of interest is that greater improvements are made in summer than in winter, and second is that man's improvements are getting fewer with time (i.e., fewer as the machine product improves).

Improvements in operational weather forecasts closely parallel improvements in NMC machine and man-machine-mix weather guidance. Figure 5 shows the verification of local weather forecasts (temperature and precipitation) prepared routinely at Chicago from 1940 through 1968. Improvement after 1958 is related to operational ADP, after 1962 to Cressman's 3-L model, and after 1966 to NMC's use of Shuman's operational P.E. model. Figure 6 shows the dramatic reduction in gross maximum-temperature errors ($\geq 10°$) for tomorrow (essentially a 36-hour forecast) at Salt Lake City. This reduction is attributed to use of NMC's machine and man-machine-mix improved guidance.

An important point to keep in mind, however, is that the man--especially the field forecaster--has been making a significant improvement over the temperature forecast guidance he receives. Figures 7a and 7b give the latest data available published by the Weather Bureau. Note especially the higher percentage of large errors by NMC as compared to Western Region local stations. These large forecast errors are most significant to the user. Precipitation verification results for the same period show only slight improvement over NMC by our local stations in the first 12-hour forecast period and no significant improvement for the second and third periods [1].

IV. TWO TYPES OF MACHINE PRODUCTS

At this time we should distinguish between the two types of computer products available; namely, a final forecast ready for direct use, and a prognostic product that is used as guidance in preparing the final forecast for a user. Present machine forecasts of upper winds and temperatures are used directly by aviation users. Viewed from an aviation support point of view, the computer makes this forecast and man is eliminated. However, viewed from the public, fire weather, etc., support point of view, the computer has provided only guidance for preparation of the final forecast. Thus computers are useful as forecasters per se if, and only if, fixed programs give a forecast to the user in final form [2]. There are very few computer-produced forecasts of this type at present, and I do not expect their number to increase significantly in the next five years.

The remaining computer output is termed guidance. To make this guidance useful involves one or more of the following manual processes: putting the forecast in user language, integrating the guidance with information not available to the computer (i.e., later data, local data, and small-scale analysis which take into account local orographic effects), updating and detailing the forecast by use of radar observations, etc. Involved then are such manual tasks as using guidance in preparing spot fire-weather forecasts, making weather forecasts for the public, detailing areas of heavy-snow accumulation, determining time of arrival of squall lines, defining local air-pollution potentials, etc. This list is long now, and it seems to me it will get longer in the 1970s as improved applied weather forecasts result in increasing application of meteorological predictions to business and other activities. Reasoning along these lines, it is then easy to expect that in the 70s all meteorological products emanating from NMC will gradually become purely machine products; but the final weather service will be a man-machine mix with the man predominating. This is depicted schematically in Figure 8.

V. MAN-MACHINE MIX AT FIELD FORECAST OFFICE

Assuming that within the next five years NWP developments will result in approximately a 100% machine output of meteorological products by NMC, what will these products be, and what impact will they have on the man-machine-mix operation in the field forecast office?

First, it seems logical to assume that global models using smaller mesh lengths or some type of spherical harmonic analysis will be developed to improve the accuracy of present predictions and to add more detail to flow patterns. Availability and operational use of SIRS and IRIS satellite data, planned for FY72, should supply data necessary to support these finer mesh global NWP models (see Figure 9).

Second, as meteorological predictions improve with such models, the demands for weather service on field forecast offices will increase. These demands for the most part will be for forecasts of details and parameters that we are not likely to get from the computer; or if we could get such forecasts from the computer, they are not likely to be timely. Also, using a computer may not be an efficient way of performing this weather service. For example, it is difficult for me to see how NMC computer products can handle the small-scale short-period forecast, including both routine and severe weather phenomena such as squall lines, heavy snows, etc. Also, radar observations will certainly make manual input to such weather service important in the foreseeable future.

I think that there is evidence to support this point of view in the recent studies of predictability by Robinson [3] and Lorenz [4]. Weather phenomena have characteristic scales or dimensions in space and, similarly, they have typical periods and durations in time. It turns out that a large number of significant weather occurrences of importance to the public are of a fairly small scale and relatively short duration. The squall line that recently caused so much trouble in Cleveland is a case in point.

It has been known for some time that smaller scale phenomena are generally less predictable than larger scale systems, and Robinson and Lorenz have shown a rather direct relationship between scale and predictability.

Figure 10 illustrates their general findings in the form of a predictability diagram. The ordinate is forecast period or length of the prediction, and the abscissa is the space scale which the forecast is to resolve. For scales and forecast periods lying below and to the right of the cross-hatched zone, theory suggests that deterministic prediction is practical in principle. The cross-hatched area lying above and left of the zone contains periods and scales which must be regarded as predictable only in a statistical sense.

The general pattern suggested is: clouds and precipitation produced by disturbances of the order of 10 degrees latitude in wave length are predictable by deterministic methods for periods up to 1 to 2 days in advance. The convective shower, representing a cell of very heavy precipitation triggered by the larger disturbance, may be predicted deterministically for periods up to 30 minutes and probabilistically for as long as the large-scale system can be predicted.

If the above analysis is correct, it is obvious that deterministic predictions of weather elements and systems that are required for reliable local weather forecasting are limited in time range.

Further it suggests that with the network data processed by the computer now and in the future, and relatively limited capacity of computers expected to be available in the 70s, we should not expect much help from NMC within the 6 - 12 hour forecast period. Our efforts then should be directed, as advocated by Roberts [5], to having the local forecast office develop conditional climatological studies relating computer-produced forecast parameters to specific user problems. I think such conditional climatology studies are needed for general public forecasts to take into account orographic effects in western United States. This reasoning also applies to terminal forecasting. Attempts at automating aviation terminal forecasts over the past ten years have been characterized by little or no success, and there is no reason to believe that there will be much success in the next five years. As a matter of fact, the Weather Bureau is considering curtailing efforts in this area because of the low probability of success in the next several years [6].

The computer should be making some inroads into station operations that will increase the quality of weather service currently given. At a recent Weather Bureau conference, it was suggested that we work toward linking several of the larger forecast offices to the computers at NMC [7]. With such a link, a station could request machine plots of the latest data, possibly every hour, for detailed analysis by station forecasters, or an evaluation of several objective studies, the results of which could be flashed to the local forecaster. This latter capability could be an important step forward since there are many useful studies available, but timewise it is impossible for a forecaster to evaluate them during preparation of an operational forecast. Consequently, he uses only those studies that can be applied quickly to phenomena that he has thought about. When the computer can compute all of the studies for him, there is less chance that an important facet of the weather, such as canyon winds, first snow of the season, etc., will be overlooked. Another important operation that this computer link will permit is hourly screening of terminal forecasts. As each hour's data come in, the computer can evaluate the unexpired portion of the existing terminal forecasts by use of conditional climatologies, and/or those few local terminal studies that may be helpful to "red flag" those forecasts that may be going "bad" in an hour or two. Such use of the computer should provide more timely amendments and reverse the usual procedure of issuing amendments after the forecast has "busted" rather than before.

Message composition by use of a computer and CRT tube certainly seems to be a strong possibility in the near future. There is a procedure whereby you compose, revise, rearrange, etc., a written meteorological release on a CRT tube; and once you are satisfied with it, you push a button and it is disseminated. This eliminates using a typewriter or preparing a transmission tape. I understand a test of this type of procedure was begun at Suitland early this July.

I think one of the big manual efforts in preparing final weather forecasts will come through use of data from geostationary satellites. It seems reasonable to expect by the middle 1970s that at least in larger Weather Bureau forecast offices we shall have what I call satellite "Instant Replay" capability. By this I mean the forecaster has satellite receiving equipment which will permit him to study time-lapse movies of cloud changes in his area of interest that have taken place over the past 3 to 24 hours. This is similar to the operational film-loop technique being tested at NMC and NESC presently.

This opportunity of studying cloud changes in some detail in real time will be especially helpful in preparing short-range forecasts and will lead to a better understanding of existing conditions at the time the forecast is being prepared. This conclusion is based on my belief that short-range forecasting presently is more a diagnostic rather than prognostic problem. In light of previous comments on predictability of the atmosphere, it also appears to me that short-period forecasts up to 12 hours will continue to remain more diagnostic than prognostic problems.

Although the computer will greatly assist the local forecaster in processing data, etc., [8], it will take a man to be responsive to users' versatile requirements. I envision the computer making only modest inroads on applied forecasting procedures at field stations through the 1970s (see Figure 8). While the manual input of forecasts and forecast guidance issued at NMC should gradually decrease to near zero, the role of man at the forecast office will remain paramount. His role will change gradually from one of evaluating centralized NMC predictions to one of accepting this guidance and adapting it to meet local area user requirements. This service-oriented role of the meteorologist--if he is trained both psychologically and academically for this job--should be challenging and rewarding. While the guidance he gets will not be perfect, it will be much improved over current guidance (see Figure 9) and will result in much improved man-machine-mix applied forecasts.

VI. REFERENCES

[1] C. F. Roberts, et al - "Report on Weather Bureau Forecast Performance 1967-68 and Comparison with Previous Years". ESSA Technical Memorandum WBTM FCST 11, March 1969, pp. 33-44.

[2] E. D. Diemer - Personal Communication dated April 10, 1969.

[3] G. R. Robinson - "Some Current Problems for Global Meteorological Observations and Experiments", Quarterly Journal of RMS, 1967. Vol. 93, pp. 409-418.

[4] E. Lorenz - "The Predictability of Flow Which Possesses Many Scales of Motion". Manuscript of scientific report by Massachusetts Institute of Technology, 1969.

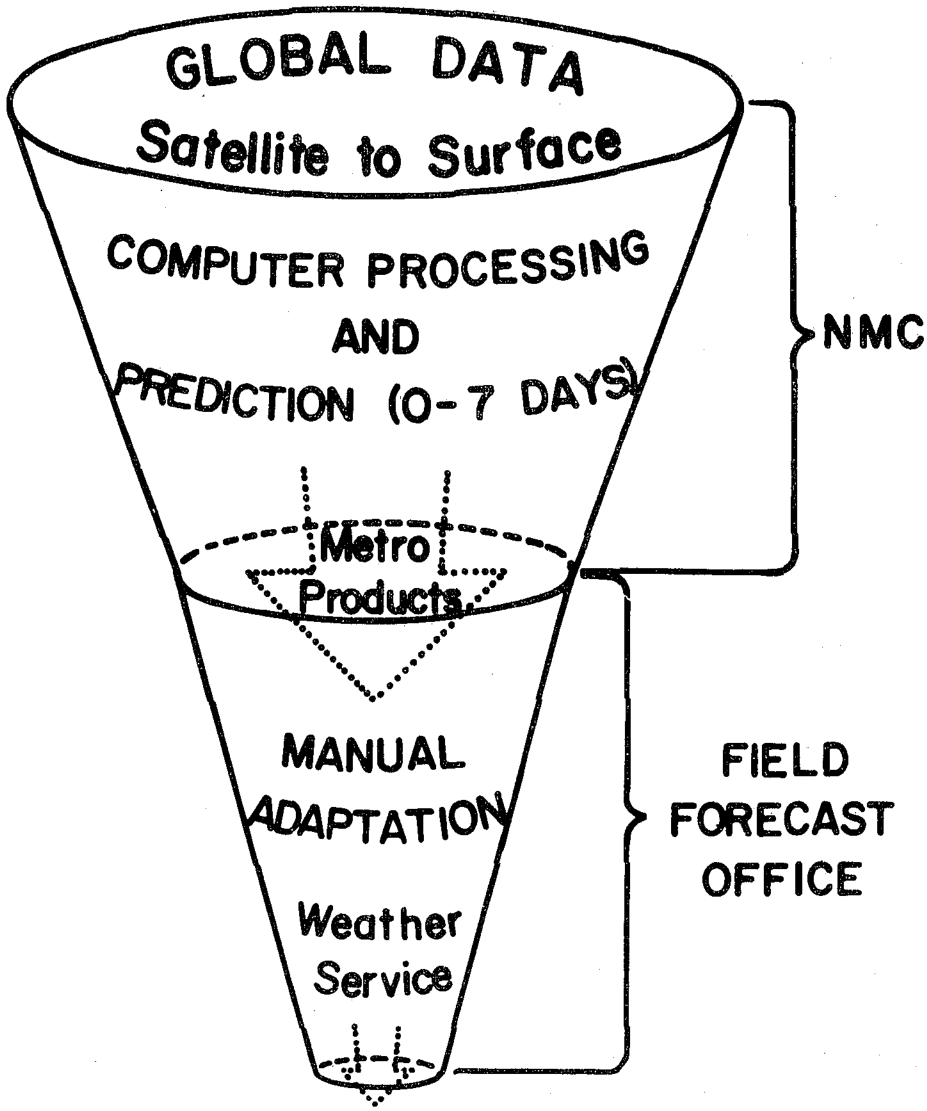
[5] C. F. Roberts - "Improving the Utility of the National Weather Service Within the Framework of the New Forecast Organization", Unpublished U. S. Weather Bureau Manuscript, 1969.

[6] "Techniques Development Laboratory" - Monthly Progress Report - U. S. Weather Bureau, May 1969.

[7] "Report of the 1969 SSD Conference - April 28, 29, 30, and May 1" - Compiled by the U. S. Weather Bureau Technical Procedures Branch - May 1969, pp. 18-21.

[8] E. M. Carlstead - "Thoughts on Man/Machine Mix in Weather Services", Personal Communication dated June 2, 1969.

FORECAST FUNNEL



Applied Weather Forecast

Fig. 1

MAN-MACHINE MIX IN OPERATIONAL WEATHER FORECASTING

1950 — 1969

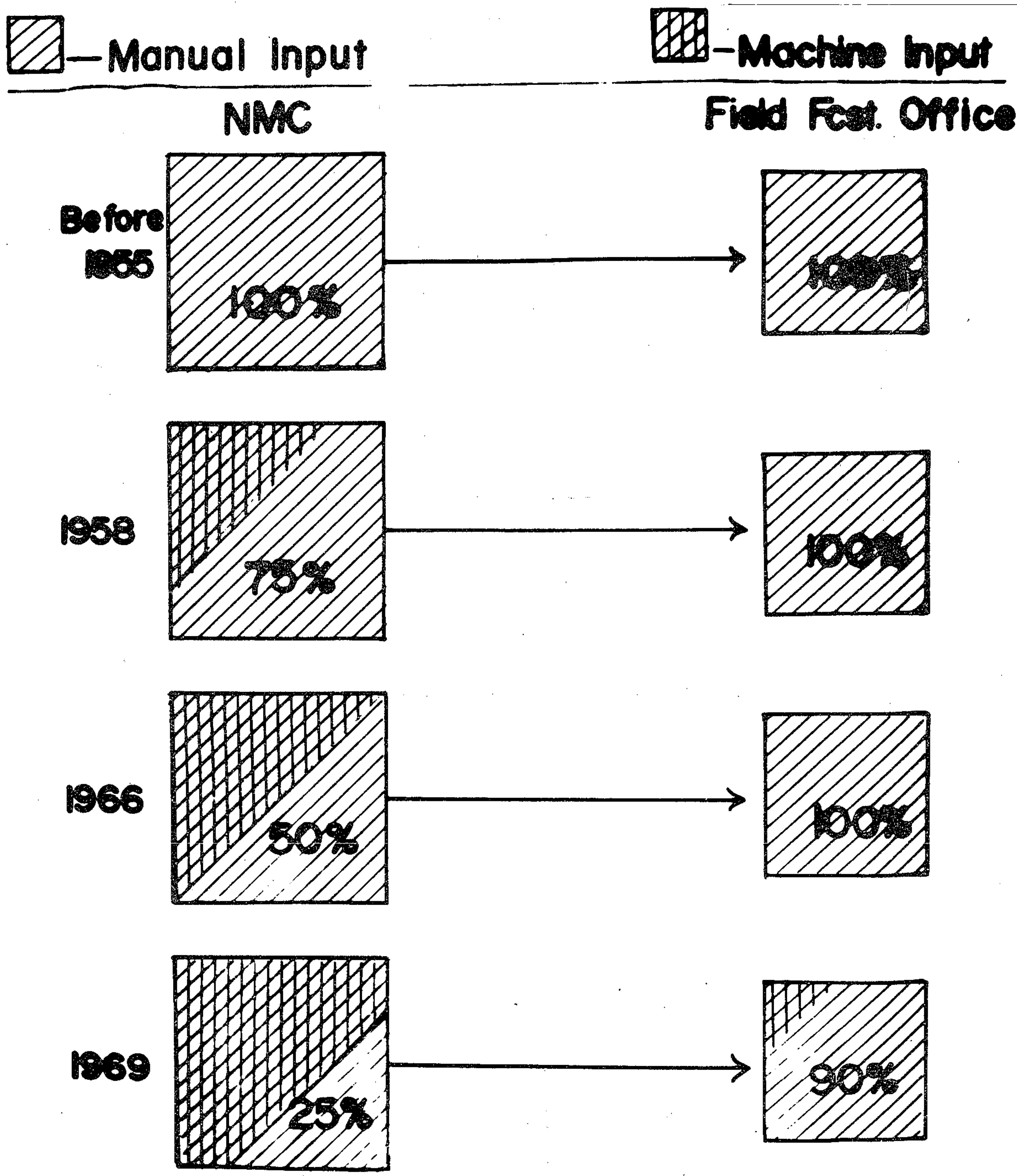


Fig. 2.

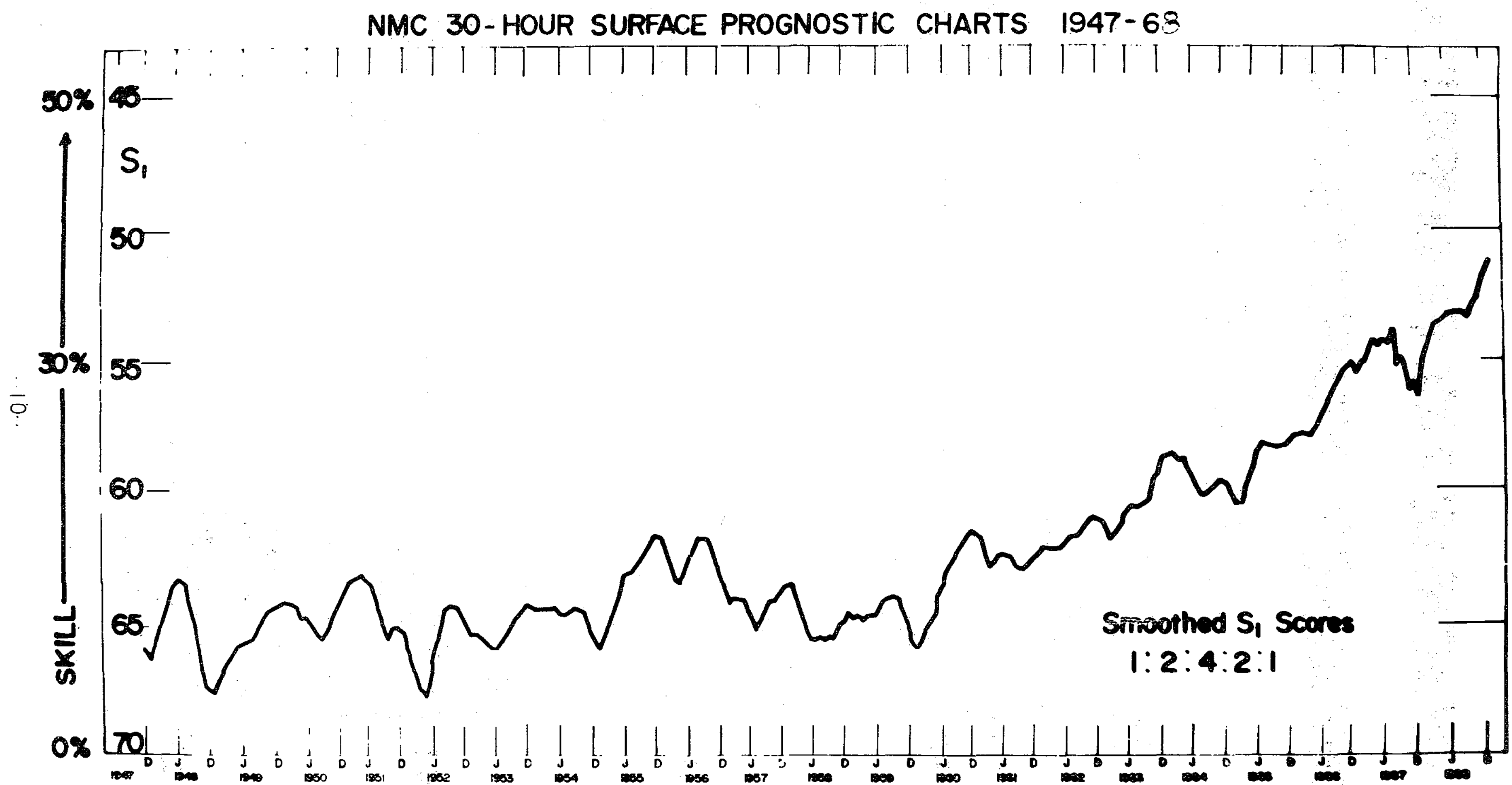

NMC 30-HOUR SURFACE PROGNOSTIC CHARTS 1947-68
50%
30%
0%
SKILL
S₁
45
50
55
60
65
70
Smoothed S₁ Scores
1:2:4:2:1
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968

Fig. 3

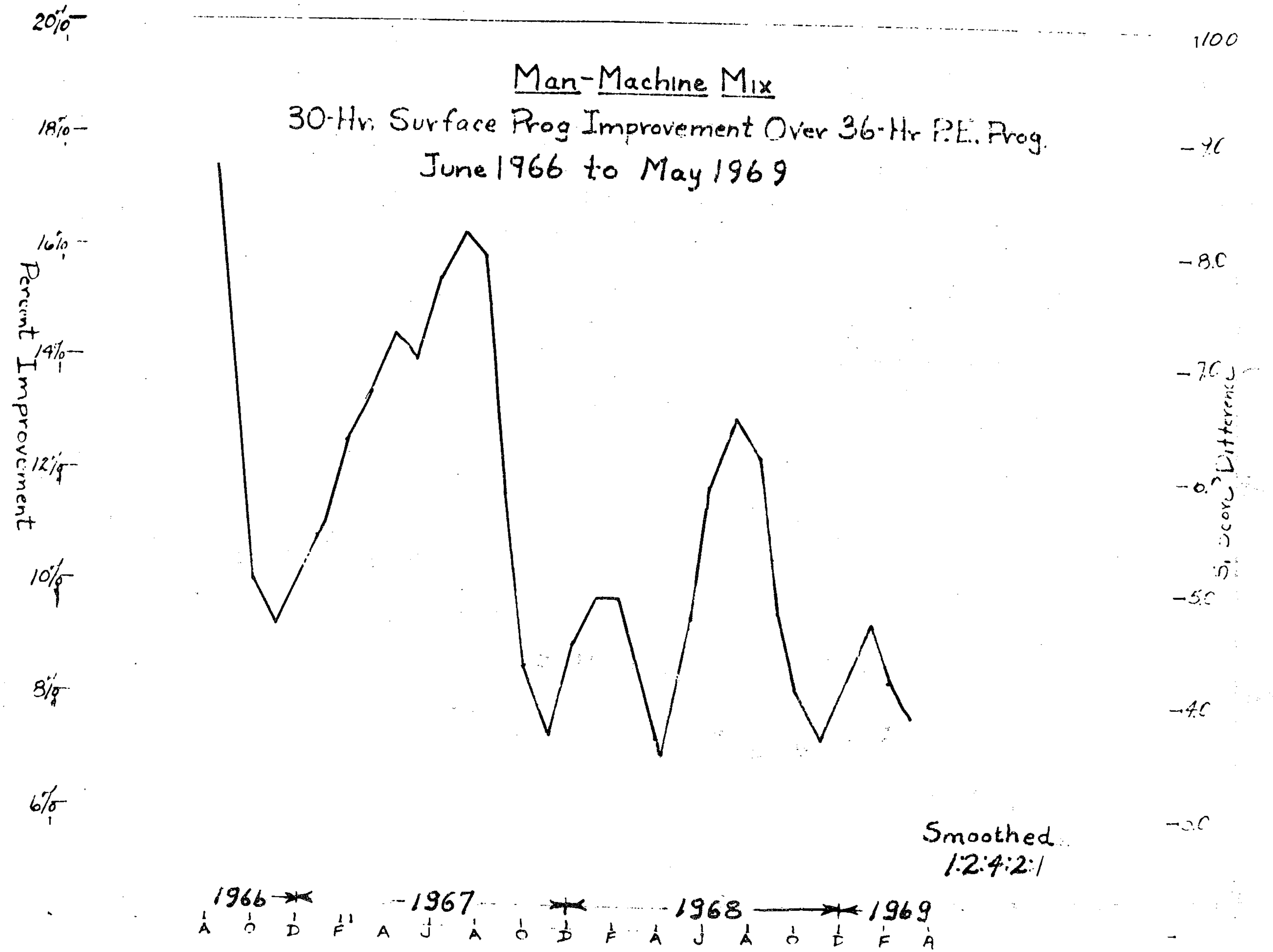
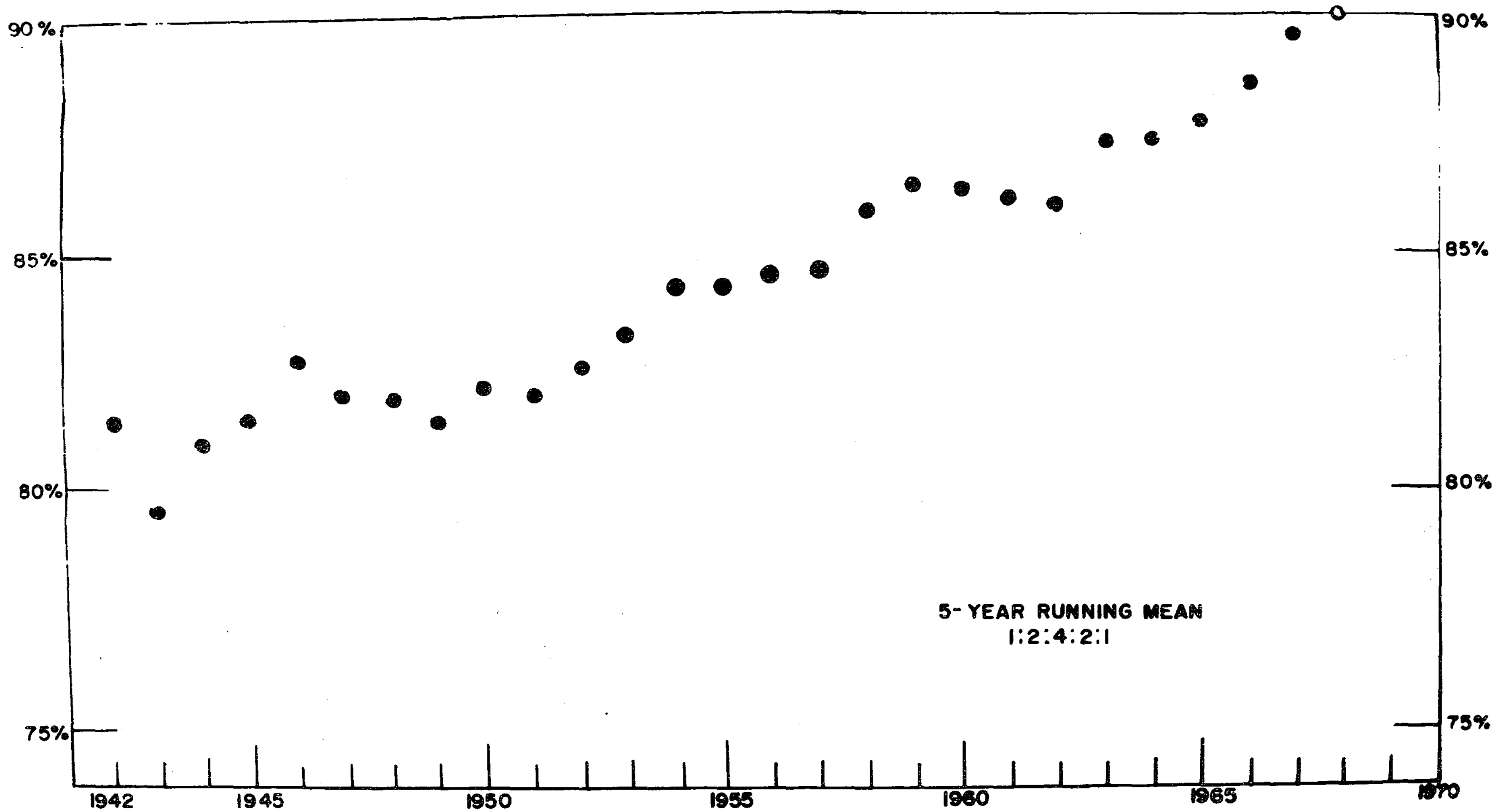

Man-Machine Mix
30-Hr. Surface Prog Improvement Over 36-Hr P.E. Prog.
June 1966 to May 1969
20%
18%
16%
14%
12%
10%
8%
6%
Percent Improvement
Smoothed
1:2:4:2:1
1966
1967
1968
1969
A O D F A J A O D F A J A O D F A

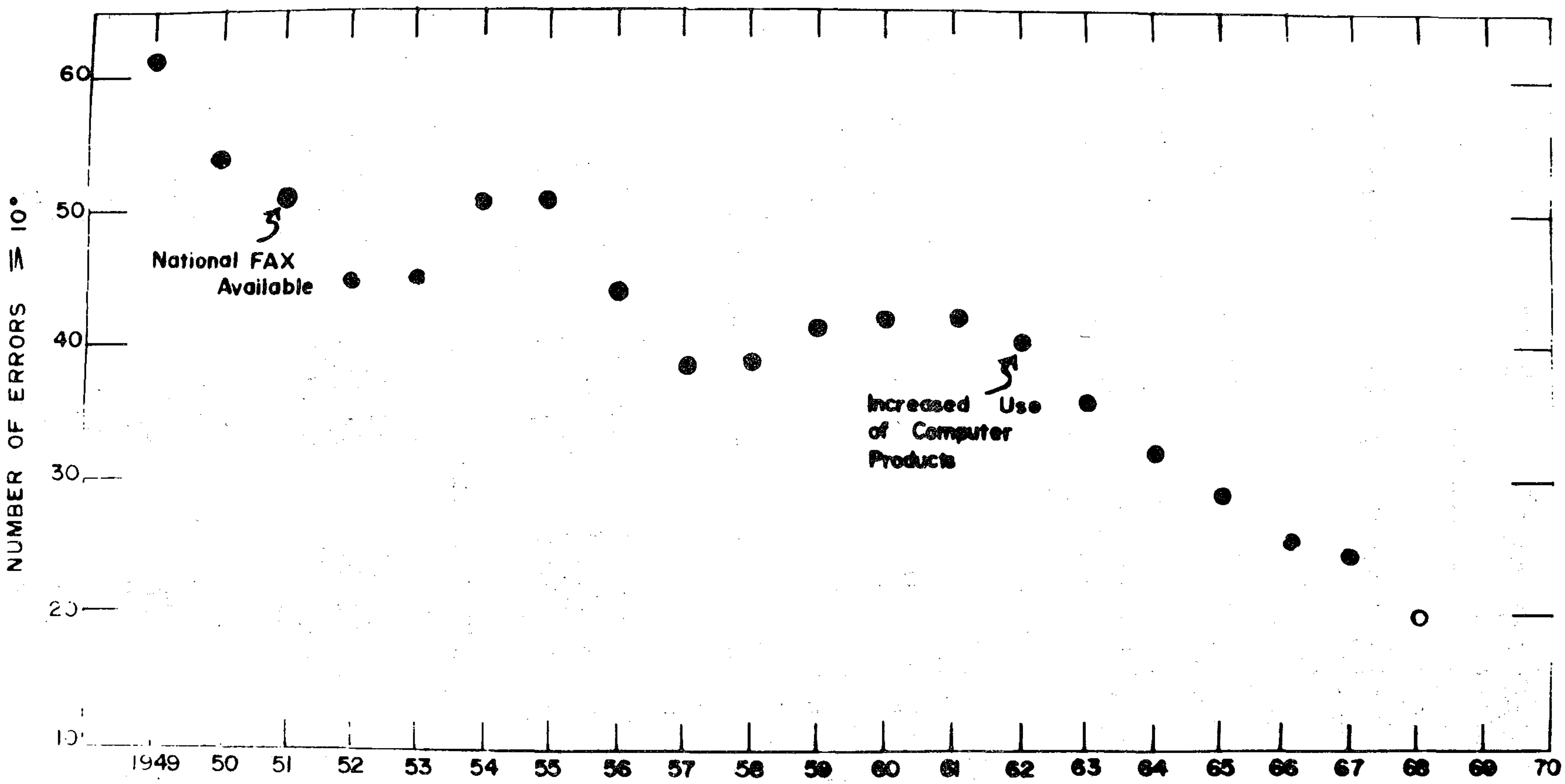
Fig 4.



PERCENTAGE OF CORRECT WEATHER AND TEMPERATURE FORECASTS BY U.S. WEATHER BUREAU

1942–1968

Figure 5



GROSS TEMPERATURE FORECAST ERRORS 1949 – 1968, Salt Lake City

3-Year Running Mean 1:2:1

Fig. 6.

WESTERN REGION TEMPERATURE FORECASTS

April – Sept. 1967

		Number Fcsts.	% Impvt. over 24-hr. Change	% Mean Forecast Error by Class 0-5°	6-10°	11-15°	>15°
1st. Prd.	LOCAL :	7434	+ 32	86	11	2	0
	NMC :	8042	- 7	70	21	6	3
2nd. Prd.	LOCAL :	7430	+ 22	81	16	3	<1
	NMC :	8040	- 19	65	25	7	3
3rd. Prd.	LOCAL :	7436	+ 10	75	19	5	1
	NMC :	8039	- 27	73	20	5	2

Fig. 7a

WESTERN REGION TEMPERATURE FORECASTS
Oct. 1967–March 1968

		Number Fcsts	% Impvt. over 24-hr. Change	% Mean Forecast Error by Class 0-5°	6-10°	11-15°	>15°
1st. Prd.	LOCAL:	8046	+37	80	16	3	0
	NMC:	8052	+8	66	24	7	3
2nd. Prd.	LOCAL:	8046	+22	73	21	5	1
	NMC:	8052	-3	60	27	10	3
3rd. Prd.	LOCAL:	8046	+10	66	24	8	2
	NMC:	8052	-11	56	28	10	6

Fig. 7b.

MAN-MACHINE MIX IN OPERATIONAL WEATHER FORECASTING IN 1970's

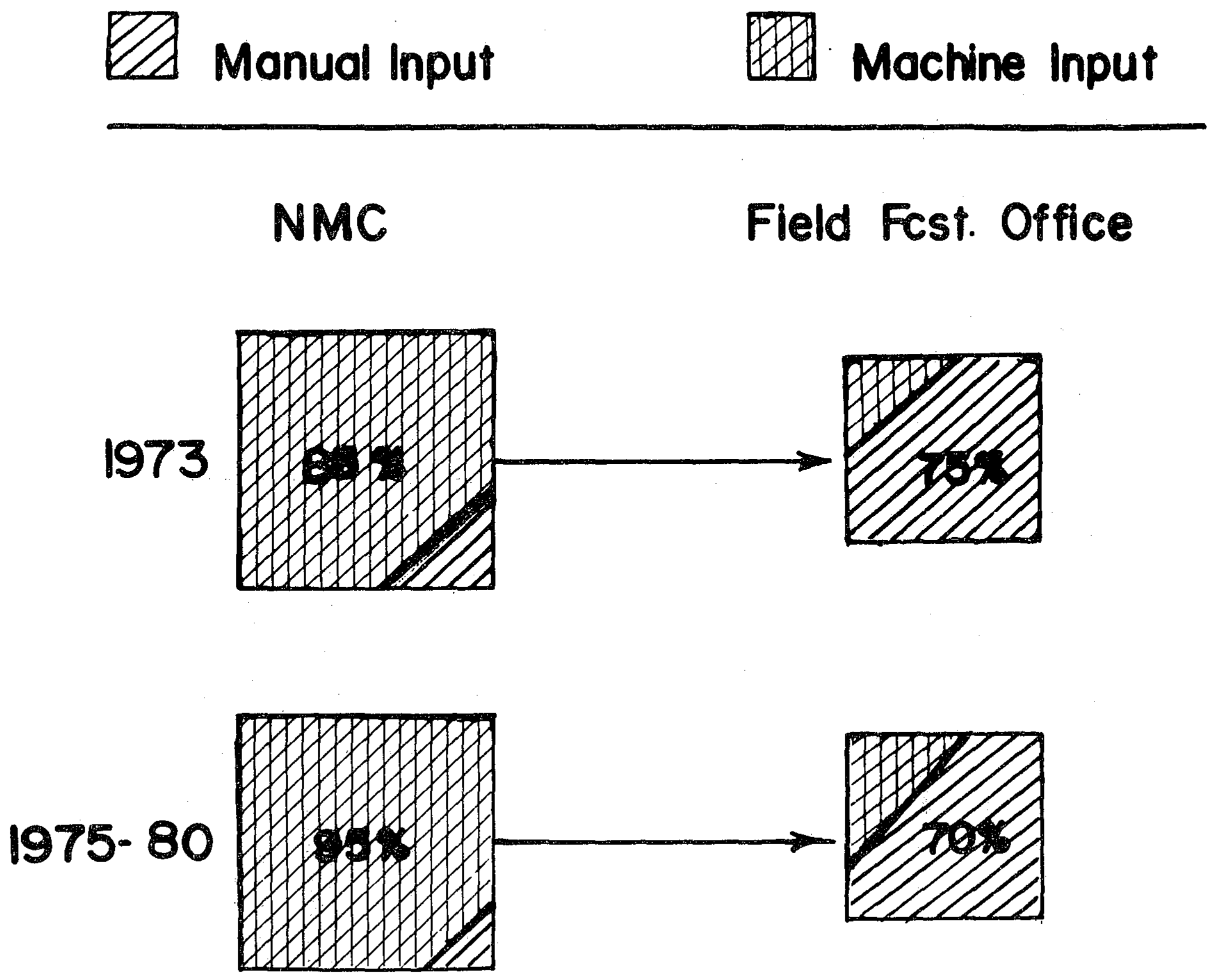


Fig. 8

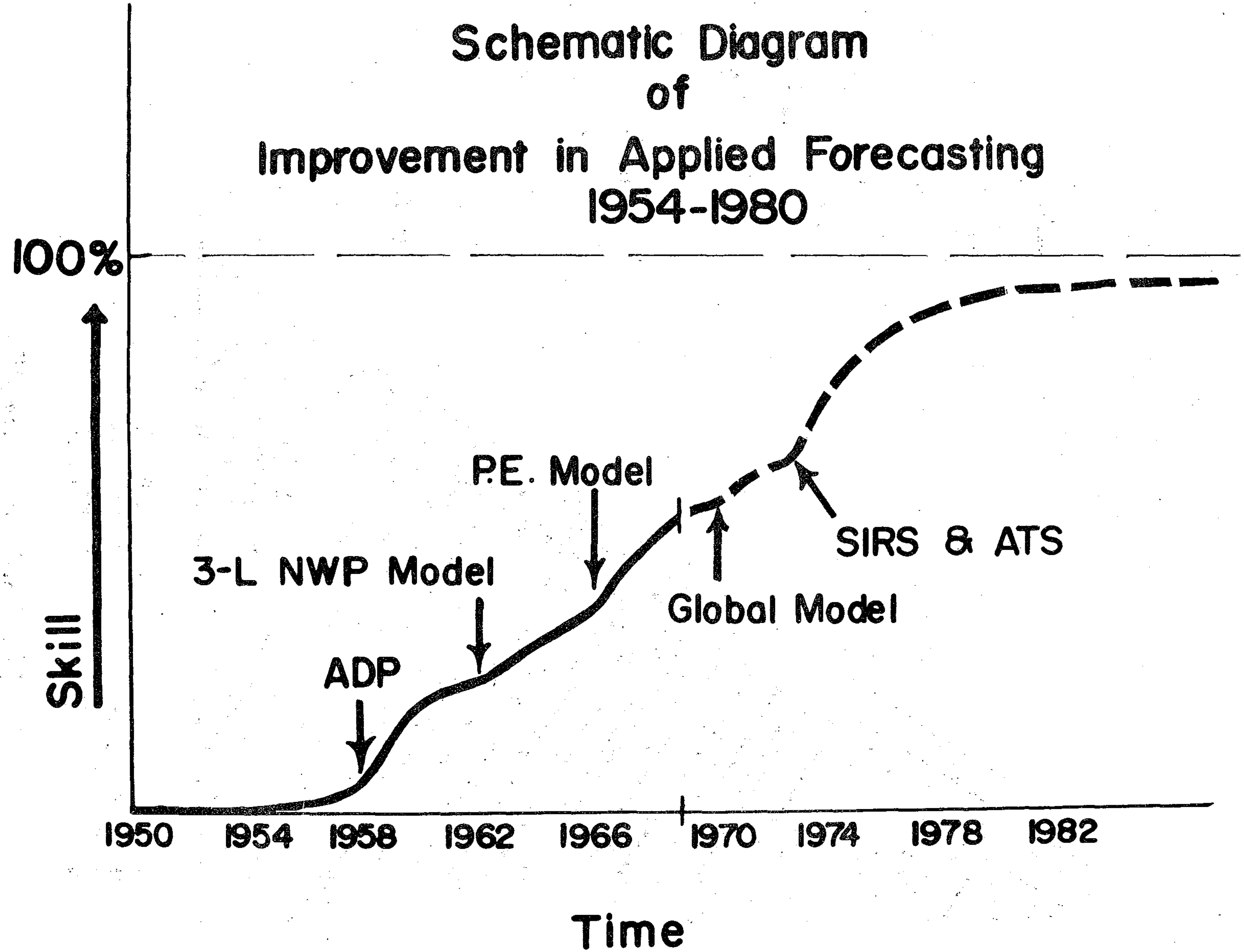

Schematic Diagram
of
Improvement in Applied Forecasting
1954-1980
100%
Skill
ADP
3-L NWP Model
P.E. Model
Global Model
SIRS & ATS
1950
1954
1958
1962
1966
1970
1974
1978
1982
Time

Fig. 9.

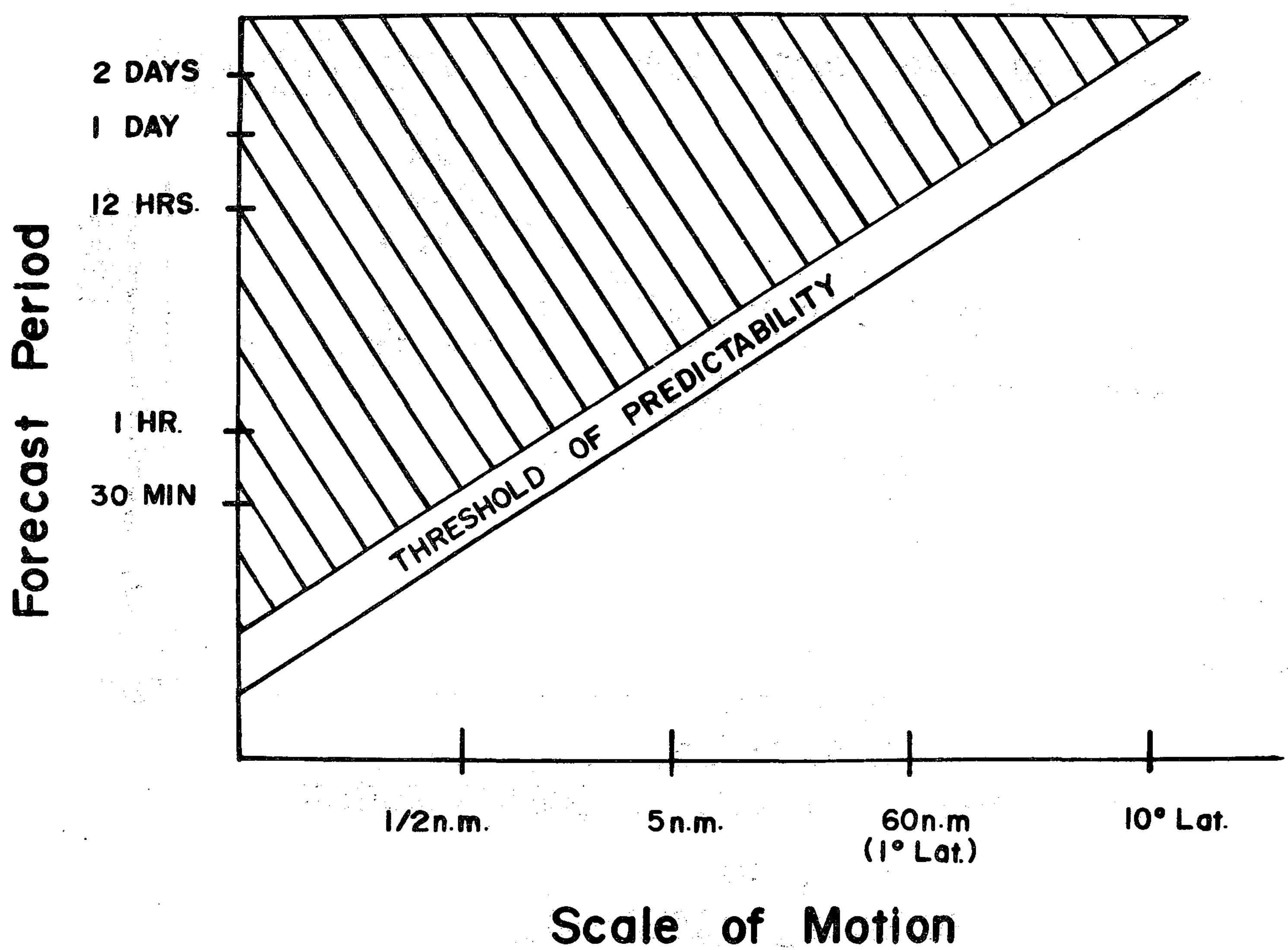

Forecast Period
2 DAYS
1 DAY
12 HRS.
1 HR.
30 MIN
THRESHOLD OF PREDICTABILITY
1/2n.m.
5n.m.
60n.m
(1° Lat.)
10° Lat.
Scale of Motion

Fig. 10.

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