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NATIONAL WEATHER SERVICE
NATIONAL METEOROLOGICAL CENTER

OFFICE NOTE 404

THE LIMITED-AREA FINE-MESH MODEL 36-HOUR S1 SCORE RECORD

Robert Y. Hirano
Quality Assurance Group

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INTRODUCTION

The 36-hour 49-point S1 score verification record for the Limited-area Fine-mesh Model begins in October 1975. A short historical description of the model, the S1 score record from October 1975 to December 1993, and comparison with other operational numerical models are presented in the following sections. The format is similar to Hirano (1992).

THE LOCAL FORECAST MODEL

A joint effort was initiated during the latter portion of 1969 between the United States Air Force Air Weather Service and the National Weather Service to develop a Local Forecast Model (LFM) to provide early guidance to forecasters (Howcroft 1971). This model was to be constructed in a similar manner as NMC's operational model, the Six-Layer Primitive Equation (6LPE); it was to run about two hours after synoptic time, over a limited area, and with a grid length one-half of the 6LPE, at 190.5km. During the developmental period, the LFM acronym was redefined to Limited-area Fine-mesh Model.

Operational LFM forecasts to 24 hours began on September 29, 1971. The LFM grid, 53X57 with 3021 points, is centered over the North American region (Figure Ib).

To improve running time, on February 7, 1973, the LFM forecast grid was changed to 53X45 with 2385 gridpoints by removing 12 grid rows over the polar region; the analysis grid was unaltered. During the first quarter of 1975, the forecast cycle was extended to 36 hours, and in December to 48 hours.

A finer mesh version of the LFM, LFM-II, was implemented on August 31, 1977. The horizontal mesh length of the new model was 127km; there are three points for every two of the older model (now referred to as LFM-I). The operational procedure was to maintain analysis and display products on the LFM-I grid with forecast and post-processing on the LFM-II grid.

On March 1, 1979, the vertical structure of the model was changed from two stratospheric layers and an insentropic cap to three stratospheric layers. Finally, on June 10, 1981, an 'in-core' version of the LFM-II became operational; it is identical with LFM-II except for the increase in grid mesh length to 190.5km and a fourth-order accuracy in finite difference approximation. This model is currently referred to as the LFM.

In the following sections, data and general discussion will refer to the model simply as the LFM unless there is a specific need to differentiate between the different versions of the model.

THE S1 SCORE

The S1 score (Teweles & Wobus 1954) is defined

$$S1 = 100. \frac{\sum |err|}{\sum |Grad|}$$

where, err = error in the forecast gradient
Grad = observed or forecast gradient, whichever is greater

The score dates back to 1947 and was designed to evaluate forecast ability of National Meteorological Center (NMC) meteorologists.

The verification area was originally a set of stations and points over southern Canada, the U. S., and adjacent ocean areas. In 1964, it was changed to a five-degree latitude by ten-degree longitude grid of 49 points, a subset of 63 points within the 25-55 degrees north latitude and 65-145 degrees west longitude region (Figure Ia).

The automated program to calculate NMC operational model S1 score was designed by van Haaren (1978); the verification record begins with October 1975.

THE HISTORICAL LFM S1 SCORE RECORD

A. THE DATA

Table I is the LFM 36-hour MSL S1 score record from October 1975 thru December 1993. Average monthly, seasonal, and annual values are presented. Seasonal and annual averages are derived from weighted monthly values. Table II is the 500MB S1 score data; the format is identical with Table I.

Table III is the official NMC 36-hour annual average S1 scores from June 1947 to December 1993 for MSL and June 1954 to December 1993 for 500MB. The historical data is composed of manual (MAN) scores thru February 1975, Primitive Equation (PE) values from

October 1975 to July 1980, and Spectral (SPEC) model S1 scores from August 1980 to December 1993.

B. ANNUAL AVERAGE S1 SCORE

Figure II is a graph of the average annual 36-hour S1 score historical record thru 1993, at MSL beginning in 1948 and at 500MB with 1955; data are from Tables I-III; LFM values are superimposed as dashed lines.

The long historical record shows a continuous improvement in 36-hour forecasts; for the LFM, however, forecast quality remains essentially unchanged after 1981 when the last major modification was implemented. Note also the sharp reduction in the difference between PE and LFM scores beginning in 1978 after a fine-mesh version of the PE became operational in January of that year.

C. S1 SCORES BY VERIFICATION PERIODS

The historical S1 score record can be divided into manual and numerical model prediction eras. These periods are:

1.	June 1947	-	June 1966	MAN (MSL)
	June 1954	-	June 1966	MAN (500MB)
2.	July 1966	-	February 1975	MAN, (PE)
3.	October 1975	-	July 1980	PE
4.	August 1980	-	December 1993	SPECTRAL

Section A of Table IV is a summary of monthly averages for these periods; LFM averages for periods 3 and 4 are included. This data is plotted in Figure III; MSL and 500MB are on the top and lower halves respectively. December is presented as the first month in order to more clearly display seasonal variation; a solid line is used for MAN, long dashed lines for the PE and SPEC, and shorter dashed lines for the LFM.

Period 1 MAN scores are nearly identical each month because of the seasonal adjustment applied to values during this time. The numerical model record, PE for period 2, LFM for periods 3 and 4, and SPEC for period 4, clearly indicate their respective contributions to the improvement in NMC forecast quality. S1 scores for period 2 MAN shows that numerical model guidance enhanced manual forecasts and the lowering of PE period 3 scores is principally the result of conversion to a fine-mesh model.

The contribution of each succeeding operational numerical model is also found in the 500MB record.

D. SKILL SCORE

A skill score can be defined using pre-model era, period 1 MAN, S1 scores as a standard

$$\text{SKILL SCORE} = 100. \frac{S1 - S1man}{S1p - S1man}$$

where, S1man = average MAN score
S1p = perfect forecast

Here, a perfect forecast has a S1 score of zero.

Average annual skill scores for NMC operational forecasts are presented in section A of Table V; LFM values are found in section B. These data are plotted in Figure IV; LFM scores are given by short dashed lines. Numerical model contribution to improvement in forecast quality at NMC is clearly evident. LFM's share is most noticeable thru the early 1980s.

Seasonal skill score data by verification periods are given in section B of Table IV and plotted in Figure V. Comments used for Figure III, the monthly S1 score by verification periods, are more more clearly depicted in this figure.

THE NESTED GRID MODEL

The Nested Grid Model (NGM) used in the regional analysis and forecast system to produce the best possible two day forecast was implemented in March 1985. In Figure VI, average monthly 36-hour MSL and 500MB S1 scores for the period, December 1988 thru December 1993, are plotted for the LFM, NGM, and SPEC. The NGM has extended the quality of regional model forecasts by about six S1 points at MSL and about four points at 500MB.

CONCLUDING REMARKS

The LFM was the first limited-area model to provide early forecast precipitation and sensible weather forecast guidance over the United States for meteorologists. It contributed significantly to the quality of NMC forecast products principally during the decade after implementation in 1975. Thereafter, it served as the first guidance available to forecasters after synoptic time until it was removed from operations this year.

REFERENCES

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Newell, J. E., and D. G. Deaven, 1981: The LFM-II Model--1980. NOAA Tech. Memo. NWS NMC 66, U.S. Department of Commerce, Washington, D.C., 20pp.

Teweles, S., and H. Wobus, 1954: Verification of prognostic charts. Bull. Amer. Met. Soc., 35, 455-463.

van Haaren, R. J., 1978: Comparative Verification of the National Meteorological Center's (NMC) Operational Forecast Models. Preprints, Conference on Weather Forecasting and Analysis and Aviation Meteorology, October 16-19, 1978, Silver Spring, MD. (AMS).

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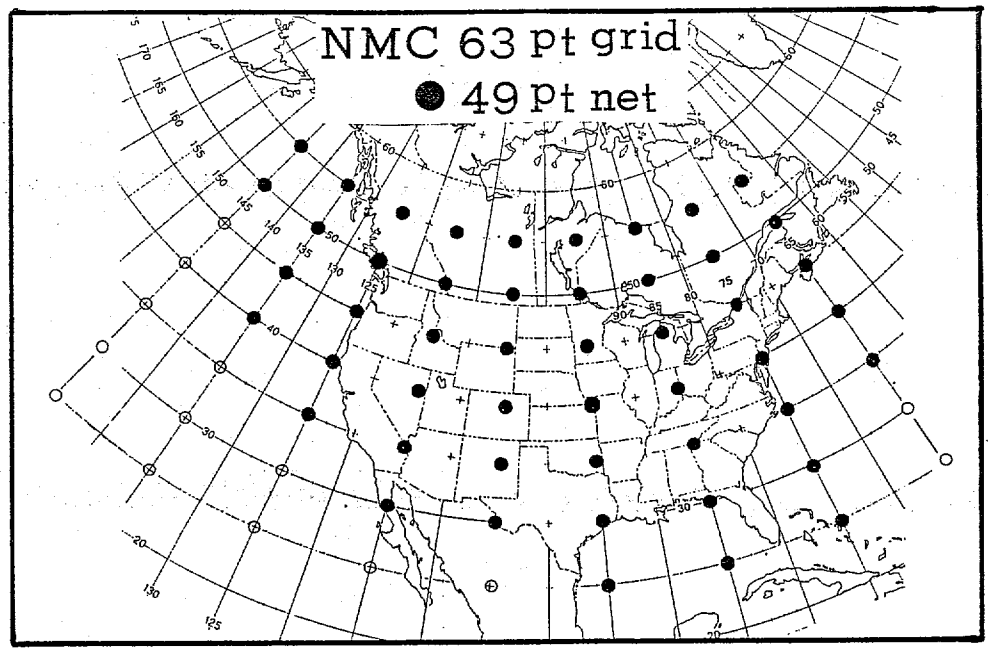
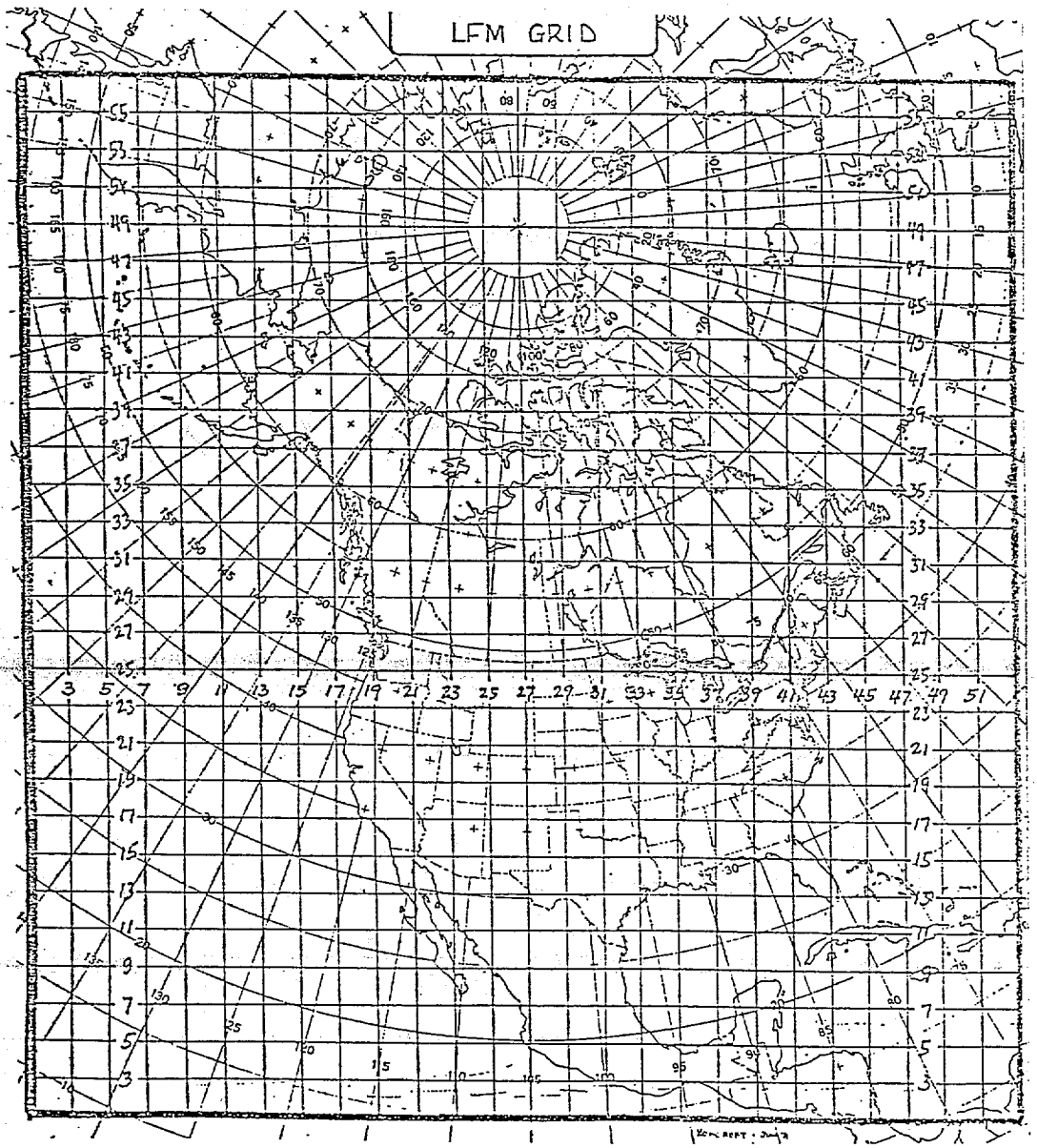
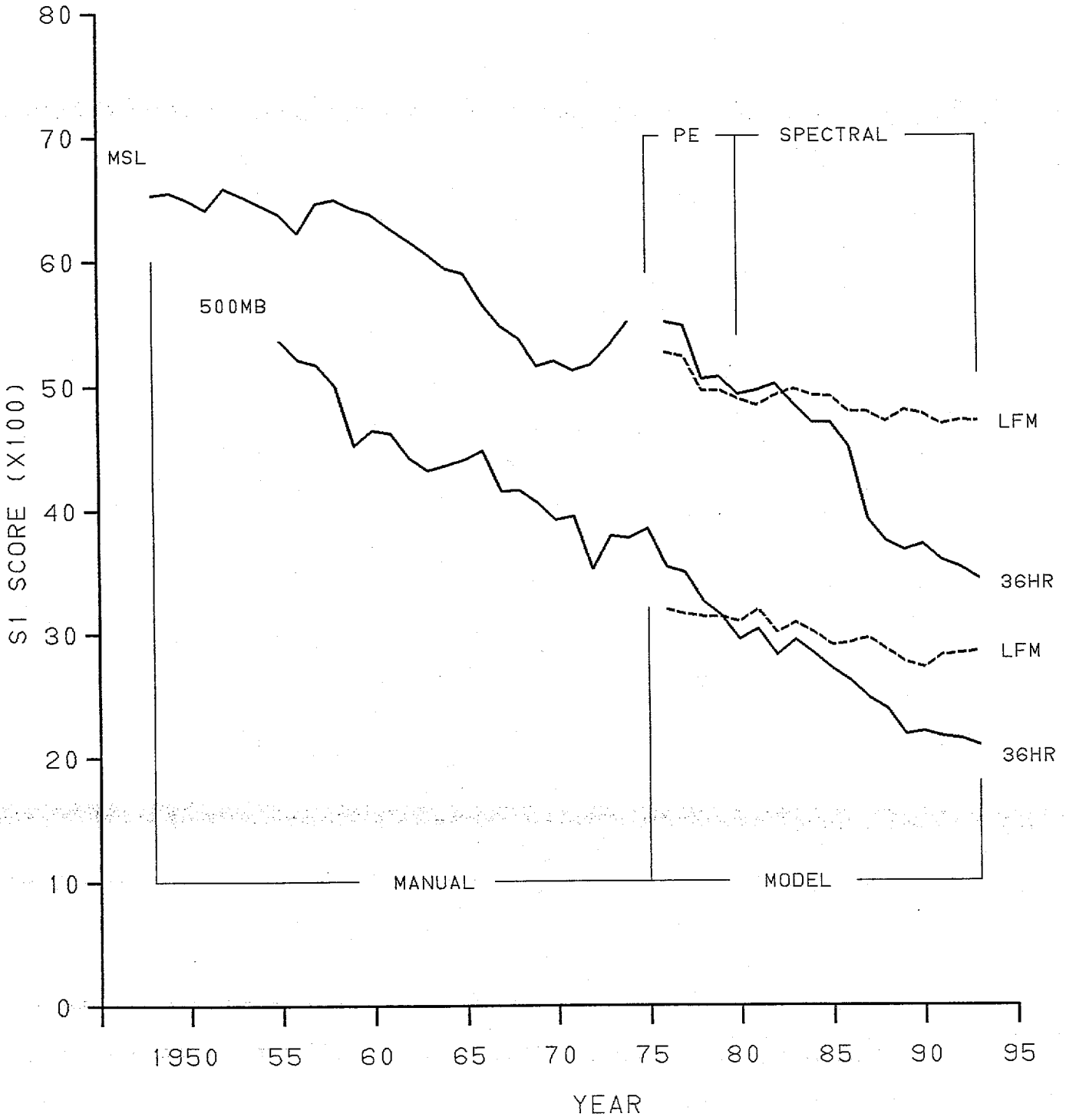


(a)

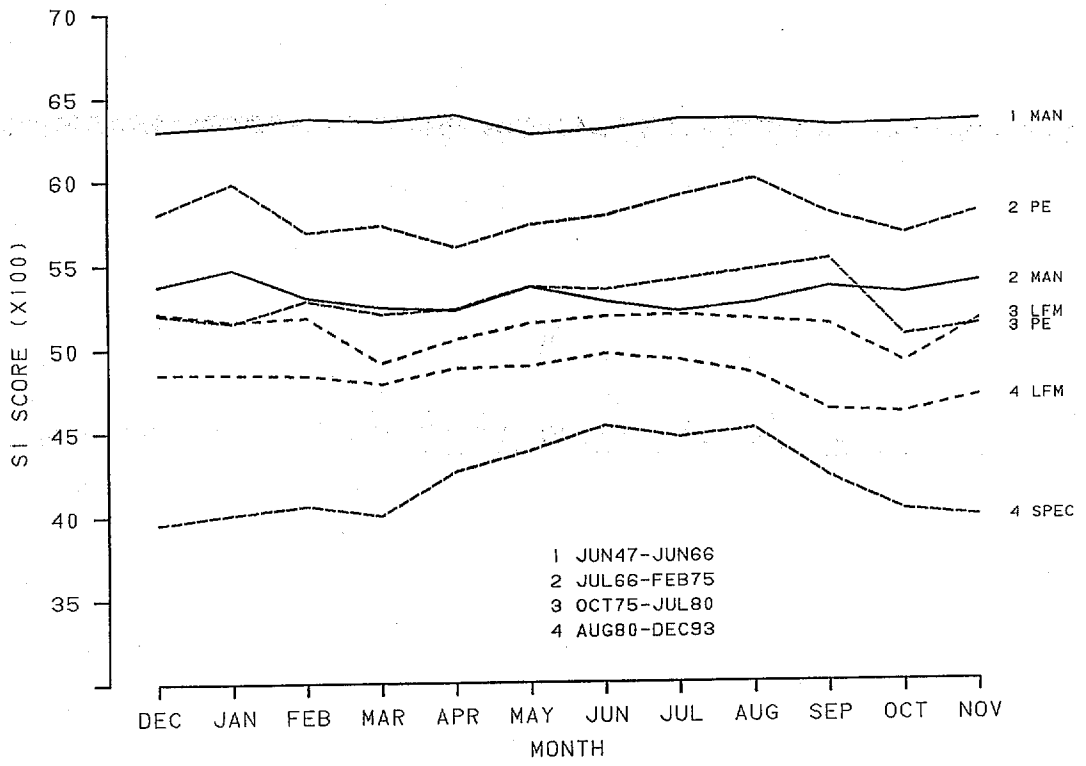


(b)

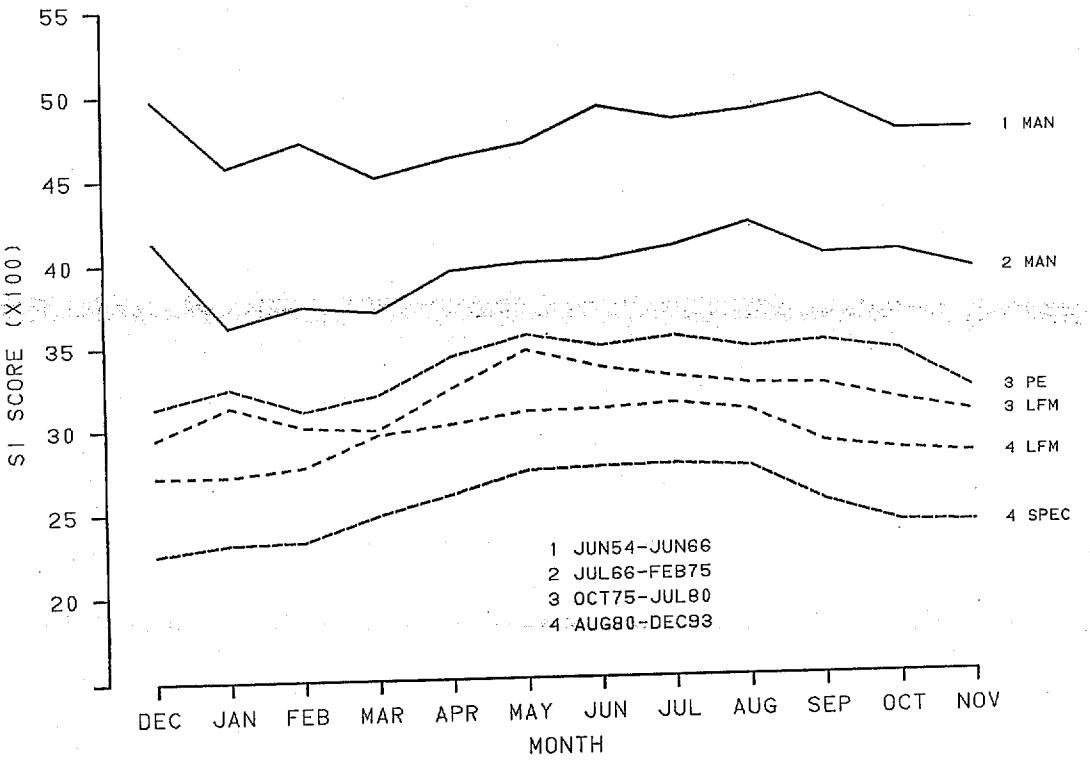
36-HOUR AVERAGE ANNUAL 49-PT S1 SCORE



36-HOUR MSL MONTHLY SI SCORE

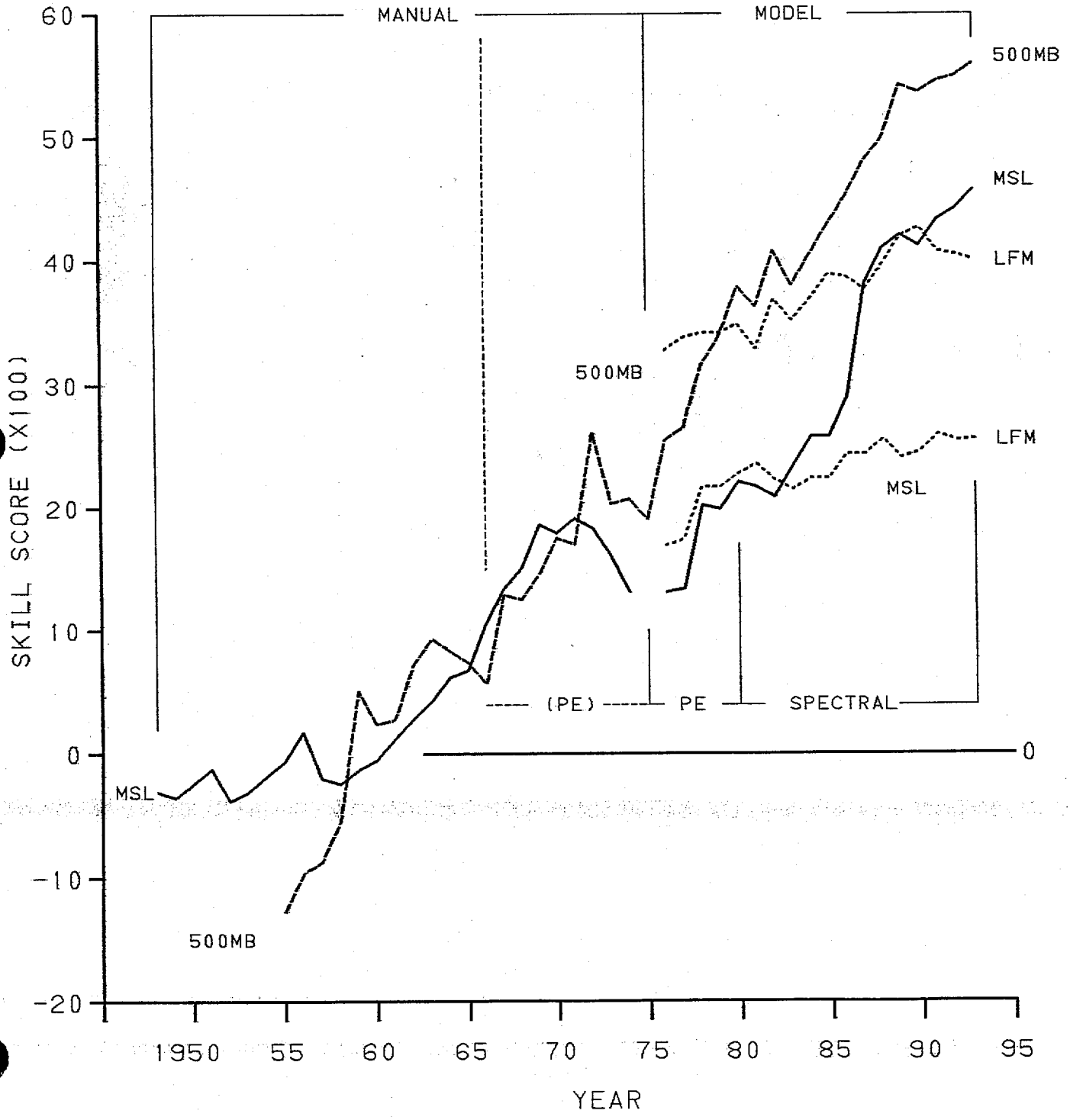


36-HOUR 500MB MONTHLY SI SCORE



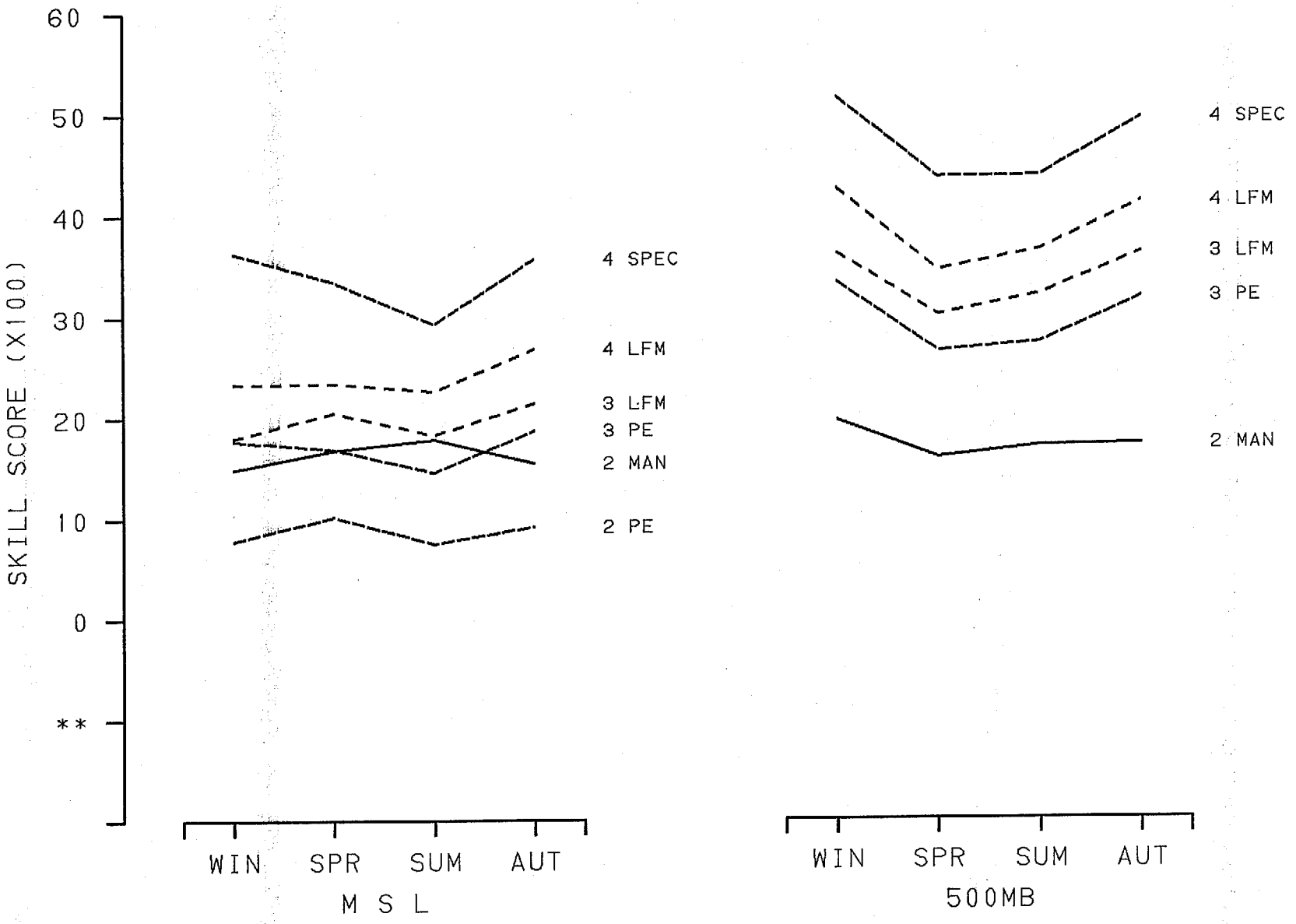
36-HOUR AVERAGE ANNUAL NMC SKILL SCORE

49-PT S1 SCORES THRU JUN66 AS STANDARD



36-HOUR SEASONAL SKILL SCORE

2 JUL66-FEB75, 3 OCT75-JUL80, 4 AUG80-DEC93



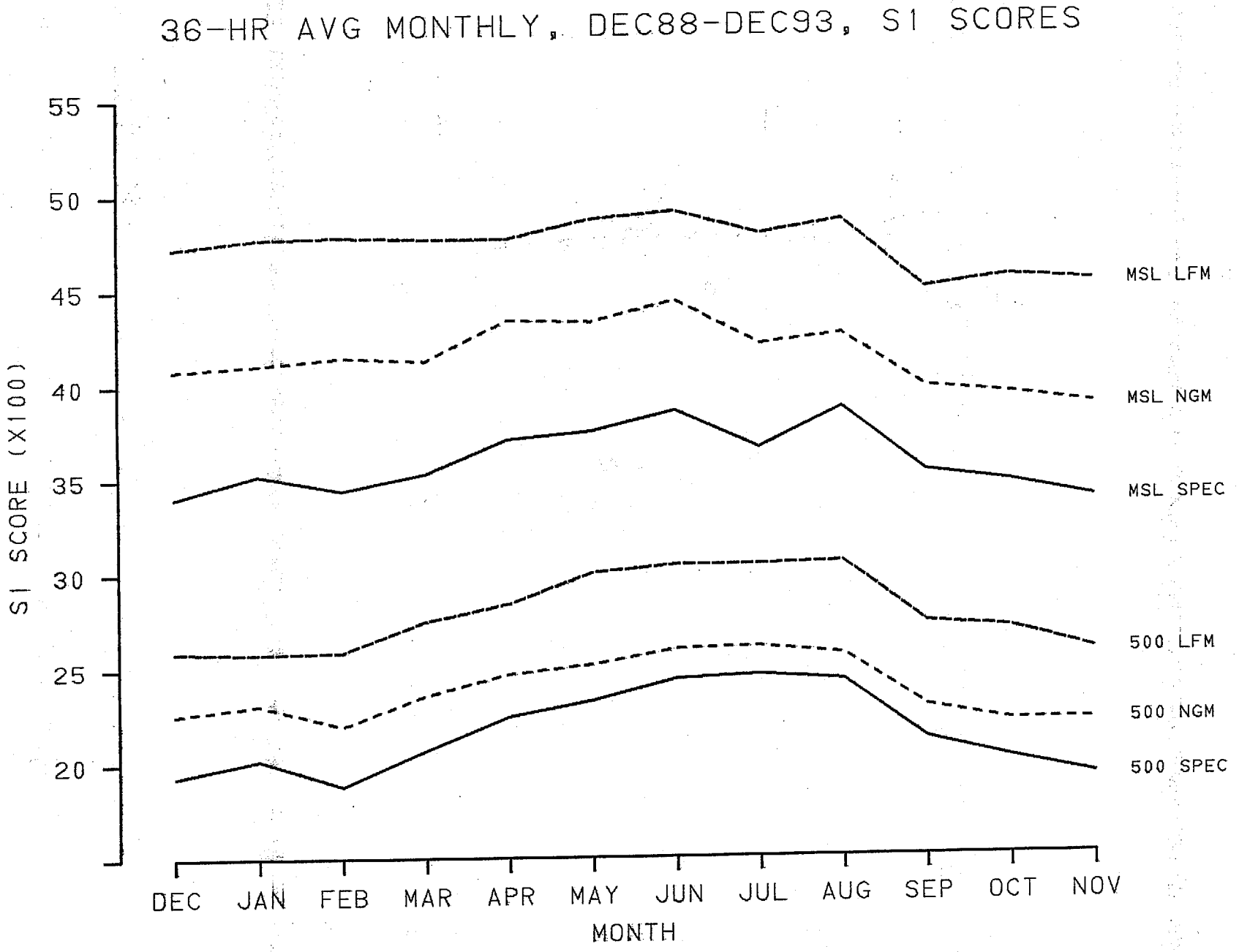

36-HR AVG MONTHLY, DEC88-DEC93, S1 SCORES
S1 SCORE (X100)
55
50
45
40
35
30
25
20
MSL LFM
MSL NGM
MSL SPEC
500 LFM
500 NGM
500 SPEC
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
MONTH

TABLE I: MSL 36-HOUR LFM S1 SCORES
OCTOBER 1975 - DECEMBER 1993

VERIFICATION GRID: 49-Point lat-lon network

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AVERAGE MONTHLY . . . . . .

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1975										54.9	54.9	55.4
1976	54.0	55.3	51.7	51.7	51.9	54.8	53.9	53.7	52.8	49.4	50.6	52.0
1977	53.3	53.7	49.7	52.4	53.8	54.7	52.6	51.9	51.4	46.0	53.8	54.5
1978	50.4	50.5	50.7	46.9	50.1	49.1	49.7	49.0	53.5	45.7	49.4	50.2
1979	50.7	48.5	46.5	52.8	50.6	49.4	51.1	51.9	47.6	49.0	48.6	48.6
1980	49.5	51.1	47.0	48.7	50.6	51.2	52.4	48.5	48.8	46.9	46.1	46.1
1981	48.3	47.6	49.1	47.9	48.1	51.7	47.0	48.5	47.6	46.2	47.8	51.1
1982	51.1	50.3	49.8	47.6	50.4	52.3	50.0	48.6	45.9	46.7	48.4	49.6
1983	49.8	48.4	45.2	52.3	50.1	50.3	53.3	52.7	45.8	46.5	49.7	52.3
1984	50.0	48.7	50.7	49.1	49.5	50.6	48.2	47.0	46.9	50.2	47.6	51.2
1985	48.7	48.1	48.7	51.3	49.9	49.5	48.7	48.7	46.7	46.2	53.9	49.3
1986	47.7	51.0	46.6	48.1	49.0	48.3	49.9	46.5	46.1	44.5	48.9	48.2
1987	49.2	49.1	45.9	49.8	47.5	47.4	53.6	47.4	47.8	44.7	44.4	48.1
1988	47.6	47.2	48.2	50.1	47.6	49.0	50.0	47.0	45.8	43.4	44.2	45.4
1989	47.2	51.7	47.7	50.8	50.2	50.7	50.0	48.9	43.7	44.9	44.7	45.7
1990	47.2	46.8	48.5	48.4	49.5	49.2	45.4	51.7	48.4	44.7	45.4	47.6
1991	48.2	46.3	47.8	47.2	47.6	49.3	47.9	47.5	44.8	46.2	43.8	45.8
1992	45.4	47.6	49.3	46.9	47.2	49.0	49.1	46.7	43.3	45.7	45.8	50.1
1993	50.6	46.9	45.2	44.9	49.2	47.0	47.1	47.8	44.8	46.2	46.8	48.4

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AVERAGE SEASONAL . . . . . .

YEAR	WINTER	SPRING	SUMMER	AUTUMN
1975	----	----	----	----
1976	54.9	51.8	54.1	50.9
1977	53.0	52.0	53.0	50.4
1978	51.8	49.3	49.3	49.5
1979	49.8	49.9	50.8	48.4
1980	49.7	48.8	50.7	47.3
1981	47.3	48.4	49.0	47.2
1982	50.9	49.3	50.3	47.0
1983	49.3	49.2	52.1	47.3

TABLE I(continued): MSL 36-HOUR LFM S1 SCORES

AVERAGE SEASONAL . . . . . .

YEAR	WINTER	SPRING	SUMMER	AUTUMN
1984	50.4	49.8	48.6	48.3
1985	49.4	50.0	49.0	48.9
1986	49.3	47.9	48.2	46.5
1987	48.8	47.7	49.5	45.6
1988	47.6	48.6	48.7	44.5
1989	48.0	49.6	49.9	44.4
1990	46.6	48.8	48.8	46.2
1991	47.4	47.5	48.2	44.9
1992	46.2	47.8	48.3	44.9
1993	49.3	46.4	47.3	45.9

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AVERAGE ANNUAL . . . . . .

YEAR	0	1	2	3	4	5	6	7	8	9
197-							52.6	52.3	49.6	49.6
198-	48.9	48.4	49.2	49.7	49.2	49.1	47.9	47.9	47.1	48.0
199-	47.7	46.9	47.2	47.1						

TABLE II: 500MB 36-HOUR LFM S1 SCORES
OCTOBER 1975 - DECEMBER 1993

VERIFICATION GRID: 49-Point lat-lon network

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AVERAGE MONTHLY . . . . . .

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1975										34.7	33.8	29.9
1976	30.5	28.0	28.8	36.3	34.6	36.2	34.6	34.6	32.7	31.3	28.9	26.5
1977	31.7	30.9	29.7	28.9	33.4	35.4	31.5	31.1	32.7	31.3	30.1	31.2
1978	31.5	32.1	29.7	33.2	34.9	32.2	32.1	31.4	32.7	27.8	29.2	28.6
1979	31.1	27.8	31.3	30.5	34.0	31.3	34.1	32.1	30.9	30.9	29.9	30.7
1980	31.7	31.3	29.5	32.5	35.4	32.0	31.6	32.1	28.9	29.7	30.4	25.7
1981	29.5	30.5	34.6	29.7	33.2	34.0	33.5	33.6	33.0	29.2	31.2	30.6
1982	26.6	27.2	32.3	30.0	33.7	31.5	32.8	28.5	31.4	29.1	26.6	29.7
1983	30.6	30.8	32.4	32.1	30.8	32.5	32.9	29.5	27.7	29.7	33.2	26.9
1984	26.1	31.4	30.5	33.4	28.9	32.2	30.3	30.8	29.0	30.0	31.1	26.3
1985	28.6	26.2	29.9	28.7	31.6	31.4	30.5	31.1	29.1	27.0	27.8	26.3
1986	27.7	27.8	27.3	31.0	30.5	29.8	32.1	31.5	28.2	28.4	25.5	29.9
1987	29.7	31.5	31.1	30.6	30.1	29.3	30.4	28.9	28.6	27.7	28.5	29.0
1988	24.6	24.2	27.8	33.1	31.1	28.2	30.8	31.3	29.8	28.5	27.7	26.4
1989	24.8	25.4	25.3	27.8	29.8	31.4	30.4	30.8	28.1	28.5	24.0	24.7
1990	25.9	24.4	27.4	26.7	28.6	28.6	31.7	30.9	28.7	25.2	24.4	24.1
1991	23.1	24.7	28.7	30.8	31.5	32.2	29.7	30.6	27.1	26.0	26.8	26.9
1992	28.2	27.2	27.9	27.3	30.2	30.2	29.8	29.3	27.6	28.6	28.2	24.7
1993	27.0	27.9	28.4	30.0	29.9	30.1	30.4	31.4	25.2	26.8	25.9	28.5

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AVERAGE SEASONAL . . . . . .

YEAR	WINTER	SPRING	SUMMER	AUTUMN
1975	----	----	----	----
1976	29.5	33.2	35.1	31.0
1977	29.7	30.7	32.6	31.4
1978	31.6	32.6	31.9	29.9
1979	29.2	31.9	32.5	30.6
1980	31.2	32.5	31.9	29.7
1981	28.5	32.5	33.7	31.1
1982	28.2	32.0	30.9	29.0
1983	30.4	31.8	31.6	30.2

TABLE II(continued): 500MB 36-HOUR LFM S1 SCORES

AVERAGE SEASONAL . . . . . .

YEAR	WINTER	SPRING	SUMMER	AUTUMN
1984	28.1	30.9	31.1	30.0
1985	27.1	30.1	31.0	28.0
1986	27.2	29.6	31.1	27.4
1987	30.3	30.6	29.5	28.3
1988	26.0	30.6	30.1	28.7
1989	25.5	27.6	30.9	26.9
1990	25.0	27.6	30.4	26.1
1991	23.9	30.3	30.8	26.6
1992	27.4	28.5	29.8	28.1
1993	26.5	29.4	30.6	26.0

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AVERAGE ANNUAL . . . . . .

YEAR	0	1	2	3	4	5	6	7	8	9
197-							31.9	31.5	31.3	31.3
198-	30.9	31.9	30.0	30.8	30.0	29.0	29.2	29.6	28.6	27.6
199-	27.2	28.2	28.3	28.5						

TABLE III: NMC 36-HOUR (30-HOUR MANUAL) AVERAGE ANNUAL S1 SCORE

FORECASTS: MANUAL: June 1947 - February 1975
NUMERICAL MODEL: PE (October 1975 - July 1980)
SPECTRAL (August 1980 -)

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MSL --- JUNE 1947 - DECEMBER 1993 . . . . . .

YEAR	0	1	2	3	4	5	6	7	8	9
194-								----	65.3	65.5
195-	64.9	64.1	65.8	65.2	64.5	63.7	62.2	64.6	64.9	64.2
196-	63.7	62.6	61.6	60.6	59.4	59.0	56.6	54.8	53.8	51.6
197-	52.0	51.2	51.7	53.2	55.1	----	55.1	54.8	50.5	50.7
198-	49.3	49.6	50.1	48.5	47.0	47.0	45.0	39.2	37.4	36.7
199-	37.2	35.9	35.3	34.4						

500MB --- JUNE 1954 - DECEMBER 1993 . . . . . .

YEAR	0	1	2	3	4	5	6	7	8	9
195-					----	53.6	52.1	51.7	50.0	45.2
196-	46.4	46.2	44.2	43.2	43.6	44.1	44.8	41.5	41.6	40.6
197-	39.2	39.5	35.2	37.9	37.7	38.5	35.4	34.9	32.5	31.4
198-	29.5	30.3	28.2	29.4	28.3	27.1	26.1	24.7	23.8	21.8
199-	22.0	21.6	21.4	20.9						

TABLE IV: 36-HOUR (30-HOUR MANUAL) SCORES BY VERIFICATION PERIODS

PERIOD 1. JUN47 - JUN66 (MSL)
JUN54 - JUN66 (500MB)
2. JUL66 - FEB75
3. OCT75 - JUL80
4. AUG80 - DEC93

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A. AVERAGE MONTHLY S1 SCORES

MEAN SEA LEVEL

PERIOD	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1 MAN	63.2	63.7	63.5	63.9	62.7	63.0	63.6	63.6	63.2	63.3	63.5	62.9
2 MAN	54.7	53.0	52.4	52.2	53.6	52.7	52.1	52.6	53.5	53.1	53.8	53.7
2 PE	59.8	56.9	57.3	56.0	57.3	57.8	59.0	60.0	57.9	56.7	58.0	58.0
3 PE	51.5	52.8	52.0	52.3	53.6	53.4	54.0	54.6	55.2	50.6	51.2	52.0
3 LFM	51.6	51.8	49.1	50.5	51.4	51.8	51.9	51.6	51.3	49.0	51.5	52.1
4 LFM	48.5	48.4	47.9	48.8	48.9	49.6	49.2	48.4	46.2	46.0	47.0	48.5
4 SPEC	40.1	40.6	40.0	42.6	43.8	45.3	44.6	45.1	42.2	40.2	39.8	39.5

500MB

PERIOD	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1 MAN	45.7	47.1	45.0	46.1	46.9	49.0	48.2	48.7	49.5	47.4	47.4	49.7
2 MAN	36.1	37.3	36.9	39.4	39.8	39.9	40.7	42.0	40.1	40.2	39.1	41.3
3 PE	32.4	31.0	31.9	34.2	35.4	34.7	35.2	34.5	34.8	34.2	31.8	31.3
3 LFM	31.3	30.0	29.8	32.3	34.5	33.4	32.8	32.3	32.2	31.2	30.4	29.4
4 LFM	27.1	27.6	29.5	30.1	30.8	30.9	31.2	30.7	28.7	28.2	27.9	27.1
4 SPEC	23.1	23.2	24.7	25.9	27.2	27.4	27.5	27.3	25.2	23.9	23.8	22.5

B. NMC SEASONAL SKILL SCORES

PERIOD	MSL WIN	MSL SPR	MSL SUM	MSL AUT	500MB WIN	500MB SPR	500MB SUM	500MB AUT
2 MAN	14.9	16.8	17.8	15.5	19.6	15.9	17.0	17.2
2 PE	7.8	10.2	7.5	9.2				
3 PE	17.7	16.9	14.6	18.7	33.4	26.5	27.3	31.8
3 LFM	18.0	20.5	18.3	21.4	36.2	30.1	32.1	36.2
4 LFM	23.3	23.4	22.6	26.8	42.6	34.5	36.5	41.2
4 SPEC	36.3	33.5	29.3	35.7	51.6	43.7	43.8	49.5

TABLE V: 36-HOUR NMC SKILL SCORE
AVERAGE MANUAL S1 SCORES THRU 1966 USED AS A STANDARD

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A. NMC AVERAGE ANNUAL SKILL

MSL.....

YEAR	0	1	2	3	4	5	6	7	8	9
194-								----	-3.0	-3.5
195-	-2.4	-1.2	-3.8	-3.0	-1.8	-0.6	1.8	-2.0	-2.4	-1.3
196-	-0.5	1.2	2.8	4.3	6.2	6.8	10.6	13.4	15.1	18.6
197-	17.9	19.1	18.3	16.0	13.1	----	13.1	13.4	20.2	19.9
198-	22.1	21.7	20.9	23.4	25.8	25.8	29.0	38.1	41.0	42.1
199-	41.2	43.3	44.2	45.7						

500MB.....

YEAR	0	1	2	3	4	5	6	7	8	9
195-						-12.7	-9.6	-8.7	-5.4	5.1
196-	2.4	2.8	7.2	9.3	8.3	7.4	5.7	12.9	12.5	14.6
197-	17.5	17.0	26.1	20.3	20.7	19.0	25.5	26.5	31.6	33.9
198-	37.9	36.3	40.8	38.0	40.5	42.9	45.2	48.0	49.8	54.2
199-	53.6	54.5	54.9	55.9						

B. LFM AVERAGE ANNUAL SKILL

MSL.....

YEAR	0	1	2	3	4	5	6	7	8	9
197-							16.9	17.4	21.7	21.7
198-	22.8	23.6	22.3	21.5	22.4	22.4	24.4	24.4	25.6	24.1
199-	24.6	26.0	25.5	25.6						

500MB.....

YEAR	0	1	2	3	4	5	6	7	8	9
197-							32.8	33.8	34.2	34.2
198-	34.9	32.9	36.9	35.2	36.9	38.9	38.7	37.7	39.7	42.0
199-	42.7	40.8	40.5	40.1						