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COMPARATIVE VERIFICATION OF GUIDANCE AND LOCAL AVIATION/PUBLIC WEATHER FORECASTS--NO. 5
(October 1977-March 1978)

David B. Gilhousen, Joseph R. Bocchieri, Gary M. Carter,
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1. INTRODUCTION

This is the fifth in our series of combined verification of the Techniques Development Laboratory's (TDL's) operational guidance forecasts and National Weather Service (NWS) local forecasts made at Weather Service Forecast Offices (WSFO's). Verification statistics for objective guidance and subjective local forecasts of probability of precipitation, opaque sky cover, surface wind, ceiling height, visibility, and max/min temperature are presented here for the cool season months of October 1977 through March 1978.

TDL's forecasts of these variables are based on the Model Output Statistics (MOS) (Glahn and Lowry, 1972) technique. Our MOS prediction equations were derived from historical archives of surface observations and forecast fields from the Limited-area Fine Mesh (LFM) (National Weather Service, 1971), Trajectory (TJ) (Reap, 1972), and/or Primitive Equation (PE) (Shuman and Hovermale, 1968) models. Our equations are currently using input from the finer mesh LFM-II (Brown, 1977a) and the 7-layer PE (7LPE) (Brown, 1977b). The LFM-II replaced the LFM model before October 1977; the 7LPE replaced the PE on January 19, 1978.

WSFO forecasts were provided to us by the Technical Procedures Branch (TPB) of the Office of Meteorology and Oceanography in conjunction with the NWS combined aviation/public weather verification system (National Weather Service, 1973). These forecasts were recorded daily for verification purposes under instructions that the value recorded be "...not inconsistent with..." the official weather forecasts. Surface observations as late as 2 hours before the first verification time may have been used in their preparation. We obtained observed data to verify the guidance and local weather forecasts from the National Climatic Center in Asheville, N.C.

2. PROBABILITY OF PRECIPITATION (PoP)

The objective PoP forecasts were generated by the cool season prediction equations described in National Weather Service Technical Procedures Bulletin No. 171 (1976a). We generated forecasts for the 12-24 h first period, the 24-36 h second period, and the 36-48 h third period. The predictors for the first period equations were forecast fields from the LFM-II model and surface variables observed at the forecast site 3 hours after the model run time.

Two types of objective guidance were produced for the second and third periods: the so-called "early" and "final" guidance. The early guidance forecasts were based on forecast fields from the LFM-II model. The final

Figure 2.1 shows the trend in the accuracy of first and third period 0000 GMT PoP forecasts expressed in terms of percent improvement over climatology. Both local and final guidance forecasts for both projections show better scores than the previous season. Several general trends are evident. First, both the guidance and local forecasts improved over the years for the 36-48 h period, especially since the 1973-74 winter season. Forecasters now seem to be able to improve over the guidance for this projection. Secondly, there has been a tendency for the 12-24 h guidance to improve and the difference between guidance and locals to decrease. Note that 190 stations were used to compute the scores for the 1973-74 winter season. Also, we are unable to present results for the 1975-76 season because of missing data.

3. PRECIPITATION TYPE

TDL's system for predicting the conditional probability of frozen precipitation (PoF) has been operational within NWS since November 1972. Frozen precipitation is defined as snow and/or sleet. The evolution of the PoF system is described in detail by Glahn and Bocchieri (1975), Bocchieri and Glahn (1976), and National Weather Service (1976b). The verification procedures used to compare the MOS PoF guidance forecasts with the local predictions are also described in detail in Bocchieri and Glahn, op. cit.

In the NWS verification, local categorical forecasts of precipitation type made at about 1000 GMT are recorded for the valid times 1800 GMT (today), 0600 GMT (tonight), and 1800 GMT (tomorrow). Note that this is a conditional forecast; that is, it is a forecast of type of precipitation if precipitation occurs. Therefore, a precipitation type forecast is always recorded. The guidance forecast is a probability of the occurrence of frozen precipitation, given that precipitation occurs; therefore, it is also a conditional forecast and is available whether or not precipitation occurs. In this verification, a guidance forecast of frozen precipitation is defined as a PoF > 50%.

Table 3.1 lists the 63 stations used in this verification. We included only cases when precipitation actually occurred. We were concerned that the forecasters may not have put much effort into making the conditional forecasts when they considered precipitation to be unlikely. Therefore, in order to isolate those situations when the forecaster thought precipitation a definite possibility, we used only the cases when the local PoP was ≥ 30%. The PoPs were valid for the 12-h periods centered on the 18-, 30-, and 42-h projections used in the verification.

Table 3.2 shows that for all stations combined the final guidance forecasts were slightly better than the local forecasts for the percent correct and skill score for the 30- and 42-h projections; the two systems scored the same for the 18-h projection. The final guidance had a better bias[1] than the locals for the 18- and 30-h projections; the opposite was true

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[1]The bias is the number of forecasts of an event divided by the number of observed events.

procedure took place during these 5 years. First, the number of stations changed from approximately 90 for the first two years to approximately 60 afterwards. Secondly, starting with the 1975-76 season, we used only cases when the local PoP was 30% or greater in order to isolate those cases when the forecaster would have been more confident that precipitation was to occur. Additionally, starting in the 1976-77 season, we verified the early PoF guidance for the 18-h projection.

The results indicate that the guidance was consistently better over the 5 years except during the 1977-78 season when the guidance and local forecasts scored the same for the 18-h projection. There was definite improvement, especially for the locals, over the span of the first four years; however, both systems showed some deterioration during the last season. Also, the early and final PoF guidance scored about the same over the last 2 seasons. The deterioration of the scores during the 1977-78 season could have been partly caused by the fact that the LFM-II and 7LPE models became operational during that season, but the forecast equations were based on output from the LFM and PE models.

4. SURFACE WIND

The objective wind forecasts were generated by early and final guidance prediction equations for the cool season (National Weather Service, 1978a). The early guidance was based on output from the LFM-II model. In contrast, the final guidance relied on PE model output from October of 1977 through mid-January of 1978, and forecasts from the new 7LPE model thereafter. The sine and cosine of the day of the year also were used as predictors in both sets of guidance equations. The definition of the objective surface wind forecast is the same as that of the observed wind: the one-minute average direction and speed for a specific time.

Since the local forecasts were recorded as calm if the wind speed was expected to be less than 8 knots, we verified the wind forecasts in two ways. First, for all those cases where both the local and guidance (early and final) wind speed forecasts were at least 8 knots, the mean absolute error (MAE) of speed was computed. Secondly, for all cases where both local and guidance forecasts were available, skill score, percent correct, and bias by category were computed from contingency tables of wind speed. The seven categories were: less than 8, 8-12, 13-17, 18-22, 23-27, 28-32, and greater than 32 knots. Table 4.1 lists the 93 stations used in the verification. Tables 4.2-4.12 show comparative verification scores (0000 GMT cycle only) for 18-, 30-, and 42-h projections for final guidance and 18- and 30-h projections for early guidance. It should also be noted that all the objective forecasts of wind speed were adjusted by an "inflation" equation (Klein et al., 1959) involving the multiple correlation coefficient and mean value of wind speed for a particular station and forecast valid time.

The results for all 93 stations combined are shown in Tables 4.2 and 4.3. The direction MAE scores reveal an advantage for the guidance that is approximately 4° for all three forecast projections. Overall, the MAE's, skill scores, and percent correct for speed were also better for the guidance. The speed MAE scores for the 18- and 30-h early guidance were substantially

Fig. 4.3 is a comparison of guidance and local skill scores computed on five (instead of seven) categories; the fifth category included all speeds greater than 22 knots. Here we see that the skill of the final guidance for both projections improved despite the use of inflation. Of particular note in Fig. 4.3 is the large magnitude of the advantage in skill of the guidance over the locals for both projections. We do not know why the skill of the local forecasts decreased during the most recent cool season; the skill of guidance forecasts remained relatively constant.

Fig. 4.4 depicts a comparison of guidance and local skill scores computed on two categories; the first category contained all speeds less than or equal to 22 knots, while the second category included speeds greater than 22 knots. In this manner, we attempted to more directly assess the skill of the guidance and local forecasts in regard to predicting strong winds. Similar to the results in Fig. 4.3, the skill of both the guidance and local forecasts for the 18-h projection increased during the 5-year span. In contrast, the local forecasts for the 42-h projection did not improve significantly from 1973 to 1978.

The 18-h early guidance MAE and skill scores in Figs. 4.1-4.4 generally indicate the superiority of these forecasts over those from the other two systems. This is quite encouraging because the early forecasts are rapidly becoming the primary source of detailed surface wind guidance available to NWS field forecasters prior to issuance of the public weather forecast.

5. OPAQUE SKY COVER

For the 1977-78 cool season, we implemented the same regionalized prediction equations for early and final guidance as were used during the previous cool season with one major addition (National Weather Service, 1978b), namely, the extension of our early guidance package to 48 hours. We continue to provide forecasts for projections of 12 through 48 hours for our final guidance package.

The regionalized equations produced probability forecasts of four categorie of opaque sky cover, more commonly known as cloud amount, as shown in Table 5.1. For both the early and final guidance packages, we convert the probability estimates to a single "best category" forecast in a manner which improves the bias characteristics of the product. For more details about our cloud amount forecast system, see National Weather Service (1978b).

For this verification, we compared the local forecasts at the 93 stations listed in Table 4.1 with a matched sample of early and final guidance forecasts. The comparison was conducted for 18-, 30-, and 42-h forecasts from the 0000 GMT cycle only. We converted the local forecasts and the surface observations used for verification from opaque sky cover amount to the categories in Table 5.1. Four-category, forecast-observed contingency tables were prepared from the transformed local and best-category guidance predictions. Using these tables, we computed the percent correct, Heidke skill score, and bias by category. The 18-h verifications covered the whole October-March cool season. However, the early guidance forecasts model output. Second, we employed the same threshold probabilities to determine the categorical forecasts that were used before the model changes. Third, the verification sample for the 30- and 42-h projections was considerably less than previous years due to the smaller matched sample of all three types of forecasts.

6. CEILING AND VISIBILITY

For the cool season 1977-78 we used the regionalized ceiling and visibility prediction equations first implemented in February 1977. On January 25, 1978 this equation set was augmented to extend the early guidance package to 48 hours. This extension to projections of 30-, 36-, 42-, and 48-h was accomplished by applying LFM-II model output and surface observations 3 hours after cycle time to forecast equations that were developed by using PE model fields and surface observations 6 hours after cycle time. Threshold probabilities derived from PE model fields were used to select the best category of ceiling and visibility for these extended projections.

Operationally, there was a change in the final guidance ceiling and visibility package on January 9, 1978 when fields from the 7LPE model replaced those from the PE model. Thus, equations and threshold probabilities developed from the PE model fields are now driven by the output of the 7LPE model.

We have continued our ceiling and visibility verification procedure with some additions. The 36- and 48-h projections for the early guidance are now included. Because of our requirment for a matched sample for verification purposes, the results for projections of 36- and 48-h for both the early and final guidance include only the sample from January 25 to March 31, 1978. To track the performance of the MOS system we have added information on trends in skill score and bias for categories 1 and 2 combined for both ceiling and visibility. We use the results for the lower two categories (i.e. ceiling < 500 feet and visibility < 1 mile) because these categories represent rare events that are difficult to forecast. Additionally, these category definitions were unaltered by the change from five to six category system.

For the period October 1977 through March 1978 we verified the forecasts for both the 0000 and 1200 GMT cycles for several projections. Early and final guidance forecasts were verified for 12-, 18-, and 24-h projections and subjective local forecasts were verified for 12-, 15-, and 21-h projections. Persistence forecasts that coincided with all the above forecasts were also verified. Persistence forecasts are the 0900 GMT observation for the 0000 GMT cycle and the 2100 or 2200 GMT observation (depending on region) for the 1200 GMT cycle.

We constructed six-category forecast-observed contingency tables for all the forecasts involved in the comparative verification. Definitions of these categories are given in Table 6.1. These categories were then used for computing several different scores: bias-by-category, percent correct, and Heidke skill score. We then collapsed the tables to two categories (categories 1 and 2 combined versus categories 3 through 6 combined) and did not use station observations as predictors. Additionally, model output from the LFM-II and from a TJ model that was dependent on the LFM-II was used in the PE-derived equations. In contrast, station observations available either 5 or 6 hours after the initial model time were used in the final guidance equations for the first two projections (approximately 24 and 36 hours). During the first part of the verification period, PE and TJ model data were input to the final guidance forecast equations for all projections. However, after the 1200 GMT cycle on January 19, the equations employed output from the 7LPE and a TJ model based on the 7LPE model as predictors.

Local forecasts for 12-h periods were obtained from the FPUS4 teletypewriter message. The objective guidance--both early and final--was available from the FOUS22 teletype bulletin. The local forecasts and objective guidanc are not precisely comparable, particularly in the forecast projections. Local forecasters predict a max for the 1200 to 0000 GMT period and a min valid during the 0000 to 1200 GMT interval. In contrast, the MOS guidance is valid for the local calendar day max or min. For example, the 24-h objective guidance based on 0000 GMT model data is valid for the calendar day that starts before 1200 GMT and ends after 0000 GMT the following day, while the local forecasts are valid only for the 1200 to 0000 GMT period. Hence, caution is necessary in comparing verification scores for the local forecasts and the objective guidance.

We verified local and objective forecasts from only the 0000 GMT cycle. Calendar day maxima and minima obtained from the National Climatic Center in Asheville, North Carolina were used as the verifying observations. We calculated the mean algebraic error (forecast minus observed temperature), the mean absolute error, and the number of absolute errors greater than 10°F for 87 stations (Table 2.1) in the conterminous United States for four forecast projections.

Verification results are shown in Table 7.1 for all 87 stations combined. The mean algebraic errors were approximately the same for the locals and guidance except for the 36- and 60-h min. For these two projections the local forecasts had large positive errors, that is, the tendency to forecast too warm a min. This, perhaps, was due to the abnormally cold winter or to the fact that we did use calendar day observations in the verifications. In terms of mean absolute errors, the final guidance was better than the early guidance at all four projections by 0.3°F to 0.6°F. This is not surprising since, for the early guidance, LFM-II data were used as input to the PE-derived equations. From earlier work (Dallavalle and Hammons, 1976), we had some indication that this would be the case. In fact, we noticed several cases during the winter when very poor early guidance forecasts were issued because of spurious noise in the LFM-II 1000 mb forecast output. For the first projection, the locals improved on the final guidance by 0.3°F in mean absolute error. Part of this difference may be because the local forecaster used the latest station observations when he/she made the forecast. Also, during October through December a programming error allowed the final guidance to occasionally use synoptic reports of the maximum or minimum that were a day old. This likely contributed to some deterioration in the final guidance. For the last three projections, the fin

Lastly, final guidance forecasts of max/min temperature continued to be about as accurate as the local forecasts for projections beyond 24 hours. For the 24-h forecasts, the local forecasts were slightly better. The final guidance was superior to the early guidance at all projections.

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Table 2.1. Eighty-seven stations used for comparative verification of guidance and local PoP and max/min temperature forecasts.

AVL	Asheville, North Carolina	DFW	Ft. Worth, Texas
RDU	Raleigh-Durham, North Carolina	JAN	Jackson, Mississippi
ORF	Norfolk, Virginia	MIA	Miami, Florida
PHL	Philadelphia, Pennsylvania	ORL	Orlando, Florida
RIC	Richmond, Virginia	TPA	Tampa, Florida
DCA	Washington, D.C.	MSY	New Orleans, Louisiana
CRW	Charleston, West Virginia	BRO	Brownsville, Texas
CHS	Charleston, South Carolina	SAT	San Antonio, Texas
CLT	Charlotte, North Carolina	IAH	Houston, Texas
CAE	Columbia, South Carolina	ATL	Atlanta, Georgia
LGA	New York (Laguardia), New York	BHM	Birmingham, Alabama
BUF	Buffalo, New York	JAX	Jacksonville, Florida
ALB	Albany, New York	MEM	Memphis, Tennessee
BOS	Boston, Massachusetts	SHV	Shreveport, Louisiana
BDL	Hartford, Connecticut	AUS	Austin, Texas
BTV	Burlington, Vermont	LIT	Little Rock, Arkansas
PWM	Portland, Maine	OKC	Oklahoma City, Oklahoma
PVD	Providence, Rhode Island	TUL	Tulsa, Oklahoma
SYR	Syracuse, New York	MAF	Midland, Texas
CLE	Cleveland, Ohio	ELP	El Paso, Texas
CMH	Columbus, Ohio	AMA	Amarillo, Texas
BAL	Baltimore, Maryland	ABQ	Albuquerque, New Mexico
ACY	Atlantic City, New Jersey	FLG	Flagstaff, Arizona
CVG	Cincinnatti, Ohio	TUS	Tucson, Arizona
DAY	Dayton, Ohio	LAS	Las Vegas, Nevada
PIT	Pittsburgh, Pennsylvania	LAX	Los Angeles, California
ICT	Wichita, Kansas	RNO	Reno, Nevada
MKC	Kansas City, Missouri	SAN	San Diego, California
STL	St. Louis, Missouri	SFO	San Francisco, California
MDW	Chicago (Midway), Illinois	BIL	Billings, Montana
MKE	Milwaukee, Wisconsin	SLC	Salt Lake City, Utah
SSM	Sault Ste Marie, Michigan	BOI	Boise, Idaho
DLH	Duluth, Minnesota	HLN	Helena, Montana
FAR	Fargo, North Dakota	GEG	Spokane, Washington
MSP	Minneapolis, Minnesota	PDX	Portland, Oregon
DSM	Des Moines, Iowa	SEA	Seattle-Tacoma, Washington
OMA	Omaha, Nebraska	CPR	Casper, Wyoming
FSD	Sioux Falls, South Dakota	RAP	Rapid City, South Dakota
DEN	Denver, Colorado	IND	Indianapolis, Indiana
BIS	Bismarck, North Dakota	SDF	Louisville, Kentucky
CYS	Cheyenne, Wyoming	DTW	Detroit, Michigan
LBF	North Platte, Nebraska	PHX	Phoenix, Arizona
BNA	Nashville, Tennessee	GTF	Great Falls, Montana
TOP	Topeka, Kansas		

Table 2.3 Same as Table 2.2 except for 26 stations in the Eastern Region.

Projection	Type of Forecast	Brier Score	Improvement Over Guidance (%)	Improvement Over Climatology (%)	Number of Cases
12-24 h (1st period)	Early/Final	.1099		46.9	3104
	Local	.1125	-2.3	45.6	
24-36 h (2nd period)	Early	.1261		39.0	3102
	Final	.1224		40.7	
	Local	.1226	2.7[1] (-0.2)	40.6	
36-48 h (3rd period)	Early	.1237		36.7	1962
	Final	.1309		33.1	
	Local	.1193	3.6[1] (8.8)	39.0	

[1] This is the percent improvement of the locals over the early guidance; the figure in parentheses is the percent improvement of the locals over the final guidance.

Table 2.5 Same as Table 2.2 except for 23 stations in the Southern Region.

Projection	Type of Forecast	Brier Score	Improvement Over Guidance (%)	Improvement Over Climatology (%)	Number of Cases
12-24 h (1st period)	Early/Final	.0830		41.1	2749
	Local	.0765	8.1	45.9	
24-36 h (2nd period)	**Early**	.1324		24.9	2661
	Final	.1325		25.4	
	Local	.1223	7.6 (7.6)	27.8	
36-48 h (3rd period)	Early	.1130		24.0	1731
	Final	.1080		27.3	
	Local	.1060	6.2 (1.9)	28.2	

[1] This is the percent improvement of the locals over the early guidance; the figure in parentheses is the percent improvement of the locals over the final guidance.

Table 3.1. Sixty-three stations used for comparative verification of guidance and local precipitation type forecasts.

PWM	Portland, Maine	ABQ	Albuquerque, New Mexico
BTV	Burlington, Vermont	GTF	Great Falls, Montana
BOS	Boston, Massachusetts	SSM	Sault Ste Marie, Michigan
PVD	Providence, Rhode Island	DTW	Detroit, Michigan
BUF	Buffalo, New York	IND	Indianapolis, Indiana
SYR	Syracuse, New York	SDF	Louisville, Kentucky
ALB	Albany, New York	MKE	Milwaukee, Wisconsin
PIT	Pittsburgh, Pennsylvania	STL	St. Louis, Missouri
PHL	Philadelphia, Pennsylvania	MCI	Kansas City, Missouri
CLE	Cleveland, Ohio	TOP	Topeka, Kansas
CMH	Columbus, Ohio	DEN	Denver, Colorado
CRW	Charleston, West Virginia	CYS	Cheyenne, Wyoming
DCA	Washington, D.C.	BIS	Bismarck, North Dakota
ORF	Norfolk, Virginia	FAR	Fargo, North Dakota
RDU	Raleigh-Durham, North Carolina	RAP	Rapid City, South Dakota
CLT	Charlotte, North Carolina	FSD	Sioux Falls, South Dakota
CAE	Columbia, South Carolina	OMA	Omaha, Nebraska
ATL	Atlanta, Georgia	MSP	Minneapolis, Minnesota
MIA	Miami, Florida	DSM	Des Moines, Iowa
JAX	Jacksonville, Florida	FLG	Flagstaff, Arizona
BHM	Birmingham, Alabama	PHX	Phoenix, Arizona
MEM	Memphis, Tennessee	SLC	Salt Lake City, Utah
JAN	Jackson, Mississippi	LAS	Las Vegas, Nevada
MSY	New Orleans, Louisiana	RNO	Reno, Nevada
SHV	Shreveport, Louisiana	SAN	San Diego, California
IAH	Houston, Texas	LAX	Los Angeles, California
SAT	San Antonio, Texas	SFO	San Francisco, California
DFW	Fort Worth, Texas	PDX	Portland, Oregon
ELP	El Paso, Texas	SEA	Seattle (Tacoma), Washington
LIT	Little Rock, Arkansas	GEG	Spokane, Washington
TUL	Tulsa, Oklahoma	BOI	Boise, Idaho
OKC	Oklahoma City, Oklahoma		

Table 3.3. Comparative verification of early and final PoF guidance and local forecasts, 0000 GMT cycle. Early PoF was verified only for the 18-h projection. Only those cases in which the local and guidance differed and the local PoP was ≥ 30% were included.

Projection (h)	Type of Forecast	Percent Correct	Number of Cases
18	Early	50	66
	Local	50	
	Final	50	78
	Local	50	
30	Final	60	77
	Local	40	
42	Final	62	72
	Local	38	

Table 4.2. Comparative verification of early and final guidance and local surface wind forecasts for 93 stations, 0000 GMT.

FCST PROJ (HOURS)	TYPE OF FCST	DIRECTION MEAN ABS ERROR (DEG)	DIRECTION NO. OF CASES	SPEED MEAN ABS ERROR (KTS)	SPEED MEAN FCST (KTS)	SPEED MEAN OBS (KTS)	SPEED NO. OF CASES	CONTINGENCY TABLE SKILL SCORE	CONTINGENCY TABLE PERCENT FCST CORRECT	BIAS-NO. FCST/NO. OBS CAT1 (NO. OBS)	CAT2 (NO. OBS)	CAT3 (NO. OBS)	CAT4 (NO. OBS)	CAT5 (NO. OBS)	CAT6 (NO. OBS)	CAT7 (NO. OBS)	NO. OF CASES
18	EARLY	25	6108	3.2	12.7	12.7	6139	0.33	55	1.17	0.96	0.80	0.75	0.69	0.69	1.00	14096
	FINAL	27		3.5	13.4			0.30	53	1.07	0.96	0.93	0.94	1.03	0.90	1.56	
	LOCAL	29		3.5	13.8			0.28	50	0.79	1.19	1.09	1.08	0.82	0.90	1.89	
										(5588)	(5044)	(2453)	(773)	(187)	(42)	(9)	
30	EARLY	30	3396	3.7	12.2	11.5	3447	0.31	62	1.06	0.95	0.89	0.68	0.69	0.53	0.40	14057
	FINAL	30		4.0	12.7			0.29	61	1.03	0.95	1.04	0.89	0.85	1.06	0.60	
	LOCAL	35		4.1	12.6			0.26	57	0.88	1.24	1.04	0.95	0.55	0.88	1.80	
										(8236)	(4094)	(1264)	(361)	(80)	(17)	(5)	
42	FINAL	40	7055	4.1	12.7	11.6	7165	0.23	48	1.03	1.02	0.94	0.86	1.01	1.02	1.17	13998
	LOCAL	44		4.1	12.5			0.18	44	0.79	1.33	0.95	0.69	0.49	0.40	0.75	
										(5498)	(5020)	(2455)	(778)	(192)	(43)	(12)	

Table 4.4 Same as Table 4.2 except for 23 stations in the Eastern Region.

FCST PROJ (HOURS)	TYPE OF FCST	DIRECTION MEAN ABS ERROR (DEG)	DIRECTION NO. OF CASES	SPEED MEAN ABS ERROR (KTS)	SPEED MEAN FCST (KTS)	SPEED MEAN OBS (KTS)	SPEED NO. OF CASES	CONTINGENCY TABLE SKILL SCORE	PERCENT FCST CORRECT	BIAS-NO. FCST/NO. OBS CAT1 (NO. OBS)	CAT2 (NO. OBS)	CAT3 (NO. OBS)	CAT4 (NO. OBS)	CAT5 (NO. OBS)	CAT6 (NO. OBS)	CAT7 (NO. OBS)	NO. OF CASES
	EARLY	26		3.0	12.6			0.32	53	1.11	1.02	0.85	0.78	1.00	0.70	0.0	
18	FINAL	27	1849	3.2	13.4	12.5	1857	0.30	51	1.02	0.96	1.01	1.06	1.47	1.20	0.25	3458
	LOCAL	28		3.5	13.9			0.25	48	0.75	1.12	1.09	1.17	1.47	1.80	1.75	
										(1137)	(1361)	(708)	(202)	(36)	(10)	(4)	
	EARLY	29		3.4	11.9			0.34	63	1.08	0.94	0.80	0.95	0.55	0.29	0.0	
30	FINAL	31	1038	3.8	13.0	11.1	1050	0.31	59	0.93	1.03	1.19	1.38	1.10	1.71	1.00	3449
	LOCAL	35		4.2	13.3			0.27	54	0.78	1.26	1.17	2.14	1.15	1.29	8.00	
										(1945)	(1060)	(342)	(74)	(20)	(7)	(1)	
42	FINAL	36	2076	3.8	13.1	11.7	2094	0.24	47	0.96	1.01	0.99	0.97	1.97	2.00	1.80	3467
	LOCAL	41		4.1	13.1			0.14	41	0.70	1.20	1.03	1.16	0.97	1.20	1.40	
										(1135)	(1387)	(687)	(204)	(39)	(10)	(5)	

Table 4.6. Same as Table 4.2 except for 24 stations in the Southern Region.

FCST PROJ (HOURS)	TYPE OF FCST	DIRECTION MEAN ABS ERROR (DEG)	DIRECTION NO. OF CASES	SPEED MEAN ABS ERROR (KTS)	SPEED MEAN FCST (KTS)	SPEED MEAN OBS (KTS)	SPEED NO. OF CASES	CONTINGENCY TABLE SKILL SCORE	PERCENT FCST CORRECT	BIAS-NO. FCST/NO. OBS CAT1 (NO. OBS)	CAT2 (NO. OBS)	CAT3 (NO. OBS)	CAT4 (NO. OBS)	CAT5 (NO. OBS)	CAT6 (NO. OBS)	CAT7 (NO. OBS)	NO. OF CASES
	EARLY	28		3.2	12.1			0.29	53	1.25	0.96	0.75	0.57	0.55	0.75	*	
18	FINAL	29	1671	3.4	12.8	12.4	1676	0.28	51	1.13	0.96	0.92	0.78	0.76	1.25	**	3686
	LOCAL	30		3.3	13.1			0.23	48	0.69	1.27	1.10	0.82	0.33	0.50	*	
										(1310)	(1468)	(667)	(204)	(33)	(4)	(0)	
	EARLY	34		3.6	11.7			0.32	64	1.05	0.98	0.80	0.49	1.13	**	*	
30	FINAL	32	766	3.7	11.7	11.2	774	0.30	63	1.09	0.89	0.89	0.52	0.38	*	*	3671
	LOCAL	36		3.7	11.7			0.27	60	0.93	1.23	0.84	0.59	0.38	*	*	
										(2204)	(1085)	(294)	(80)	(8)	(0)	(0)	
42	FINAL	42	1906	3.9	12.1	11.4	1924	0.20	46	1.09	1.02	0.90	0.69	0.46	1.80	**	3604
	LOCAL	46		3.8	12.0			0.14	44	0.77	1.38	0.86	0.38	0.09	0.40	**	
										(1260)	(1423)	(682)	(199)	(35)	(5)	(0)	

* This category was neither forecast nor observed.
** This category was forecast once but was never observed.

Table 4.8. Distribution of absolute errors associated with early and final guidance and local forecasts of surface wind direction for 93 stations, 0000 GMT cycle.

FORECAST PROJECTION (HOURS)	TYPE OF FORECAST	PERCENTAGE FREQUENCY OF ABSOLUTE ERRORS BY CATEGORY					
		0-30°	40-60°	70-90°	100-120°	130-150°	160-180°
18	EARLY	77.8	14.9	3.7	1.6	1.1	0.9
	FINAL	75.6	16.3	4.2	1.9	1.1	0.9
	LOCAL	72.5	17.6	5.4	2.3	1.2	1.0
30	EARLY	72.3	17.0	5.0	2.5	1.8	1.4
	FINAL	70.8	17.6	6.0	2.7	1.7	1.2
	LOCAL	64.3	21.2	7.0	3.3	2.6	1.6
42	FINAL	60.2	20.6	8.3	4.9	3.4	2.6
	LOCAL	55.3	21.8	9.6	5.8	4.4	3.1

Table 4.11. Same as Table 4.8 except for 24 stations in the Southern Region.

FORECAST PROJECTION (HOURS)	TYPE OF FORECAST	PERCENTAGE FREQUENCY OF ABSOLUTE ERRORS BY CATEGORY					
		0-30°	40-60°	70-90°	100-120°	130-150°	160-180°
18	EARLY	74.7	17.0	4.4	1.7	1.1	1.1
	FINAL	71.9	18.9	5.0	2.1	1.4	0.7
	LOCAL	70.2	20.2	4.9	2.5	1.3	0.9
30	EARLY	67.4	17.8	8.0	2.7	2.5	1.7
	FINAL	69.5	17.0	7.1	3.5	1.8	1.2
	LOCAL	62.7	21.4	7.7	4.1	2.5	1.7
42	FINAL	56.1	23.2	9.4	5.4	3.5	2.4
	LOCAL	52.9	23.6	10.0	5.7	4.8	3.0

Table 5.1 Definitions of the categories used for guidance forecasts of cloud amount.

Category	Cloud Amount (Opaque Sky Cover in tenths)
1	0-1
2	2-5
3	6-9
4	10

Table 4.12. Same as Table 4.8 except for 18 stations in the Western Region.

FORECAST PROJECTION (HOURS)	TYPE OF FORECAST	PERCENTAGE FREQUENCY OF ABSOLUTE ERRORS BY CATEGORY					
		0-30°	40-60°	70-90°	100-120°	130-150°	160-180°
18	EARLY	72.9	13.1	4.7	3.2	3.9	2.3
	FINAL	72.3	14.2	5.1	2.8	2.6	3.0
	LOCAL	69.9	15.7	6.4	2.3	3.2	2.6
30	EARLY	67.3	17.2	4.8	4.6	3.2	2.9
	FINAL	69.5	15.3	6.3	2.7	2.9	3.4
	LOCAL	62.5	18.6	8.0	4.4	3.4	3.2
42	FINAL	56.3	15.5	8.3	7.7	6.2	6.1
	LOCAL	51.5	18.6	6.9	7.6	8.3	7.2

Table 5.4. Same as Table 5.2 except for 28 stations in the Central Region.

PROJECTION (HRS)	TYPE OF FORECAST	BIAS - NO. FCST/NO. OBS				PERCENT CORRECT	SKILL SCORE	NO. OF CASES
		CAT 1 (No. Obs.)	CAT 2 (No. Obs.)	CAT3 (No. Obs)	CAT4 (No. Obs.)			
18	EARLY	1.10	0.67	1.13	1.05	52.1	.342	4127
	FINAL	1.12	0.64	1.11	1.06	52.7	.349	
	LOCAL	0.57 (1101)	1.43 (852)	1.40 (720)	0.87 (1454)	49.2	.321	
30	EARLY	1.07	0.56	1.01	1.11	55.5	.339	1390
	FINAL	0.78	0.56	1.27	1.31	52.7	.305	
	LOCAL	0.51 (517)	2.21 (206)	2.02 (147)	0.72 (520)	42.1	.236	
42	EARLY	0.93	0.64	1.64	1.00	44.8	.258	1439
	FINAL	0.75	0.56	1.82	1.14	44.4	.255	
	LOCAL	0.33 (415)	1.62 (338)	1.59 (233)	0.85 (453)	36.1	.156	

Table 5.6. Same as Table 5.2 except for 18 stations in the Western Region.

PROJECTION (HRS)	TYPE OF FORECAST	BIAS - NO. FCST/NO. OBS				PERCENT CORRECT	SKILL SCORE	NO. OF CASES
		CAT 1 (No. Obs.)	CAT 2 (No. Obs.)	CAT3 (No. Obs)	CAT4 (No. Obs.)			
18	EARLY	1.25	0.82	0.81	1.04	50.0	.321	2788
	FINAL	1.28	0.76	0.91	1.00	50.3	.325	
	LOCAL	0.86 (702)	1.07 (608)	1.22 (553)	0.93 (925)	53.7	.378	
30	EARLY	1.20	1.01	0.53	1.05	48.9	.285	926
	FINAL	0.99	0.90	0.62	1.24	50.5	.302	
	LOCAL	0.58 (270)	1.45 (167)	1.69 (156)	0.79 (333)	43.5	.250	
42	EARLY	1.46	0.70	0.95	0.95	40.5	.194	924
	FINAL	1.04	0.77	0.97	1.13	42.6	.213	
	LOCAL	0.70 (190)	1.25 (195)	1.28 (213)	0.84 (326)	40.5	.198	

Table 6.2. Comparative verification of early and final guidance, persistence, and local ceiling forecasts for 93 stations, 0000 GMT cycle.

Projection (h)	Type of Forecast	Bias by Category						Percent Correct	Heidke Skill Score
		1	2	3	4	5	6		
12	Early	.69	.99	.96	1.08	1.01	1.00	62.4	.392
	Final	.74	.90	1.02	1.03	1.06	.99	65.0	.434
	Local	.51	.95	.84	1.18	1.10	.97	72.5	.559
	Persistence	.79	.92	.88	.98	.99	1.04	74.9	.587
	No. Obs.	316	682	868	2065	2013	8086		
15	Local	.34	.63	.73	1.26	1.23	.96	65.5	.441
	Persistence	1.07	.92	.79	.95	1.08	1.03	65.4	.427
	No. Obs.	247	720	1043	2282	1942	8759		
18	Early	.44	.94	.99	1.01	1.08	.97	61.7	.359
	Final	.25	.90	1.04	1.07	1.14	.96	62.5	.373
	Persistence	2.40	1.32	.92	.86	1.08	.99	61.3	.347
	No. Obs.	106	478	837	2380	1863	8538		
21	Local	.12	.34	.66	1.22	1.22	.96	63.3	.364
	Persistence	3.46	1.59	1.11	.96	.95	.97	58.4	.287
	No. Obs.	76	414	737	2270	2219	9267		
24	Early	.26	.88	.99	1.08	1.01	1.00	64.3	.361
	Final	.44	.82	1.07	1.07	1.09	.97	63.8	.359
	Persistence	2.44	1.53	1.21	1.05	.94	.95	56.6	.249
	No. Obs.	104	412	638	1943	2147	8959		
36	Early	.42	.65	.68	1.13	1.06	1.03	57.8	.293
	Final	.68	.74	.83	1.33	1.30	.89	54.7	.286
	Persistence	.99	.96	.96	.97	.96	1.02	49.7	.165
	No. Obs.	78	223	301	756	709	2904		
48	Early	.64	.67	.91	.86	1.13	1.02	61.3	.266
	Final	.59	.73	.76	.93	1.44	.95	58.7	.251
	Persistence	3.50	1.79	1.52	1.05	.96	.92	49.1	.104
	No. Obs.	22	120	190	699	712	3230		

Table 6.4. Same as 6.2 except for 1200 GMT cycle.

Projection (h)	Type of Forecast	Bias by Category 1	2	3	4	5	6	Percent Correct	Heidke Skill Score
12	Early	.43	.86	1.04	.99	1.04	1.00	65.8	.390
	Final	.46	.93	1.05	.96	1.02	1.01	68.0	.426
	Local	.29	.85	.91	1.20	1.03	.97	75.3	.565
	Persistence	.71	.95	1.08	1.09	.96	.99	75.9	.574
	No. Obs.	103	398	641	1987	2188	8911		
15	Local	.21	.82	.93	1.26	.95	.98	69.6	.465
	Persistence	.54	.85	1.01	1.11	.97	1.00	67.7	.427
	No. Obs.	135	453	702	1982	2224	9179		
18	Early	.72	.92	1.09	1.09	1.04	.97	62.0	.354
	Final	.92	1.09	.95	1.03	1.01	.99	63.1	.366
	Persistence	.35	.78	.95	1.09	.99	1.01	62.2	.342
	No. Obs.	212	496	737	1997	2177	8835		
21	Local	.18	.77	.99	1.33	.96	.97	62.8	.378
	Persistence	.28	.61	.87	1.04	1.05	1.04	58.3	.280
	No. Obs.	256	628	810	2118	2041	8819		
24	Early	.80	.89	1.08	1.08	1.02	.98	58.5	.335
	Final	.75	1.05	1.04	1.06	1.11	.96	58.5	.341
	Persistence	.23	.56	.77	1.03	1.03	1.08	55.0	.245
	No. Obs.	322	693	912	2129	2091	8305		
36	Early	.85	1.10	.87	.89	1.23	.98	61.4	.293
	Final	.35	.79	.92	1.04	1.52	.90	57.9	.265
	Persistence	.85	.93	1.21	1.10	1.01	.97	52.4	.137
	No. Obs.	26	137	209	733	717	3335		
48	Early	.57	.58	.86	.88	1.20	1.04	55.4	.251
	Final	.57	.61	.86	.96	1.40	.97	53.7	.246
	Persistence	.26	.55	.82	1.03	.99	1.07	46.8	.095
	No. Obs.	84	234	308	780	738	3011		

Table 6.6. Comparative verification of early and final guidance, persistence, and local ceiling forecasts for 93 stations, 0000 GMT. Scores are computed from two-category contingency tables.

Projection (h)	Type of Forecast	Rel Freq Cats. 1&2 combined	Bias Cats. 1&2 combined	Percent correct	Heidke Skill Score	Threat Score
12	Early	.071	.894	91.9	.356	.247
	Final		.849	93.0	.431	.306
	Local		.809	94.8	.566	.422
	Persistence		.878	95.1	.607	.463
15	Local	.064	.551	93.9	.363	.244
	Persistence		.956	93.2	.421	.297
18	Early	.041	.851	94.3	.224	.145
	Final		.777	94.5	.216	.141
	Persistence		1.515	92.7	.262	.175
21	Local	.032	.380	96.3	.121	.072
	Persistence		1.880	92.6	.176	.118
24	Early	.036	.752	95.0	.182	.116
	Final		.746	95.0	.188	.119
	Persistence		1.715	92.0	.149	.104
36	Early	.061	.591	92.8	.215	.147
	Final		.724	92.4	.235	.158
	Persistence		.970	90.2	.127	.098
48	Early	.029	.662	96.3	.202	.124
	Final		.711	96.2	.195	.120
	Persistence		2.056	92.4	.099	.072

Table 6.8. Same as Table 6.6 except for 1200 GMT cycle.

Projection (h)	Type of Forecast	Rel Freq Cats. 1&2 combined	Bias Cats. 1&2 combined	Percent correct	Heidke Skill Score	Threat Score
12	Early Final Local Persistence	.035	.772 .834 .733 .900	95.6 95.9 97.0 97.3	.277 .351 .487 .576	.168 .229 .335 .419
15	Local Persistence	.040	.679 .781	96.0 96.0	.390 .423	.257 .284
18	Early Final Persistence	.049	.860 1.042 .653	93.4 93.2 94.9	.250 .288 .353	.165 .193 .224
21	Local Persistence	.060	.598 .518	93.6 93.2	.306 .229	.203 .150
24	Early Final Persistence	.070	.862 .957 .455	90.6 91.0 92.0	.232 .298 .176	.177 .210 .119
36	Early Final Persistence	.032	1.061 .718 .920	95.0 95.9 94.4	.212 .215 .054	.135 .134 .043
48	Early Final Persistence	.062	.575 .597 .472	92.6 92.4 91.9	.204 .195 .070	.136 .131 .056

Table 6.10. Trend in Heidke skill score for ceiling categories 1 and 2 combined for the comparative verification of early and final guidance, persistence, and local forecasts for 93 stations, 0000 GMT cycle.

Projection (h)	Type of Forecast	Year 1975/76	Year 1976/77	Year 1977/78
12	Early		.317	.352
	Final	.368	.226	.431
	Local	.540	.452	.566
	Persistence	.607	.529	.607
	No. Cases	13915	4199	14030
15	Local	.320		.363
	Persistence	.242		.421
	No. Cases	14984		14993
18	Early		.190	.224
	Final	.144	.246	.216
	Persistence	.239	.123	.262
	No. Cases	14009	4227	14202
21	Local	.166	.053	.121
	Persistence	.167	.086	.176
	No. Cases	14979	4279	14983
24	Early		.166	.182
	Final	.043	.144	.188
	Persistence	.131	.050	.149
	No. Cases	14052	4224	14203
36	Early			.215
	Final		.187	.235
	Persistence		.054	.127
	No. Cases		4227	4971
48	Early			.202
	Final		.132	.195
	Persistence		.036	.099
	No. Cases		4224	4973

Table 6.12. Same as 6.10 except 1200 GMT cycle.

Projection (h)	Type of Forecast	Year 1975/76	1976/77	1977/78
12	Early		.157	.277
	Final	.301	.251	.351
	Local	.472	.420	.487
	Persistence	.520	.387	.576
	No. Cases	13486	4217	14228
15	Local	.387	.343	.390
	Persistence	.344	.249	.423
	No. Cases	14779	3232	14675
18	Early		.215	.250
	Final	.149	.272	.288
	Persistence	.274	.215	.353
	No. Cases	13632	4269	14454
21	Local	.237	.270	.306
	Persistence	.195	.143	.229
	No. Cases	14786	4216	14672
24	Early		.272	.232
	Final	.100	.253	.298
	Persistence	.126	.106	.176
	No. Cases	13723	4269	14452
36	Early			.212
	Final		.064	.215
	Persistence		-.002	.054
	No. Cases		4266	5157
48	Early			.204
	Final		.153	.195
	Persistence		.002	.070
	No. Cases		4269	5755

Table 6.14. Trend in bias for ceiling categories 1 and 2 combined for the comparative verification of early and final guidance, persistence, and local forecasts for 93 stations, 0000 GMT cycle.

Projection (h)	Type of Forecast	Year 1975/76	1976/77	1977/78
12	Early		.79	.89
	Final	.59	.37	.84
	Local	.76	.67	.88
	Persistence	.82	.81	.81
	No. Cases			
15	Local	.54		.55
	Persistence	.95		.96
	No. Cases			
18	Early		1.26	.85
	Final	.20	1.00	.78
	Persistence	1.66	1.73	1.52
	No. Cases			
21	Local	.35	.17	.38
	Persistence	2.27	2.22	1.88
	No. Cases			
24	Early		1.00	.75
	Final	.10	.73	.75
	Persistence	2.09	1.99	1.72
	No. Cases			
36	Early			.59
	Final		.89	.72
	Persistence		.80	.97
	No. Cases			
48	Early			.66
	Final		1.16	.71
	Persistence		1.77	2.06
	No. Cases			

Table 6.16. Same as 6.14 except for 1200 GMT.

Projection (h)	Type of Forecast	Year 1975/76	1976/77	1977/78
12	Early		1.00	.77
	Final	.66	.91	.83
	Local	.69	.67	.90
	Persistence	.91	.94	.73
	No. Cases			
15	Local	.62	.59	.68
	Persistence	.73	.74	.78
	No. Cases			
18	Early		1.24	.86
	Final	.28	1.06	1.04
	Persistence	.60	.63	.65
	No. Cases			
21	Local	.50	.54	.60
	Persistence	.45	.51	.52
	No. Cases			
24	Early		.77	.86
	Final	.17	.84	.96
	Persistence	.36	.39	.46
	No. Cases			
36	Early			1.06
	Final		1.57	.72
	Persistence		.89	.92
	No. Cases			
48	Early			.58
	Final		.92	.60
	Persistence		.39	.47
	No. Cases			

Table 7.1. Comparative verification of early and final guidance and local max/min temperature forecasts for 87 stations, 0000 GMT cycle.

FORECAST PROJECTION (HOURS)	TYPE OF FORECAST	MEAN ALGEBRAIC ERROR (°F)	MEAN ABSOLUTE ERROR (°F)	NUMBER (%) OF ABSOLUTE ERRORS ≥ 10°	NUMBER OF CASES
24 (MAX)	EARLY	0.3	4.2	1056 (8.0)	13206
	FINAL	-0.2	3.7	699 (5.3)	
	LOCAL	-0.1	3.4	559 (4.2)	
36 (MIN)	EARLY	0.1	4.5	1091 (9.7)	11291
	FINAL	-0.2	4.2	918 (8.1)	
	LOCAL	0.7	4.2	917 (8.1)	
48 (MAX)	EARLY	0.2	4.8	1550 (11.8)	13121
	FINAL	-0.2	4.5	1339 (10.2)	
	LOCAL	-0.4	4.4	1244 (9.5)	
60 (MIN)	EARLY	-0.1	5.7	2025 (18.1)	11191
	FINAL	-0.1	5.1	1586 (14.2)	
	LOCAL	0.5	5.1	1540 (13.8)	

Table 7.3. Same as Table 7.1 except for 22 stations in the Central Region.

FORECAST PROJECTION (HOURS)	TYPE OF FORECAST	MEAN ALGEBRAIC ERROR (°F)	MEAN ABSOLUTE ERROR (°F)	NUMBER (%) OF ABSOLUTE ERRORS ≥ 10°	NUMBER OF CASES
24 (MAX)	EARLY	0.7	4.1	243 (7.3)	3330
	FINAL	-0.2	3.8	175 (5.3)	
	LOCAL	-0.2	3.5	147 (4.4)	
36 (MIN)	EARLY	0.3	5.2	370 (14.4)	2575
	FINAL	-0.3	5.0	341 (13.2)	
	LOCAL	0.7	4.7	301 (11.7)	
48 (MAX)	EARLY	0.3	4.8	389 (11.8)	3308
	FINAL	-0.5	4.8	389 (11.8)	
	LOCAL	-0.7	4.5	329 (10.0)	
60 (MIN)	EARLY	-0.1	6.3	561 (22.7)	2473
	FINAL	0.0	5.8	475 (19.2)	
	LOCAL	0.6	5.7	469 (19.0)	

Table 7.5. Same as Table 7.1 except for 16 stations in the Western Region.

FORECAST PROJECTION (HOURS)	TYPE OF FORECAST	MEAN ALGEBRAIC ERROR (°F)	MEAN ABSOLUTE ERROR (°F)	NUMBER (%) OF ABSOLUTE ERRORS ≥ 10°	NUMBER OF CASES
24 (MAX)	EARLY	-0.7	4.4	220 (9.1)	2421
	FINAL	-0.1	3.5	110 (4.5)	
	LOCAL	0.1	3.1	72 (3.0)	
36 (MIN)	EARLY	-0.9	4.0	164 (7.4)	2206
	FINAL	-1.0	3.8	134 (6.1)	
	LOCAL	-0.2	3.6	125 (5.7)	
48 (MAX)	EARLY	-0.7	4.8	288 (12.0)	2406
	FINAL	-0.5	4.2	205 (8.5)	
	LOCAL	-0.5	4.1	200 (8.3)	
60 (MIN)	EARLY	-1.0	5.1	294 (13.3)	2217
	FINAL	-1.7	4.6	243 (11.0)	
	LOCAL	-0.7	4.4	197 (8.9)	

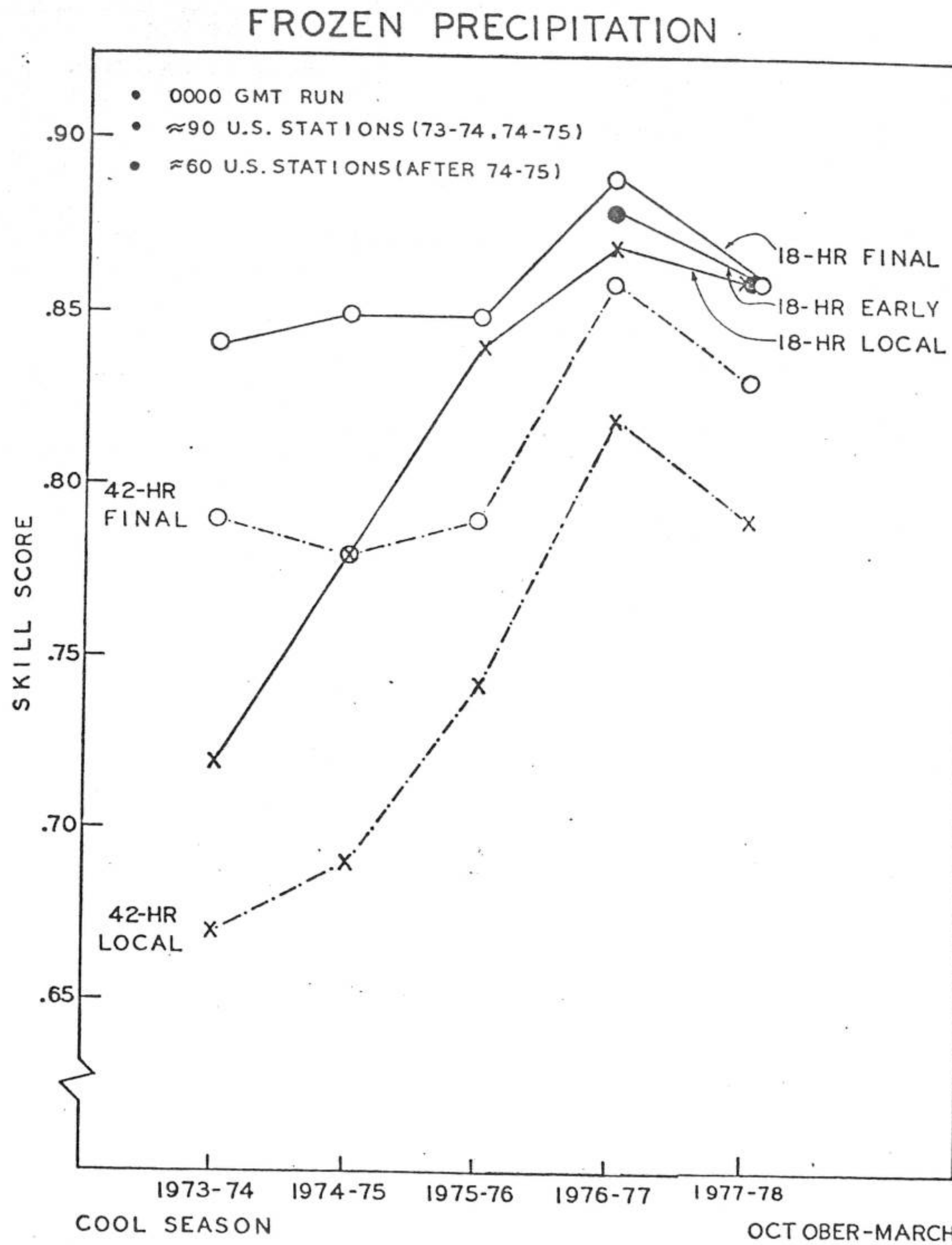

Figure 3.1. The trend in skill scores for guidance and local forecasts of frozen precipitation.

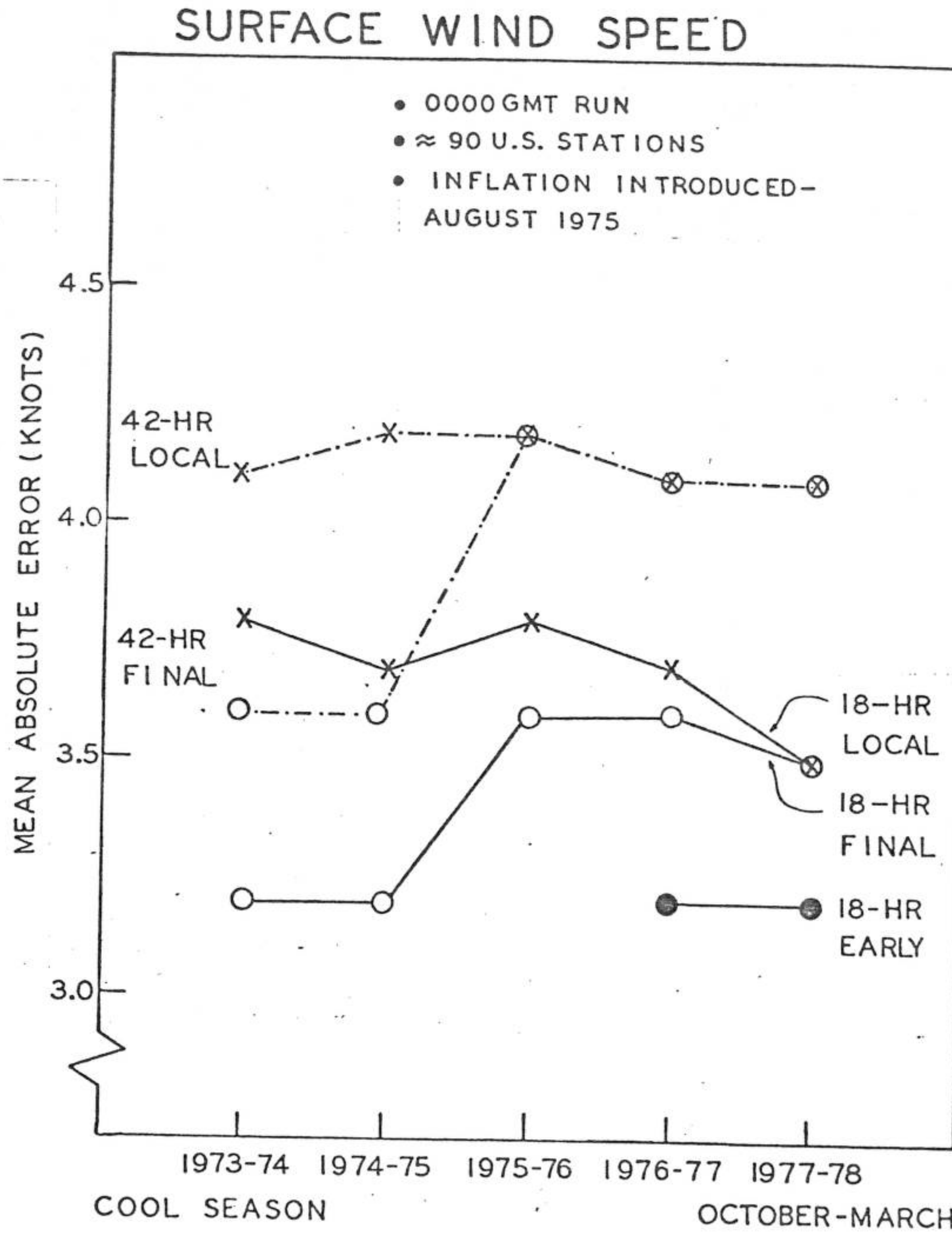

Figure 4.2. Same as Fig. 4.1 except for wind speed forecasts.

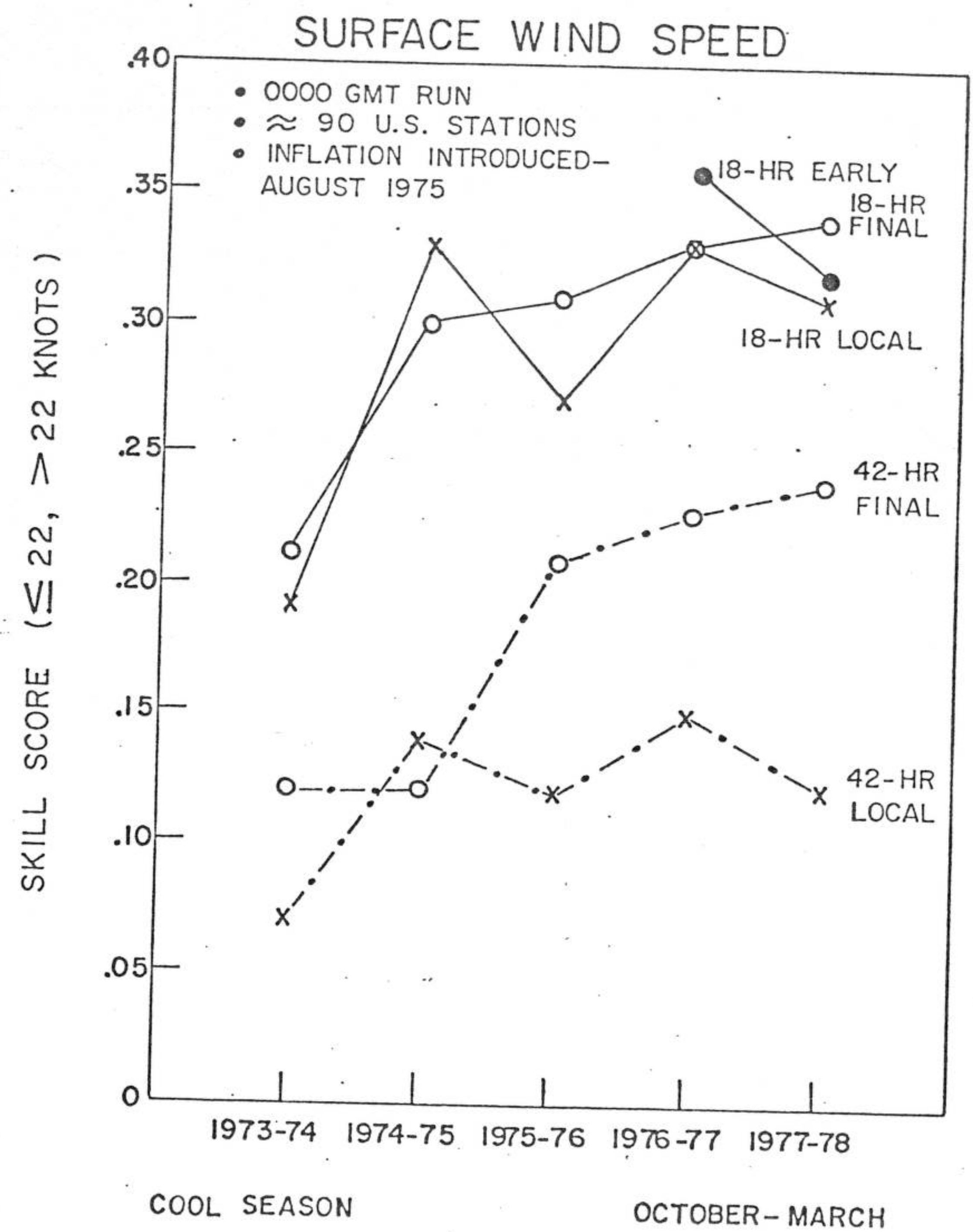

Figure 4.4. Same as Fig. 4.3 except for two-category contingency tables.

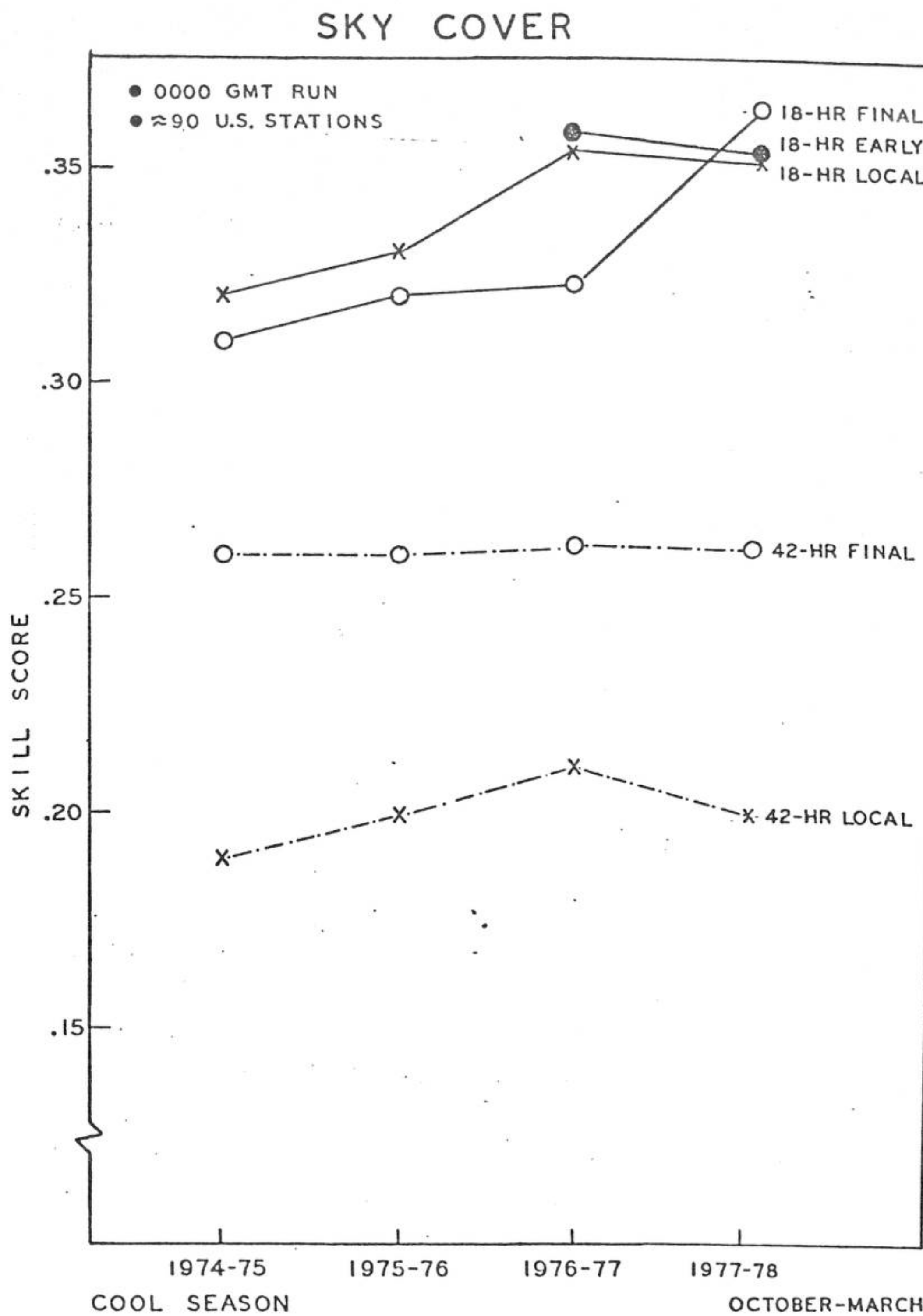

Figure 5.2. Skill score for local and guidance cloud amount forecasts for the cool season.

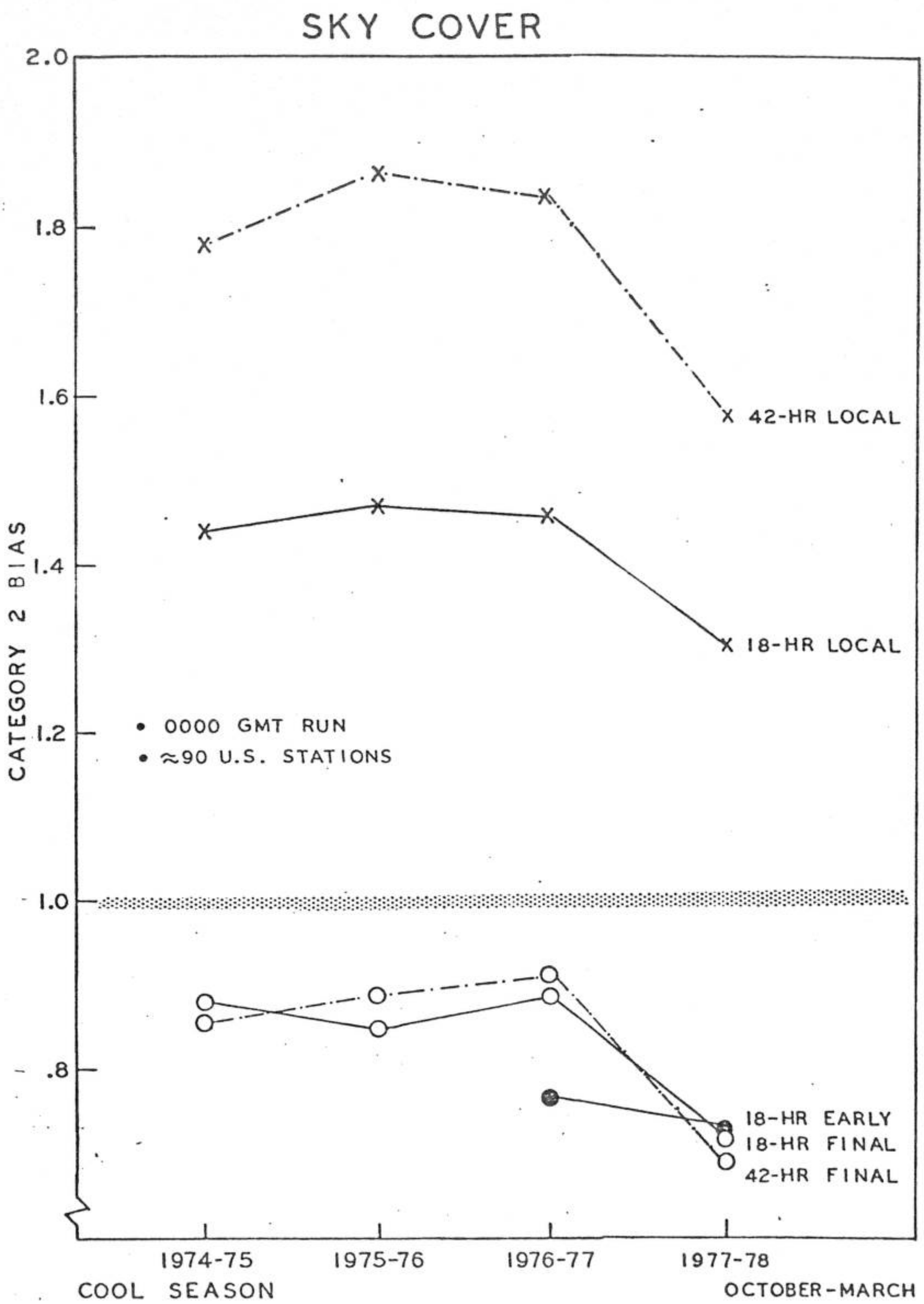

Figure 5.4. Same as Fig. 5.3 except for category 2 bias.