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COMPARATIVE VERIFICATION OF GUIDANCE AND LOCAL AVIATION/PUBLIC WEATHER FORECASTS--NO. 9
(October 1979 - March 1980)

Joseph R. Bocchieri, J. Paul Dallavalle, Karl L. Hebenstreit,
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1. INTRODUCTION

This is the ninth in the series of Techniques Development Laboratory (TDL) office notes which compare the performance of TDL's automated guidance forecasts with National Weather Service (NWS) local forecasts made at Weather Service Forecast Offices (WSFO's). The local forecasts, which are produced subjectively, may or may not be based on the automated guidance. We present verification statistics for the cool season months of October 1979 through March 1980 for probability of precipitation, precipitation type, surface wind, opaque sky cover, ceiling height, visibility, and maximum/minimum (max/min) temperature.

The objective guidance is based on equations developed through the Model Output Statistics (MOS) technique (Glahn and Lowry, 1972). We derived these prediction equations by using archived surface observations and forecast fields from the Limited-area Fine Mesh (LFM) model (National Weather Service, 1971), the LFM-II model (National Weather Service, 1977a), the Trajectory (TJ) model (Reap, 1972), and/or the 6-layer coarse mesh Primitive Equation (6LPE) model (Shuman and Hovermale, 1968). In operations, however, forecast fields from the LFM-II and the 7-layer PE (7LPE) model[1] (National Weather Service, 1977b) are employed in the MOS guidance equations when LFM or PE data, respectively, are required. Unless indicated otherwise, we usually refer to MOS forecasts based on the LFM-II as "early" guidance; "final" guidance indicates that the objective forecasts were dependent on the 7LPE. Also, the observation times of surface weather elements used as predictors in the early and final guidance generally differ.

The local forecasts from the WSFO's were collected by the Technical Procedures Branch of the Office of Meteorology and Oceanography for the purposes of the NWS combined aviation/public weather verification system (National Weather Service, 1973). These forecasts were recorded for verification according to the direction that they be "...not inconsistent with..." the official weather prognosis. Surface observations as late as 2 hours before the first valid forecast time may have been used in the preparation of the local forecasts. We obtained the observed verification data from the National Climatic Center in Asheville, North Carolina.

2. PROBABILITY OF PRECIPITATION (PoP)

The objective PoP forecasts were produced by the cool season prediction equations described in Technical Procedures Bulletin No. 244 (National Weather Service, 1978a). Guidance was available for the first, second, and third periods, which correspond to 12-24, 24-36, and 36-48 hours, respectively, after

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[1] In August 1980, the 7LPE model was replaced in operations by the Spectral model (Sela, 1980).

all three third period forecasts in 1979-80 were at least as accurate as the first period final guidance in 1974-75. The first and third period improvement in 1979-80 is because of the abnormally large improvement in the Southern Region for those periods; the second period showed no such improvement.

3. PRECIPITATION TYPE

The early guidance conditional probability of precipitation type (PoPT) forecast system (Bocchieri, 1979) gives forecasts for three categories: frozen (snow or ice pellets), freezing (freezing rain or drizzle), and liquid (rain). Precipitation in the form of mixed snow and ice pellets is included in the frozen category; all other mixed precipitation types are included in the liquid category. Here, the frozen, freezing, and liquid categories will be referred to as simply snow, freezing rain, and rain, respectively.

In the final guidance conditional probability of frozen precipitation (PoF) system (Glahn and Bocchieri, 1975; Bocchieri and Glahn, 1976; and National Weather Service, 1976), freezing rain forecasts aren`t explicitly available; that is, freezing rain is considered as rain in PoF. Another difference between the PoPT and PoF systems is that in PoPT probability forecasts are transformed so that a "best category" is also provided operationally; in PoF, a categorical forecast isn`t available.

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`s a forecast of type of precipitation if precipitation occurs. Therefore, a precipitation type forecast is always recorded. The PoPT and PoF guidance forecasts are also conditional and are available whether or not precipitation occurs.

Table 3.1 lists the 62 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 $\geq$ 30%. The PoPs were valid for the 12-h periods centered on the 18-, 30-, and 42-h projections used in the verification.

We first did a comparative verification between the early PoPT guidance and the local forecasts for the snow, freezing rain, and rain categories. The manner in which the guidance "best category" is calculated is described in Bocchieri (1979). Table 3.2 shows the verification results; note that the scores for the freezing rain category are not shown for this season because there weren`t enough cases to be meaningful. The results for all stations combined indicate that: (1) the guidance was better than the local forecasts for percent correct and skill score[2] for the 18- and 30-h projections. At 42 hours, there was little

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[2] The skill score used throughout this paper is the Heidke skill score (Panofsky and Brier, 1965).

replaced the early PoF system in the 1978-79 season, was better than the final PoF guidance for the 1978-79 and 1979-80 seasons and for both projections. Also, the skill of all systems, except the 18-h local forecasts, improved in 1979-80 as compared to the previous season, especially at the 42-h projection.

4. SURFACE WIND

The cool season objective wind forecasts were generated by LFM-based (early) equations (National Weather Service, 1980). These equations do not include surface weather observations as predictors. Wind guidance produced by final equations was terminated in May 1979, so the final guidance was not verified for the 1979-80 cool season. We only verified the 18-, 30-, and 42-h forecast projections from 0000 GMT. Note that 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.

Two factors may have had an impact on this verification. First, the equations used for this cool season were new. These relationships were derived from an improved version of our screening regression program that reduced the instances when highly related predictors were selected in an individual equation. Equations derived in this manner should produce more accurate forecasts. Secondly, the LFM model topography was changed in October 1979. This modification drastically altered some model surface pressure forecasts, especially in the West. Unfortunately, surface pressure had been selected as a predictor in some of the forecast equations. Therefore, it is possible that poor guidance for some western U.S. locations was produced. However, it is also possible that the improved method of equation development mentioned above may have masked some of the deleterious effects of the model topography change.

Since the local forecasts were recorded as calm if the wind speed was expected to be less than 8 knots, we verifed the wind forecasts in two ways. First, for all those cases where both the local and guidance 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, the 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 94 stations used in the verification. Tables 4.2-4.12 show comparative verification scores for the 18-, 30-, and 42-h projections. It should be noted that all the guidance 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 94 stations combined are shown in Tables 4.2 and 4.3. The direction MAE scores reveal an advantage for the guidance that is approximately 5° for all three forecast projections combined. Overall, the speed MAE`s, skill scores, and percent correct were also better for the guidance. Both the biases by category in Table 4.2 and the contingency tables in Table 4.3 indicate that the guidance underestimated winds stronger than 32 knots (category 7) at the 18- and 42-h projections. Winds stronger than 22 knots (categories 5, 6, and 7) were underestimated by the guidance at the 30-h projection. For most categories, the guidance exhibited better bias characteristics than the local forecasts. In fact, the biases of the guidance wind speed forecasts for this cool season were the best of any of the previous 6 cool seasons (see, for example, Hebenstreit et al., 1979).

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 assess more directly 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 increased from the 1978-79 to the 1979-80 season. Again, the early guidance scores exhibit a clear superiority over the local forecasts, particularly in the 1979-80 season.

The early guidance MAE`s and skill scores in Fig. 4.1-4.4 generally indicate the superiority of these forecasts over the final guidance. This is quite encouraging because the early guidance is now the only source of detailed surface wind guidance available to NWS field forecasters prior to issuance of the public weather forecast.

5. OPAQUE SKY COVER

The early guidance equations used in forecasting opaque sky cover were unchanged for the 1979-80 cool season; the equations used LFM-II model output and 0300 (1500) GMT surface observations to produce forecasts for eight projections at 6-h intervals from 6 to 48 hours after 0000 (1200) GMT. Final opaque sky cover guidance was terminated at the start of the 1979-80 cool season and, hence, was not verified.

The regionalized equations produced probability forecasts of four categories of opaque sky cover, more commonly known as cloud amount, as shown in Table 5.1. The probability estimates were converted to a single "best" category forecast in a manner which produced good bias characteristics, that is, a bias value of approximately 1.0 for each category. For more details about our cloud amount forecast system, see Technical Procedures Bulletin No. 234 (National Weather Service, 1978b).

We compared the local forecasts with a matched sample of early guidance forecasts at the 94 stations listed in Table 4.1 for the 18-, 30-, and 42-h forecast projections from the 0000 GMT cycle only. The local forecasts and the surface observations used for verification were converted 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 objective predictions. Using these tables, we computed the percent correct, skill score, and bias by category.

The results for all stations combined are shown in Table 5.2. At the 30- and 42-h projections, the guidance forecasts were clearly superior to the local forecasts in terms of percent correct and skill score. However, the differences at the 18-h projection were small. Examination of the bias-by-category scores shows that, at each projection and category, the guidance forecasts were better (i.e., closer to 1.0) than the local forecasts. The local forecasts exhibited a strong tendency to overforecast the scattered and broken categories and to a lesser degree to underforecast the clear and overcast categories.

The verification scores for stations in the NWS Eastern, Southern, Central, and Western Regions are given in Tables 5.3 through 5.6, respectively. The percent correct and skill scores for the guidance forecasts were, for the most part, superior to those of the local forecasts. At the 18-h projection, the skill score for the Central Region was slightly better than that of the guidance and, in the projections, the six-category skill of the local forecast was greater than persistence except for visibility at 15-h from the 1200 GMT cycle. The two-category persistence skill exceeded that of the locals at the 15- and 21-h projections for the 0000 GMT cycle and for ceiling at the 15-h projection for the 1200 GMT cycle. The guidance forecast six-category skill was less than persistence for visibility at the 18-h projection for both cycles and at the 36-h projection for the 0000 GMT cycle. Guidance two-category skill lost to persistence for ceiling at the 18-h projection for both cycles and for visibility at the 36-h projection for the 0000 GMT cycle. For all other projections the skill of the guidance exceeded that of persistence for both the two and six-category tables with the skill of persistence decreasing more rapidly with the time of the projection.

The purpose of using the threshold probability technique to select the "best" category for ceiling and visibility was to improve the bias characteristics of the guidance forecasts. The bias-by-category scores show that for most projections the guidance had better bias scores (i.e., were closer to 1.0) than either the local or persistence forecasts. The bias of the 12-h persistence (actually 3-h from observation) is better than that of either the locals or guidance. The biases of the 36-h persistence forecasts (actually a 27-h projection) should be as good as those of 12-h persistence. Tables 6.2-6.9 show this to be true.

Figs. 6.1 to 6.8 present the year-to-year variations of two-category skill and bias for projections of 12-, 15-, 18-, and 21-h for the 0000 GMT cycle. In general, these data show that the guidance bias characteristics for the difficult-to-forecast low categories were closer to the desired 1.0 than local and persistence forecasts since the implementation of the threshold technique of best category selection in February 1977. The skill score for guidance forecasts exhibits variation from year-to-year. Since the sample size for the 1976-77 cool seasons (Feb 8 to Mar 31) was relatively small, the scores fluctuate in most of the graphs for that season. We note the precipitous drop in skill for the 18-h projection for ceiling. This trend is also noted for longer projections and may be attributable to the fact that the equations were developed on only 4 years of LFM (1972-76) data but are now using values from the LFM II fields.

7. MAX/MIN TEMPERATURE

The objective max/min guidance for October 1979 through March 1980 was generated by several different sets of regression equations. However, the predictand for both the early and final guidance was the local calendar day max or min valid approximately 24, 36, 48, and 60 hours after initial model time (0000 or 1200 GMT). The final automated forecasts were based on equations developed by stratifying archived 6LPE and TJ model output, station observations, and the first two harmonics of the day of the year into seasons of 3-month duration (Hammons et al., 1976). We used fall (September-November), winter (December-February), and spring (March-May) equations to produce the final guidance during the appropriate months of the 1979-80 cool season. Operationally, the equations employed output from the 7LPE and the TJ models as predictors. Station observations taken 6 hours after the initial model time also were used in the final guidance equations for the first two projections.

In contrast, the early guidance system depended on prediction equations derived from LFM model output, station observations available 3 hours after initial model time, and the first two harmonics of the day of the year (Carter et al., 1979).

final guidance was more accurate for the 60-h min, particularly in the Central and Western Regions. In every region but the Eastern, the local forecasts improved upon the objective guidance at all four projections. For the Eastern Region, the early guidance and the local forecasts were equally accurate in the first three projections. In all regions, the local forecasts of the 60-h min were substantially more accurate than the early guidance.

The mean absolute errors (0000 GMT cycle only) during the last 9 cool seasons are given in Fig. 7.1 for the max forecasts. For both the local forecasts and final guidance, there has been an overall increase in accuracy since the 1971-72 cool season. The greatest improvement in the objective guidance occurred in the 1973-74 cool season with the implementation of the first MOS forecast equations based on 6-month seasons (Klein and Hammons, 1975). The introduction of LFM-derived early guidance equations in the 1978-79 cool season narrowed the gap between the local forecasts and the guidance although the local forecasts increased the margin of improvement in the 1979-80 cool season.

An analogous time series is shown in Fig. 7.2 for the min forecasts. Verifications for the 60-h projection are available only for the last 3 seasons. For the 36-h projection, there has been an overall improvement in both the local forecasts and the objective guidance. Certainly, natural variability and the difficulty of predicting the min during the cool season accounts for the irregular manner of the improvement. Unlike the max, the objective min guidance showed its greatest increase in accuracy in the 1975-76 cool season when we switched from 6-month to 3-month MOS forecast equations (Hammons et al., 1976). For the first time, for both the 36- and 60-h projections, the local forecasts showed more skill than all available guidance in the 1979-80 cool season.

8. CONCLUSIONS

This verification indicates that both guidance and local forecasts generally showed improvement in the 1979-80 cool season as compared to the previous cool season for PoP, precipitation type, surface wind speed and max/min temperatures. In PoP, for instance, it`s notable that both the guidance and local third period forecasts were at least as accurate as the first period final guidance in 1974-75. The scores for surface wind direction, opaque sky cover, ceiling, and visibility were generally about the same or worse during the 1979-80 cool season than in the previous season.

The local PoP forecasts for the 1979-80 cool season generally improved upon the guidance, especially in the Central and Western Regions and for the first period. For both the second and third periods, the early guidance PoP was better than the final guidance in all regions except in the Western Region where the final guidance was superior.

The early and final precipitation type guidance was generally better than the local forecasts, except in the Western Region where there was little difference between the scores. The early guidance was generally better than the final guidance for all projections.

The guidance wind speed and direction forecasts were generally more accurate than the local forecasts in both the national and regional verifications. The bias characteristics of the guidance wind speed forecasts improved during the 1979-80 cool season and, in fact, were the best of any of the previous 6 cool seasons.

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

AVL	Asheville, North Carolina	DFW	Dallas-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
BWI	Baltimore, Maryland	ABQ	Albuquerque, New Mexico
ACY	Atlantic City, New Jersey	FLG	Flagstaff, Arizona
CVG	Cincinnati, Ohio	TUS	Tucson, Arizona
DAY	Dayton, Ohio	LAS	Las Vegas, Nevada
PIT	Pittsburgh, Pennsylvania	LAX	Los Angeles, California
ICT	Wichita, Kansas	RNO	Reno, Nevada
MCI	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 Climate (%)	Number of Cases
12-24 h	Early/Final	.0952		48.36	
(1st period)	Local	.0922	3.18	50.00	2799
24-36 h	Early	.1024		44.93	
(2nd period)	Final	.1096		40.60	2765
	Local	.1027	-0.31*(6.19)	44.76	
36-48 h	Early	.1193		34.36	
(3rd period)	Final	.1278		29.41	2760
	Local	.1168	1.35*(8.58)	35.47	

*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 22 stations in the Central Region.

Projection	Type of Forecast	Brier Score	Improvement Over Guidance (%)	Improvement Over Climate (%)	Number of Cases
12-24 h (1st period)	Early/Final	.0854		40.17	
	Local	.0790	7.40	44.60	2661
24-36 h (2nd period)	Early	.1064		30.38	
	Final	.1090		28.66	2622
	Local	.1033	2.96*(5.52)	32.44	
36-48 h (3rd period)	Early	.1128		20.70	
	Final	.1137		20.07	2622
	Local	.1124	0.36*(1.30)	20.98	

*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-two stations used for comparative verification of guidance and local precipitation type forecasts.

PWM	Portland, Maine	OKC	Oklahoma City, Oklahoma
BTV	Burlington, Vermont	ABQ	Albuquerque, New Mexico
BOS	Boston, Massachusetts	GTF	Great Falls, Montana
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 Franicsco, 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

Table 3.3. Comparative verification of early PoPT guidance and local forecasts. Only those cases in which the locals and guidance differed, and the local PoP was $\geq$ 30%, were included.

Projection (h)	Type of Forecast	Percent Correct	Number of Cases
18	Early	74	53
	Local	26	
30	Early	58	62
	Local	39	
42	Early	49	51
	Local	49	

Table 4.1. Ninety-four stations used for comparative verification of guidance and local sky cover, surface wind, ceiling, and visibility forecasts.

PWM	Portland, Maine	GTF	Great Falls, Montana
BTV	Burlington, Vermont	TCC	Tucumcari, New Mexico
CON	Concord, New Hampshire	APN	Alpena, Michigan
BOS	Boston, Massachusetts	DTW	Detroit, Michigan
PVD	Providence, Rhode Island	SBN	South Bend, Indiana
BUF	Buffalo, New York	IND	Indianapolis, Indiana
SYR	Syracuse, New York	LEX	Lexington, Kentucky
ALB	Albany, New York	SDF	Louisville, Kentucky
JFK	New York (Kennedy), New York	MSN	Madison, Wisconsin
EWR	Newark, New Jersey	MKE	Milwaukee, Wisconsin
ERI	Erie, Pennsylvania	ORD	Chicago (O'Hare), Illinois
AVP	Scranton, Pennsylvania	SPI	Springfield, Illinois
PIT	Pittsburgh, Pennsylvania	STL	St. Louis, Missouri
PHL	Philadelphia, Pennsylvania	MCI	Kansas City, Missouri
CLE	Cleveland, Ohio	TOP	Topeka, Kansas
CMH	Columbus, Ohio	DDC	Dodge City, Kansas
HTS	Huntington, West Virginia	DEN	Denver, Colorado
CRW	Charleston, West Virginia	GJT	Grand Junction, Colorado
DCA	Washington, D.C.	SHR	Sheridan, Wyoming
ORF	Norfolk, Virginia	CYS	Cheyenne, Wyoming
RDU	Raleigh-Durham, North Carolina	BIS	Bismarck, North Dakota
CLT	Charlotte, North Carolina	FAR	Fargo, North Dakota
CHS	Charleston, South Carolina	RAP	Rapid City, South Dakota
CAE	Columbia, South Carolina	FSD	Sioux Falls, South Dakota
ATL	Atlanta, Georgia	BFF	Scottsbluff, Nebraska
SAV	Savannah, Georgia	OMA	Omaha, Nebraska
MIA	Miami, Florida	MSP	Minneapolis, Minnesota
JAX	Jacksonville, Florida	DSM	Des Moines, Iowa
BHM	Birmingham, Alabama	BRL	Burlington, Iowa
MOB	Mobile, Alabama	INL	International Falls, Minnesota
TYS	Knoxville, Tennessee	FLG	Flagstaff, Arizona
MEM	Memphis, Tennessee	PHX	Phoenix, Arizona
MEI	Meridian, Mississippi	CDC	Cedar City, Utah
JAN	Jackson, Mississippi	SLC	Salt Lake City, Utah
MSY	New Orleans, Louisiana	LAS	Las Vegas, Nevada
SHV	Shreveport, Louisiana	RNO	Reno, Nevada
IAH	Houston, Texas	SAN	San Diego, California
SAT	San Antonio, Texas	LAX	Los Angeles, California
DFW	Dallas-Fort Worth, Texas	FAT	Fresno, California
ABI	Abilene, Texas	SFO	San Francisco, California
LBB	Lubbock, Texas	PDX	Portland, Oregon
ELP	El Paso, Texas	PDT	Pendleton, Oregon
LIT	Little Rock, Arkansas	SEA	Seattle (Takoma), Washington
FSM	Fort Smith, Arkansas	GEG	Spokane, Washington
TUL	Tulsa, Oklahoma	BOI	Boise, Idaho
OKC	Oklahoma City, Oklahoma	PIH	Pocatello, Idaho
ABQ	Albuquerque, New Mexico	MSO	Missoula, Montana

Table 4.3. Contingency tables for early guidance and local surface wind speed forecasts for 94 stations, 0000 GMT cycle.

18-h Forecasts

GUIDANCE

		1	2	3	4	5	6	7	T
	1	3693	1206	208	20	0	0	0	5127
	2	1622	2274	750	71	8	3	0	4728
	3	205	934	1058	314	37	2	0	2550
OBS	4	17	96	328	287	75	6	2	811
	5	1	9	47	81	50	14	0	202
	6	0	3	2	10	11	7	0	33
	7	0	1	1	2	3	0	0	7
	T	5538	4523	2394	785	184	32	2	13458

LOCAL

		1	2	3	4	5	6	7	T
	1	2814	1953	326	32	2	0	0	5127
	2	993	2666	923	138	6	2	0	4728
	3	128	937	1140	317	18	10	0	2550
OBS	4	15	132	362	255	35	12	2	811
	5	1	11	63	84	34	8	1	202
	6	0	2	6	12	11	1	1	33
	7	0	0	0	3	1	3	0	7
	T	3951	5701	2820	839	107	36	4	13458

30-h Forecasts

GUIDANCE

		1	2	3	4	5	6	7	T
	1	6287	1445	196	21	0	1	0	7950
	2	1516	1611	499	62	5	0	0	3693
	3	178	588	440	102	5	0	0	1313
OBS	4	21	76	143	78	22	2	0	342
	5	1	15	24	21	8	1	0	70
	6	0	3	4	7	4	1	0	19
	7	1	1	3	1	0	1	0	7
	T	8004	3739	1309	292	44	6	0	13394

LOCAL

		1	2	3	4	5	6	7	T
	1	5327	2279	299	39	4	2	0	7950
	2	1243	1832	540	69	8	1	0	3693
	3	146	645	413	95	12	2	0	1313
OBS	4	15	117	123	69	14	4	0	342
	5	3	19	24	17	5	2	0	70
	6	0	4	4	8	2	1	0	19
	7	0	1	4	0	1	0	1	7
	T	6734	4897	1407	297	46	12	1	13394

42-h Forecasts

GUIDANCE

		1	2	3	4	5	6	7	T
	1	3267	1368	344	48	0	0	0	5027
	2	1653	2068	787	151	19	2	0	4680
	3	318	925	886	306	43	10	1	2489
OBS	4	35	176	321	174	60	18	1	785
	5	3	28	56	55	35	13	2	192
	6	0	2	7	9	8	5	0	31
	7	0	1	1	3	2	1	0	8
	T	5276	4568	2402	746	167	49	4	13212

LOCAL

		1	2	3	4	5	6	7	T
	1	2538	2036	404	46	3	0	0	5027
	2	1168	2559	841	103	7	2	0	4680
	3	303	1137	825	193	26	5	0	2489
OBS	4	53	277	304	131	17	3	0	785
	5	10	37	85	40	13	4	3	192
	6	0	4	15	8	3	1	0	31
	7	2	1	1	1	3	0	0	8
	T	4074	6051	2475	522	72	15	3	13212

Table 4.5. Same as Table 4.2 except for 24 stations in the Southern Region.

Fcst. Proj. (h)	Type of Fcst.	Direction		Speed													
								Contingency Table									
										Bias by Category							
		Mean Abs. Error (Deg)	No. of Cases	Mean Abs. Error (Kts)	Mean Fcst. (Kts)	Mean Obs. (Kts)	No. of Cases	Skill Score	Percent Fcst. Correct	1 (No. Obs)	2 (No. Obs)	3 (No. Obs)	4 (No. Obs)	5 (No. Obs)	6 (No. Obs)	7 (No. Obs)	No. of Cases
18	Early	27	2071	3.0	12.5	11.6	2083	0.32	54	1.10	0.90	1.01	1.21	1.02	1.25	*	3629
	Local	30		3.2	12.8			0.28	52	0.68 (1254)	1.21 (1525)	1.11 (652)	1.25 (154)	0.50 (40)	0.00 (4)	* (0)	
30	Early	32	1094	3.5	11.7	10.2	1112	0.37	66	0.98	1.01	1.12	1.06	0.36	0.00	*	3604
	Local	37		3.8	11.6			0.27	59	0.86 (2266)	1.38 (972)	0.94 (285)	0.70 (69)	0.27 (11)	1.00 (1)	* (0)	
42	Early	37	1964	3.7	12.9	11.2	1978	0.22	47	1.05	0.88	1.06	1.34	1.53	2.67	*	3513
	Local	43		3.7	12.3			0.17	45	0.76 (1214)	1.26 (1476)	0.99 (629)	0.68 (155)	0.31 (36)	0.00 (3)	* (0)	

* This category was neither forecast nor observed.

Table 4.7. Same as Table 4.2 except for 18 stations in the Western Region.

Fcst. Proj. (h)	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 by Category: 1 (No. Obs)	Bias by Category: 2 (No. Obs)	Bias by Category: 3 (No. Obs)	Bias by Category: 4 (No. Obs)	Bias by Category: 5 (No. Obs)	Bias by Category: 6 (No. Obs)	Bias by Category: 7 (No. Obs)	Contingency Table: No. of Cases
18	Early	38	767	4.4	13.1	11.8	782	0.31	61	0.95	1.21	1.07	0.77	0.77	0.60	0.00	2562
	Local	38		4.4	13.6			0.29	59	0.86 (1625)	1.43 (515)	1.12 (272)	1.02 (111)	0.37 (30)	1.00 (5)	0.50 (4)	
30	Early	40	591	4.3	11.7	9.8	614	0.27	64	0.95	1.15	1.18	0.61	0.36	1.00	0.00	2538
	Local	43		4.4	11.9			0.25	63	0.92 (1755)	1.33 (532)	0.97 (184)	0.80 (54)	0.27 (11)	0.00 (1)	0.00 (1)	
42	Early	46	734	4.9	12.5	10.7	758	0.23	56	0.89	1.43	1.06	0.72	0.44	0.40	0.00	2506
	Local	55		5.0	12.2			0.20	54	0.87 (1589)	1.59 (509)	0.93 (264)	0.50 (109)	0.20 (25)	0.60 (5)	0.00 (5)	

Table 4.9. Same as Table 4.8 except for 24 stations in the Eastern Region.

Forecast Projection (h)	Type of Forecast	Percentage Frequency of Absolute Errors by Category					
		0–30°	40–60°	70–90°	100–120°	130–150°	160–180°
18	Early	77.5	15.5	4.0	1.7	1.0	0.3
	Local	74.4	17.3	4.1	2.3	1.5	0.4
30	Early	72.7	18.5	4.8	2.2	1.1	0.7
	Local	65.5	22.1	6.9	3.4	1.3	0.9
42	Early	70.4	16.3	6.7	3.3	1.8	1.5
	Local	62.6	20.7	7.9	4.1	2.7	1.9

Table 4.11. Same as Table 4.8 except for 29 stations in the Central Region.

Forecast Projection (h)	Type of Forecast	Percentage Frequency of Absolute Errors by Category					
		0–30°	40–60°	70–90°	100–120°	130–150°	160–180°
18	Early	82.5	11.2	3.0	1.5	1.1	0.6
	Local	75.3	14.8	4.9	2.5	1.7	0.8
30	Early	76.1	14.2	4.8	3.2	1.0	0.8
	Local	69.1	17.2	6.6	3.3	2.3	1.4
42	Early	69.6	17.0	6.8	3.2	1.9	1.6
	Local	60.9	21.5	8.4	4.2	3.1	1.9

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 5.3. Same as Table 5.2 except for 24 stations in the Eastern Region.

Projection (h)	Type of Forecast	Bias by Category				Percent Correct	Skill Score	Number of Cases
		1	2	3	4			
	Early	1.08	0.63	1.02	1.13	52.4	.337	
18	Local	0.53	1.54	1.47	0.76	48.6	.313	3063
	No. Obs.	710	600	597	1156			
	Early	1.16	0.66	1.11	0.95	57.5	.365	
30	Local	0.65	1.91	2.22	0.71	48.1	.297	3014
	No. Obs.	1005	385	316	1308			
	Early	1.24	0.71	1.08	0.97	45.3	.250	
42	Local	0.44	1.82	1.51	0.64	40.2	.210	3002
	No. Obs.	690	596	596	1120			

Table 5.5. Same as Table 5.2 except for 28 stations in the Central Region.

Projection (h)	Type of Forecast	Bias by Category				Percent Correct	Skill Score	Number of Cases
		1	2	3	4			
18	Early	0.96	0.68	1.20	1.13	51.4	.333	4137
	Local	0.60	1.35	1.43	0.86	50.7	.340	
	No. Obs.	1050	901	730	1456			
30	Early	1.01	0.63	1.01	1.13	54.9	.334	3939
	Local	0.52	2.03	2.17	0.74	43.5	.252	
	No. Obs.	1457	593	407	1482			
42	Early	1.12	0.81	0.99	1.03	46.0	.259	4016
	Local	0.46	1.74	1.52	0.65	37.7	.176	
	No. Obs.	971	874	717	1454			

Table 6.1. Definitions of the categories used for guidance forecasts of ceiling and visibility.

Category	Ceiling (ft)	Visibility (mi)
1	<200	<1/2
2	200-400	1/2-7/8
3	500-900	1-2 1/2
4	1000-2900	3-4
5	3000-7500	5-6
6	>7500	>6

Table 6.3. Same as Table 6.2 except for visibility.

Projection (h)	Type of Forecast	Bias by Category 1	2	3	4	5	6	Percent Correct	Skill Score
12	Early	1.00	1.13	0.87	1.22	0.97	0.99	72.1	.296
	Local	0.61	1.09	0.81	1.51	1.19	0.97	77.4	.448
	Persistence	0.78	0.85	0.81	0.83	0.88	1.05	81.4	.490
	No. Obs.	299	198	729	797	964	10089		
15	Local	0.40	0.60	0.45	1.18	0.93	1.07	72.5	.308
	Persistence	0.95	0.70	0.65	0.79	0.76	1.09	73.0	.307
	No. Obs.	262	268	1043	931	1211	10658		
18	Early	0.82	1.09	0.83	1.21	1.00	1.00	74.1	.247
	Persistence	2.31	1.19	0.82	1.00	0.89	1.01	74.5	.253
	No. Obs.	105	150	752	692	976	10916		
21	Local	0.11	0.45	0.43	1.26	1.00	1.03	79.9	.265
	Persistence	3.88	1.35	0.94	1.26	1.08	0.97	74.2	.190
	No. Obs.	65	136	711	591	869	11969		
24	Early	0.65	0.96	0.80	1.16	0.86	1.01	80.2	.271
	Persistence	3.08	1.44	1.07	1.18	1.16	0.96	74.5	.178
	No. Obs.	79	124	577	589	751	11472		
36	Early	0.37	0.67	0.86	1.09	0.91	1.04	69.8	.053
	Persistence	0.81	0.87	0.81	0.82	.087	1.05	68.1	.126
	No. Obs.	300	206	761	845	1006	10472		
48	Early	0.13	0.99	0.98	0.96	0.77	1.02	78.9	.201
	Persistence	3.12	1.38	1.10	1.15	1.18	0.96	71.5	.080
	No. Obs.	78	130	564	605	704	13591		

Table 6.5. Same as Table 6.3 except for 1200 GMT cycle.

Projection (h)	Type of Forecast	Bias by Category						Percent Correct	Skill Score
		1	2	3	4	5	6		
12	Early	0.35	0.89	0.99	0.96	0.91	1.01	81.7	.314
	Local	0.40	0.78	0.73	1.45	1.35	0.97	84.4	.469
	Persistence	0.69	1.04	1.17	0.92	1.13	0.99	86.4	.521
	No. Obs.	68	114	545	528	722	11213		
15	Local	0.33	0.98	0.97	1.65	1.35	0.95	81.0	.372
	Persistence	0.47	1.12	1.47	0.89	1.18	0.98	82.4	.378
	No. Obs.	113	121	490	636	762	12138		
18	Early	0.78	0.80	1.02	1.11	0.92	1.00	78.6	.278
	Persistence	0.29	0.98	1.20	0.83	1.09	1.00	79.1	.291
	No. Obs.	174	126	549	659	778	11390		
21	Local	0.31	1.08	1.11	1.90	1.21	0.93	73.0	.280
	Persistence	0.21	0.79	1.11	0.76	1.02	1.03	75.7	.232
	No. Obs.	245	177	646	742	880	11524		
24	Early	0.77	1.08	1.30	1.02	0.89	0.99	70.4	.261
	Persistence	0.17	0.60	0.86	0.64	0.82	1.09	71.7	.184
	No. Obs.	306	207	767	857	1037	10502		
36	Early	0.30	0.87	1.13	1.00	0.83	1.01	78.6	.219
	Persistence	0.65	1.01	1.16	0.90	1.12	0.99	74.7	.118
	No. Obs.	79	123	572	608	755	11540		
48	Early	0.41	1.00	0.98	0.89	0.88	1.04	69.5	.189
	Persistence	0.17	0.58	0.85	0.63	0.83	1.38	67.9	.077
	No. Obs.	301	213	779	868	1027	13676		

Table 6.7. Same as Table 6.6 except for visibility.

Projection (h)	Type of Forcast	Rel. Freq. Cats. 1&2 combined	Bias Cats. 1&2 combined	Percent Correct	Skill Score	Threat Score
12	Early		1.05	94.2	.221	.144
	Local	.038	0.80	96.9	.524	.370
	Persistence		0.81	96.9	.529	.375
15	Local		0.50	96.2	.292	.183
	Persistence	.037	0.82	95.6	.327	.211
18	Early		0.98	97.0	.187	.112
	Persistence	.019	1.65	96.0	.185	.114
21	Local		0.34	98.3	.090	.051
	Persistence	.014	2.17	96.1	.105	.065
24	Early		0.84	97.6	.128	.075
	Persistence	.015	2.08	96.0	.107	.067
36	Early		0.50	94.8	.053	.040
	Persistence	.037	0.74	94.2	.126	.084
48	Early		0.67	97.7	.104	.061
	Persistence	.015	2.03	95.7	.044	.033

Table 6.9. Same as Table 6.7 except for 1200 GMT cycle.

Projection (h)	Type of Forcast	Rel. Freq. Cats. 1&2 combined	Bias Cats. 1&2 combined	Percent Correct	Skill Score	Threat Score
12	Early		0.69	98.1	.153	.089
	Local	.016	0.64	98.5	.315	.192
	Persistence		0.92	98.5	.412	.265
15	Local		0.66	98.1	.278	.168
	Persistence	.016	0.81	97.8	.259	.156
18	Early		0.79	96.7	.151	.091
	Persistence	.022	0.58	97.1	.142	.084
21	Local		0.63	96.1	.170	.104
	Persistence	.030	0.45	96.2	.094	.059
24	Early		0.89	94.2	.157	.103
	Persistence	.038	0.34	95.3	.055	.038
36	Early		0.65	97.8	.098	.057
	Persistence	.015	0.87	97.3	.018	.016
48	Early		0.34	94.5	.081	.057
	Persistence	.038	0.65	95.1	.001	.010

Table 7.2. Same as Table 7.1 except for 26 stations in the Eastern Region.

Forecast Projection (h)	Type of Forecast	Mean Algebraic Error (°F)	Mean Absolute Error (°F)	Number(%) of Absolute Errors ≥ 10°	Number of Cases
24 (Max)	Early	0.2	3.4	116 (3.8)	3054
	Final	-0.6	3.4	123 (4.0)	
	Local	-0.4	3.4	124 (4.1)	
36 (Min)	Early	-0.9	3.9	161 (5.3)	3030
	Final	-0.7	4.0	180 (5.9)	
	Local	0.6	3.9	193 (6.4)	
48 (Max)	Early	-1.2	4.5	311 (10.3)	3028
	Final	-1.2	4.5	298 (9.8)	
	Local	-1.5	4.5	287 (9.5)	
60 (Min)	Early	-1.4	5.1	412 (13.6)	3030
	Final	-0.6	5.0	378 (12.5)	
	Local	0.2	4.7	344 (11.4)	

Table 7.4. Same as Table 7.1 except for 22 stations in the Central Region.

Forecast Projection (h)	Type of Forecast	Mean Algebraic Error (^{o}F)	Mean Absolute Error (^{o}F)	Number(%) of Absolute Errors $\geq 10^{o}$	Number of Cases
24 (Max)	Early	-0.4	3.7	137 (4.8)	2843
	Final	-1.5	4.1	204 (7.2)	
	Local	-0.7	3.5	108 (3.8)	
36 (Min)	Early	-0.6	4.6	283 (10.0)	2820
	Final	-0.5	4.5	272 (9.6)	
	Local	0.6	4.4	269 (9.5)	
48 (Max)	Early	-0.3	4.7	292 (10.4)	2801
	Final	-1.5	5.1	399 (14.2)	
	Local	-1.0	4.5	273 (9.7)	
60 (Min)	Early	-1.7	6.1	613 (21.9)	2801
	Final	0.2	5.4	448 (16.0)	
	Local	-0.0	5.4	450 (16.1)	

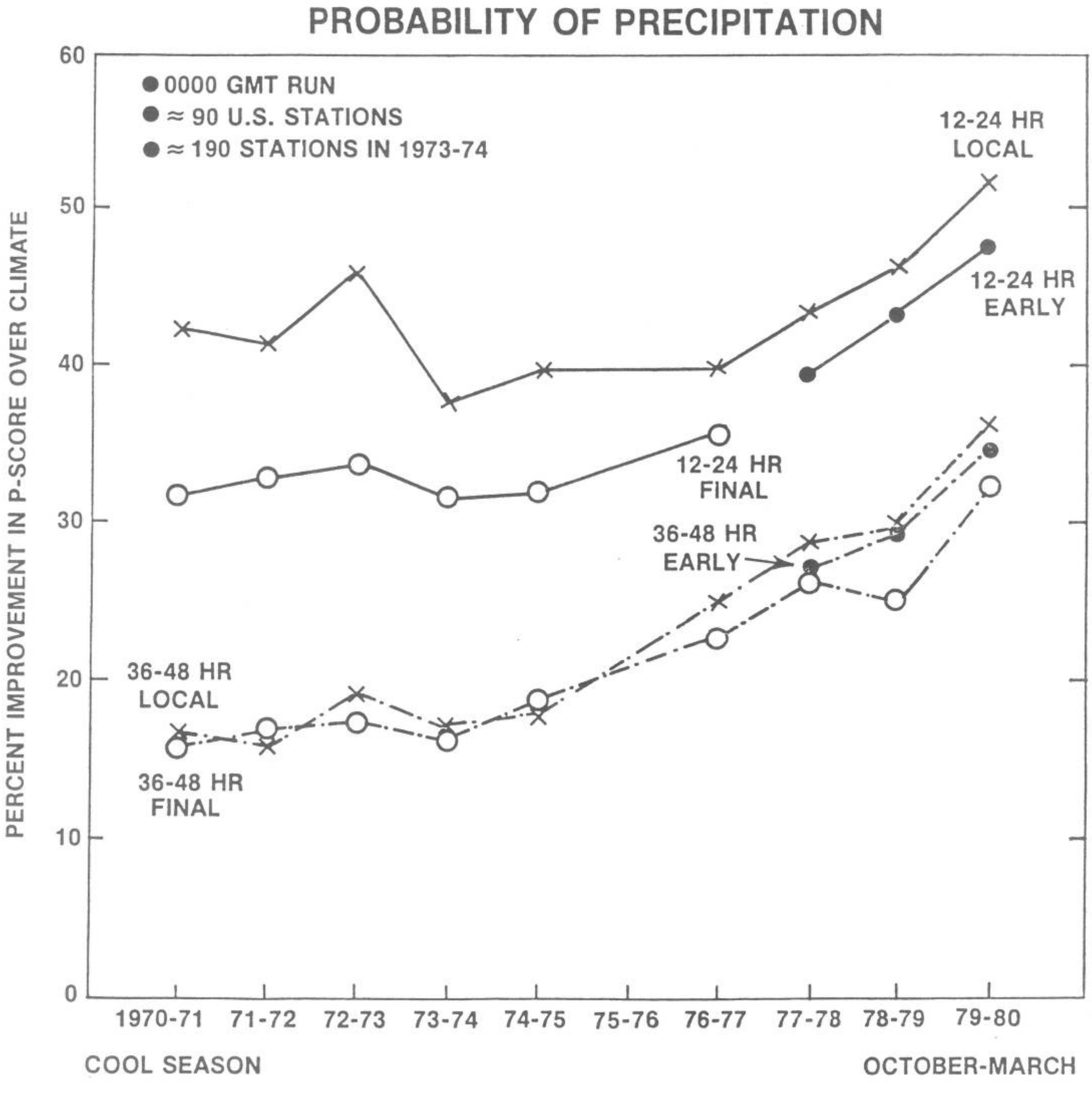

Fig. 2.1. Percent improvement over climate in the Brier score (P-score) of the local and guidance PoP forecasts for the cool season. Results for 1975-76 were unavailable due to missing data.

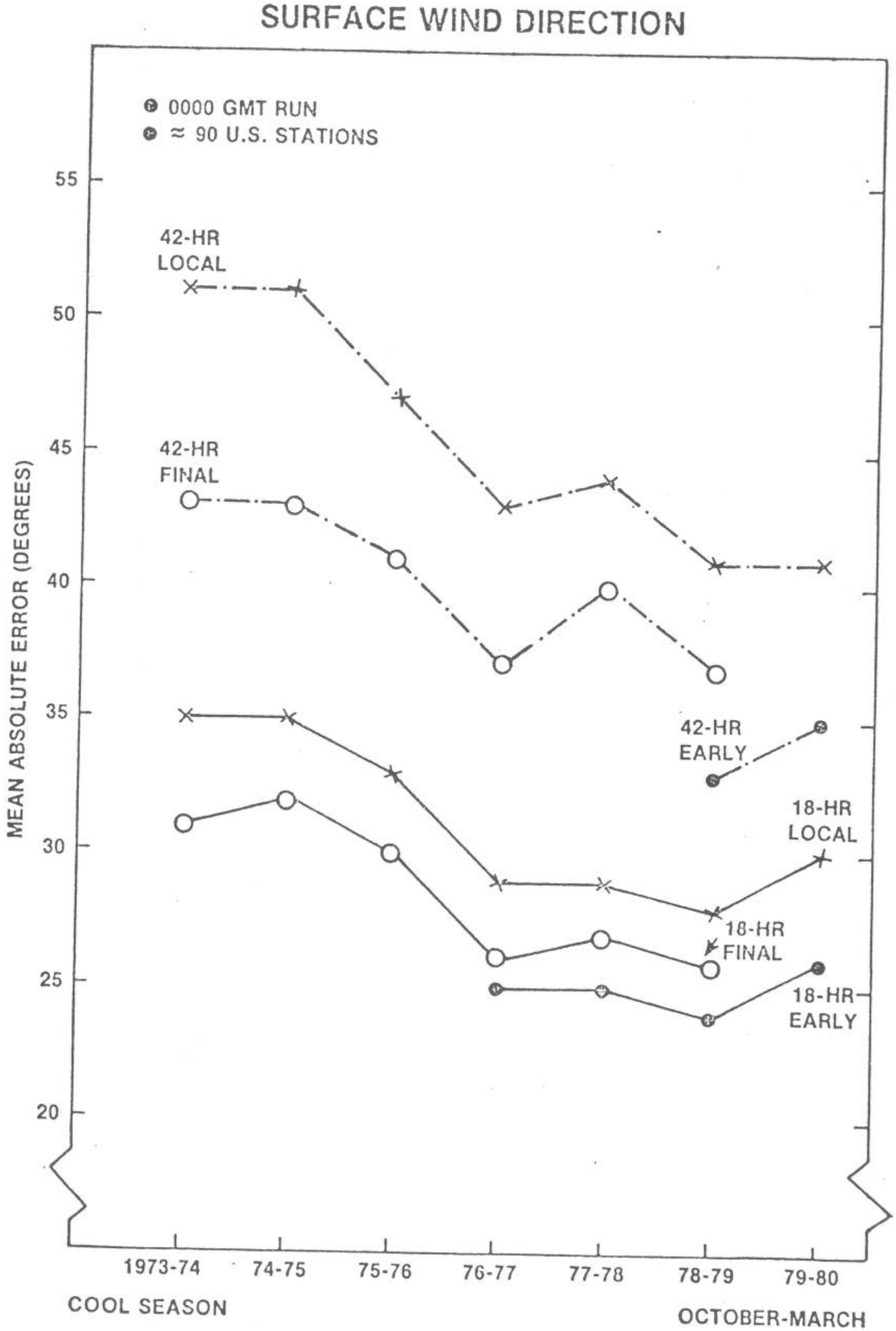

Fig. 4.1. Mean absolute errors for local and guidance surface wind direction forecasts for the cool season.

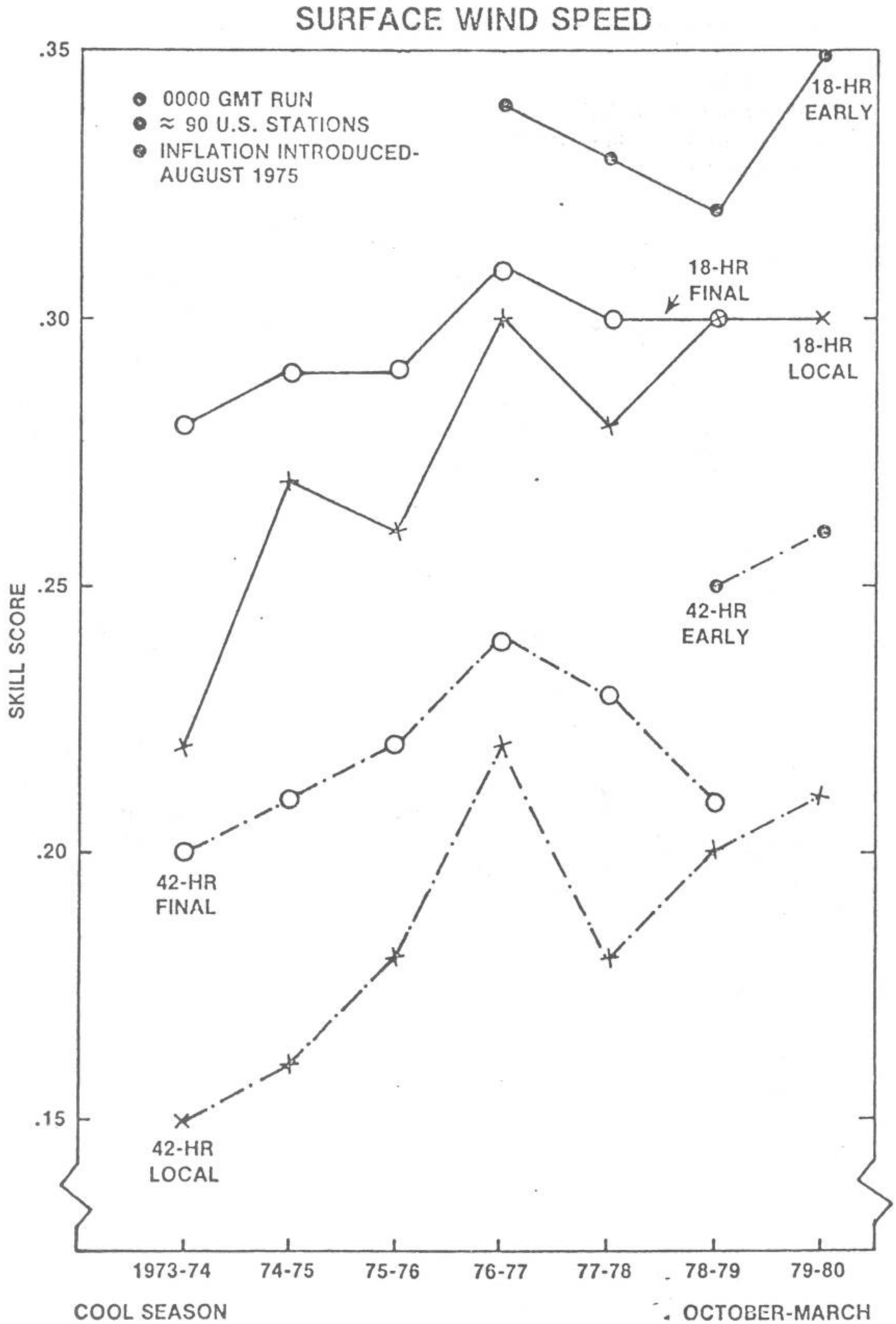

Fig. 4.3. Skill scores computed from five category contingency tables for local and guidance surface wind speed forecasts for the cool season.

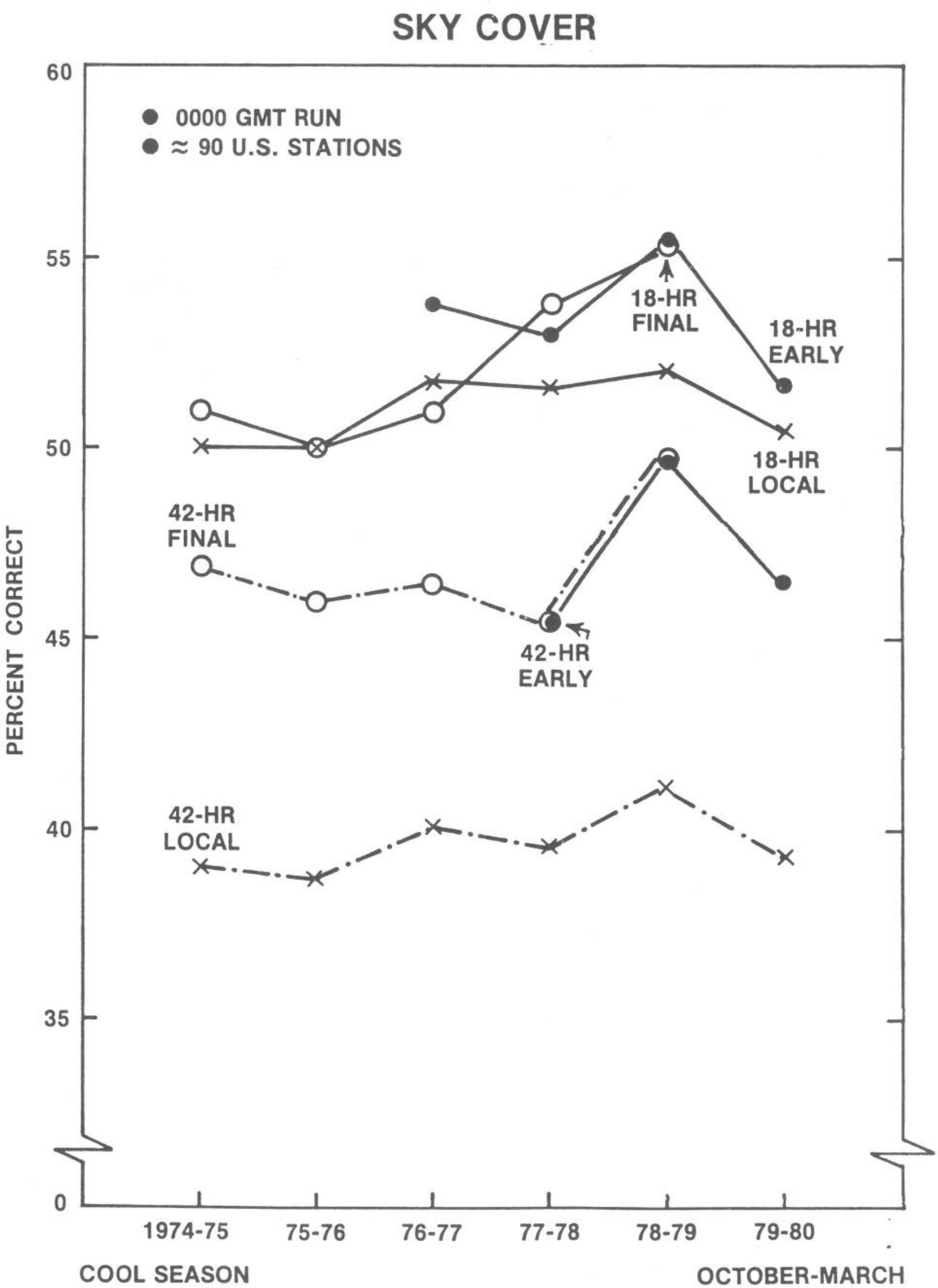

Fig. 5.1. Percent correct for local and guidance cloud amount forecasts for the cool season.

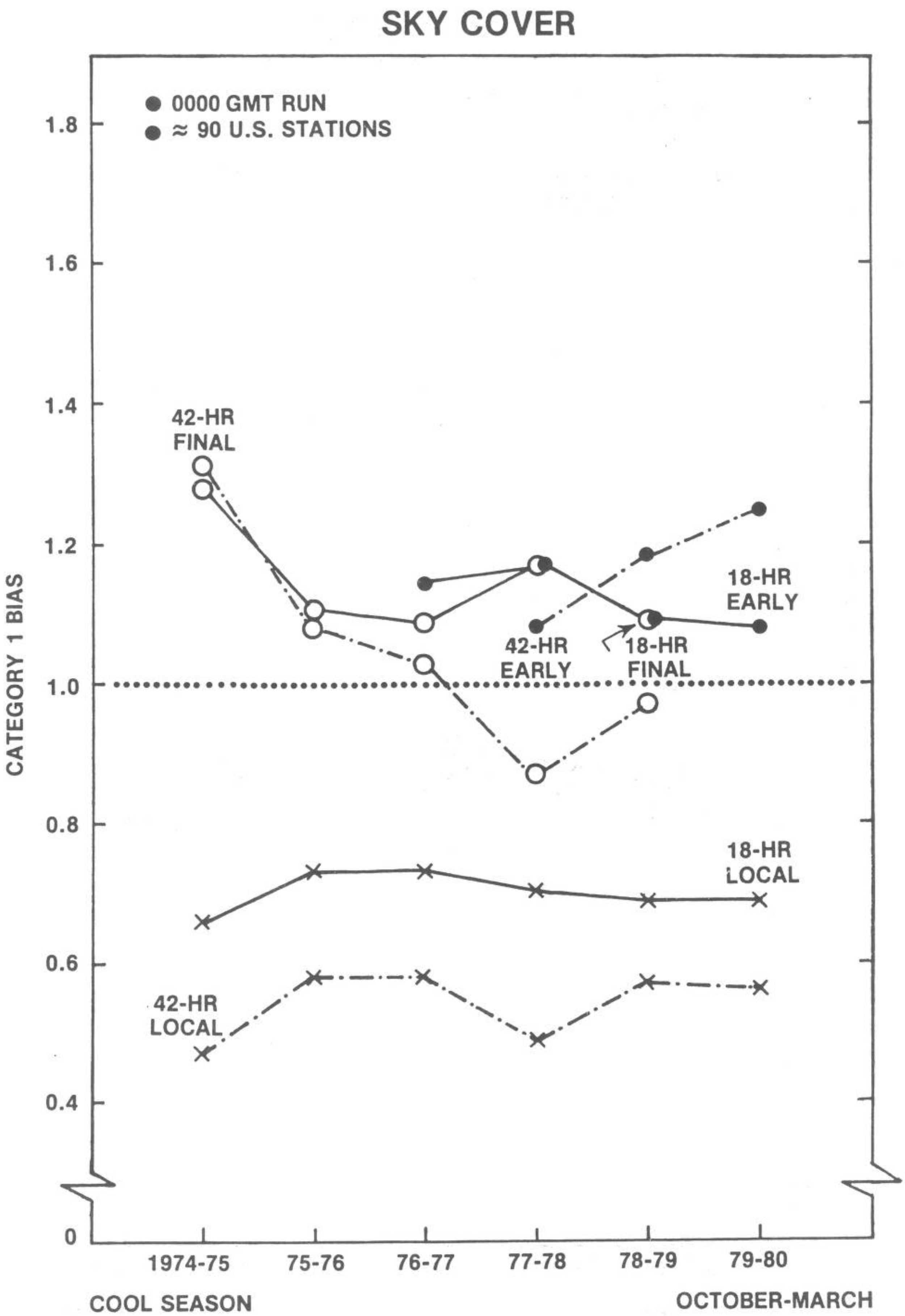

Fig. 5.3. Category 1 bias of the local and guidance cloud amount forecasts for the cool season.

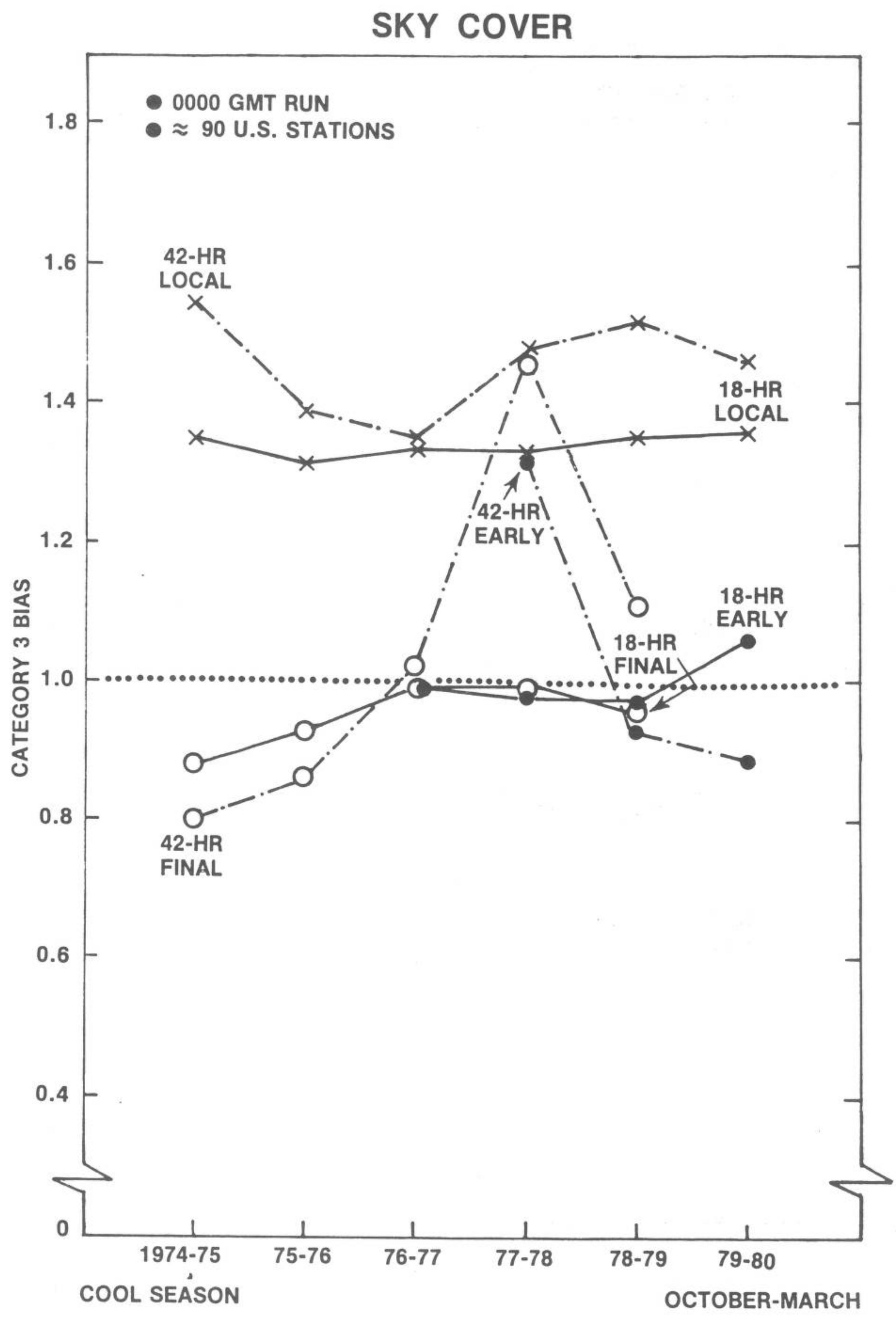

Fig. 5.5. Same as Fig. 5.3 except for category 3 bias.

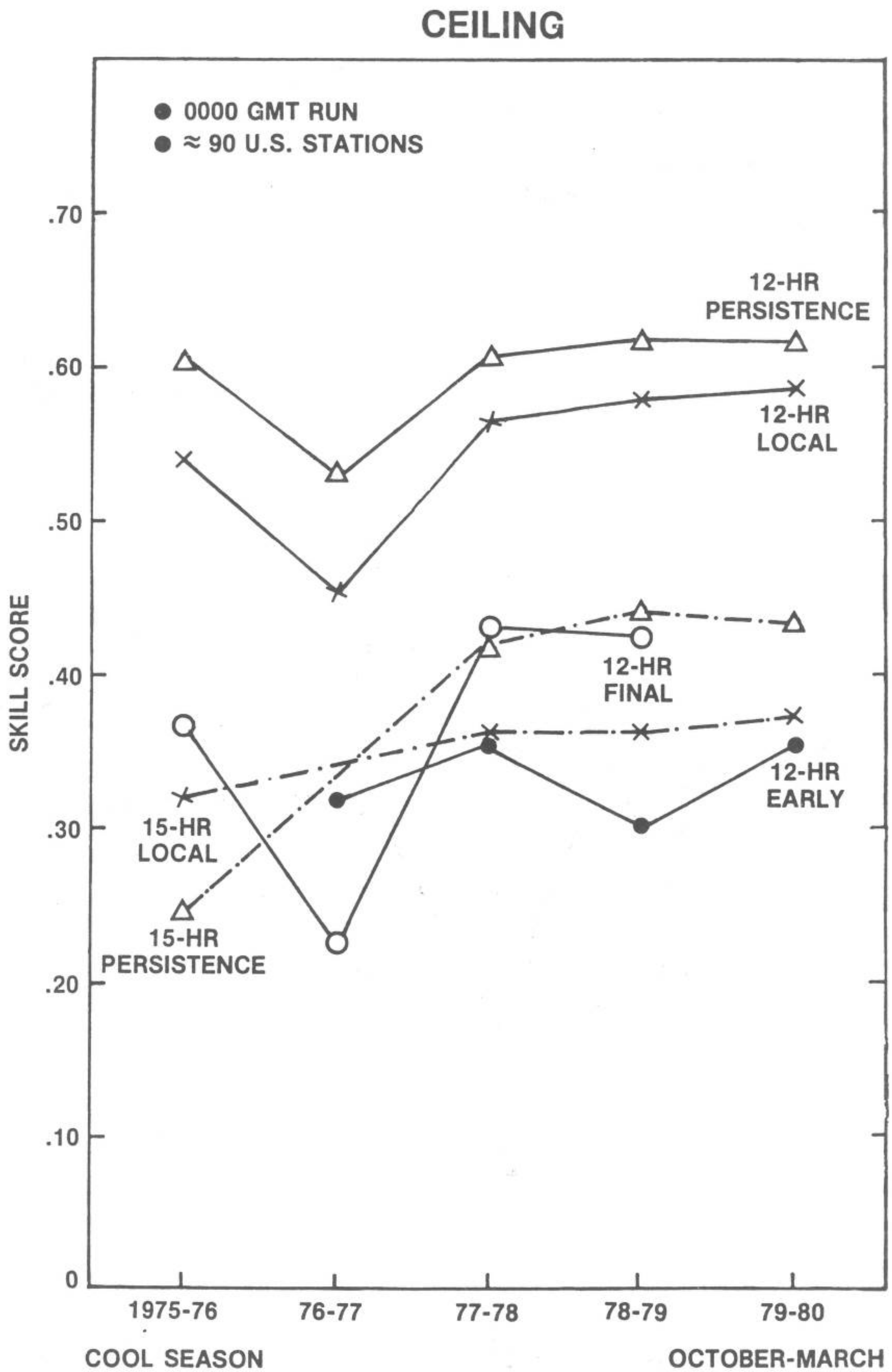

Fig. 6.1. Skill score computed from two-category contingency tables for guidance, local, and persistence ceiling forecasts for the cool season.

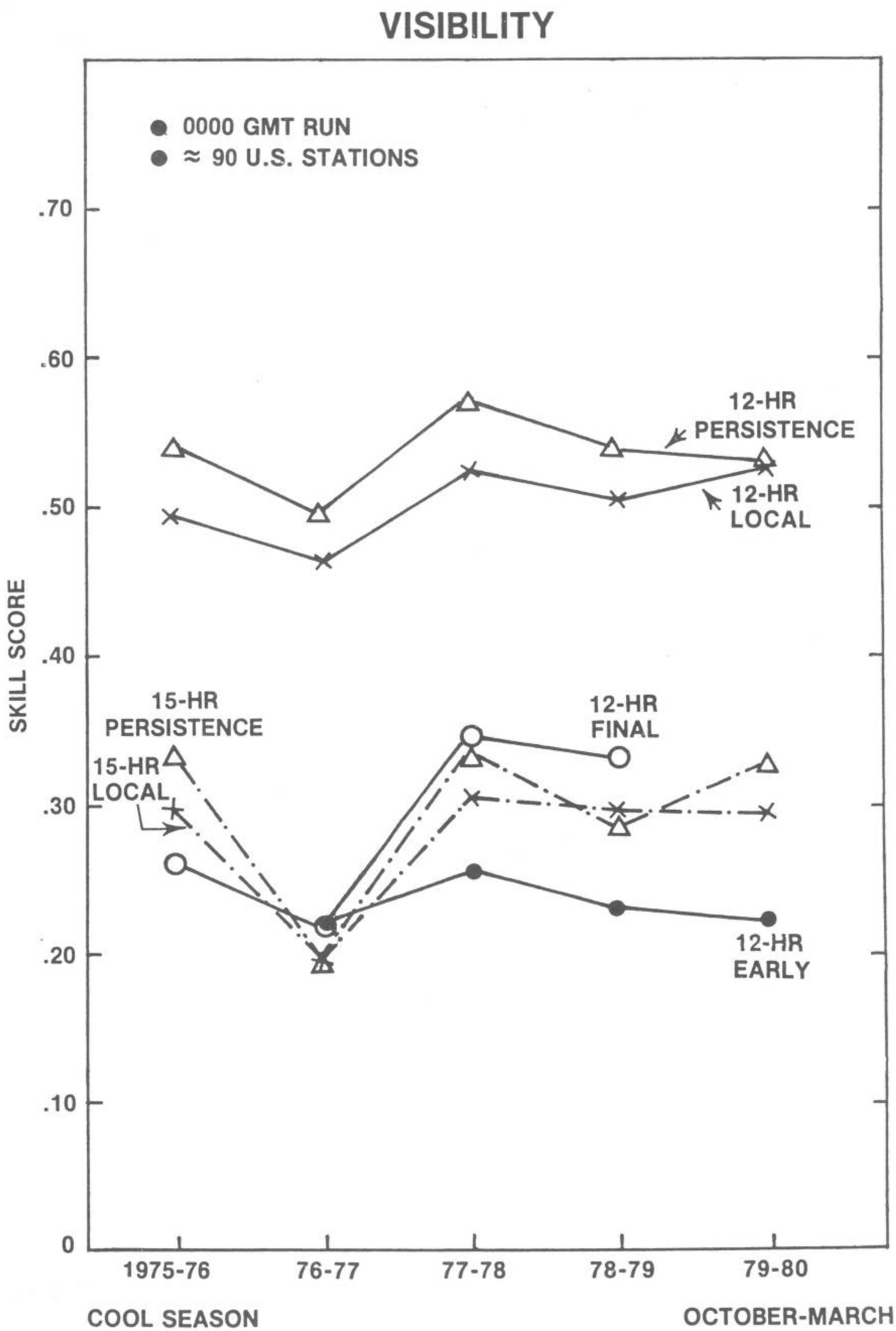

Fig. 6.3. Same as Fig. 6.1 except for visibility forecasts.

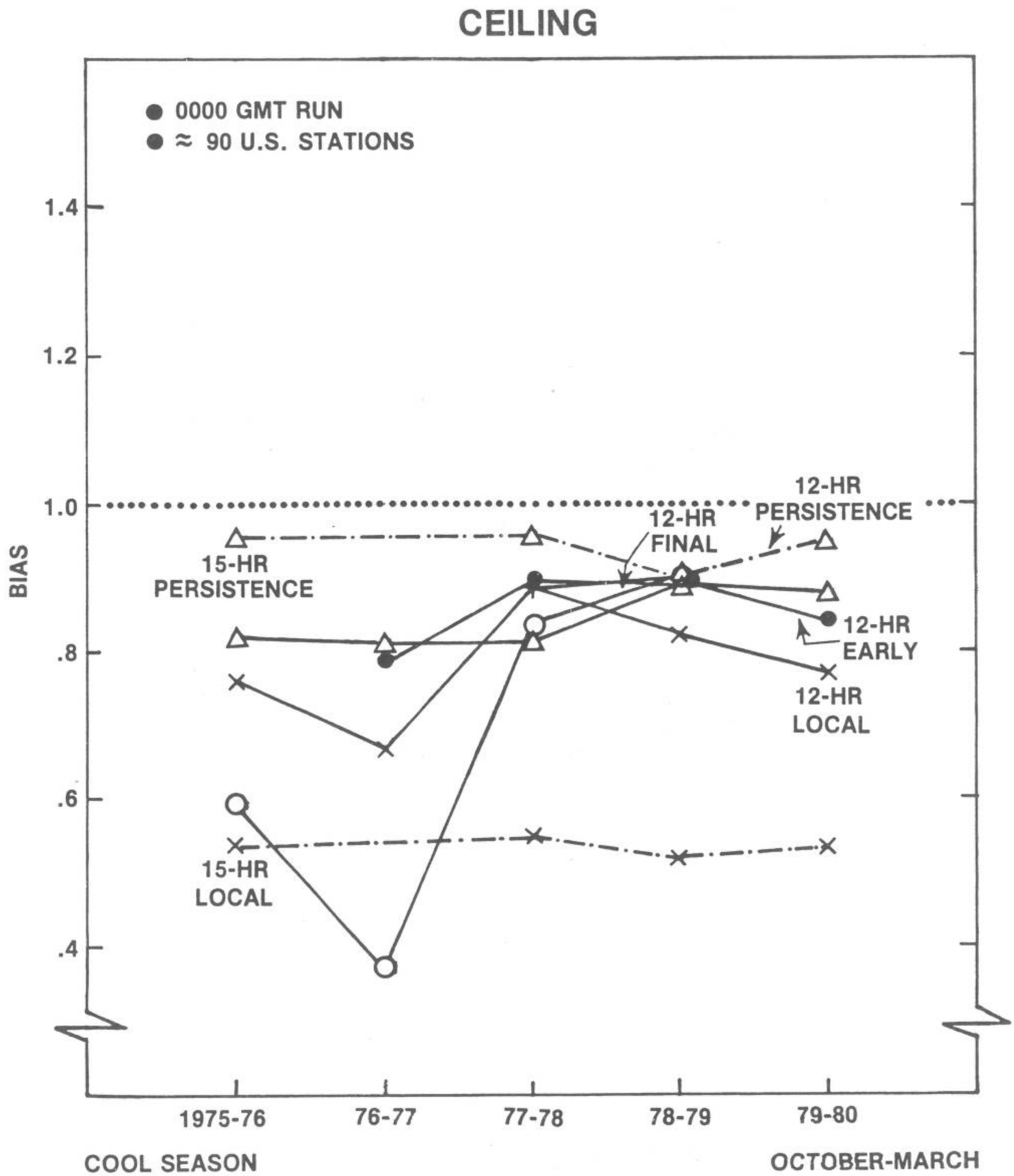

Fig. 6.5. Bias for categories 1 and 2 combined for guidance, local, and persistence ceiling forecasts for the cool season.

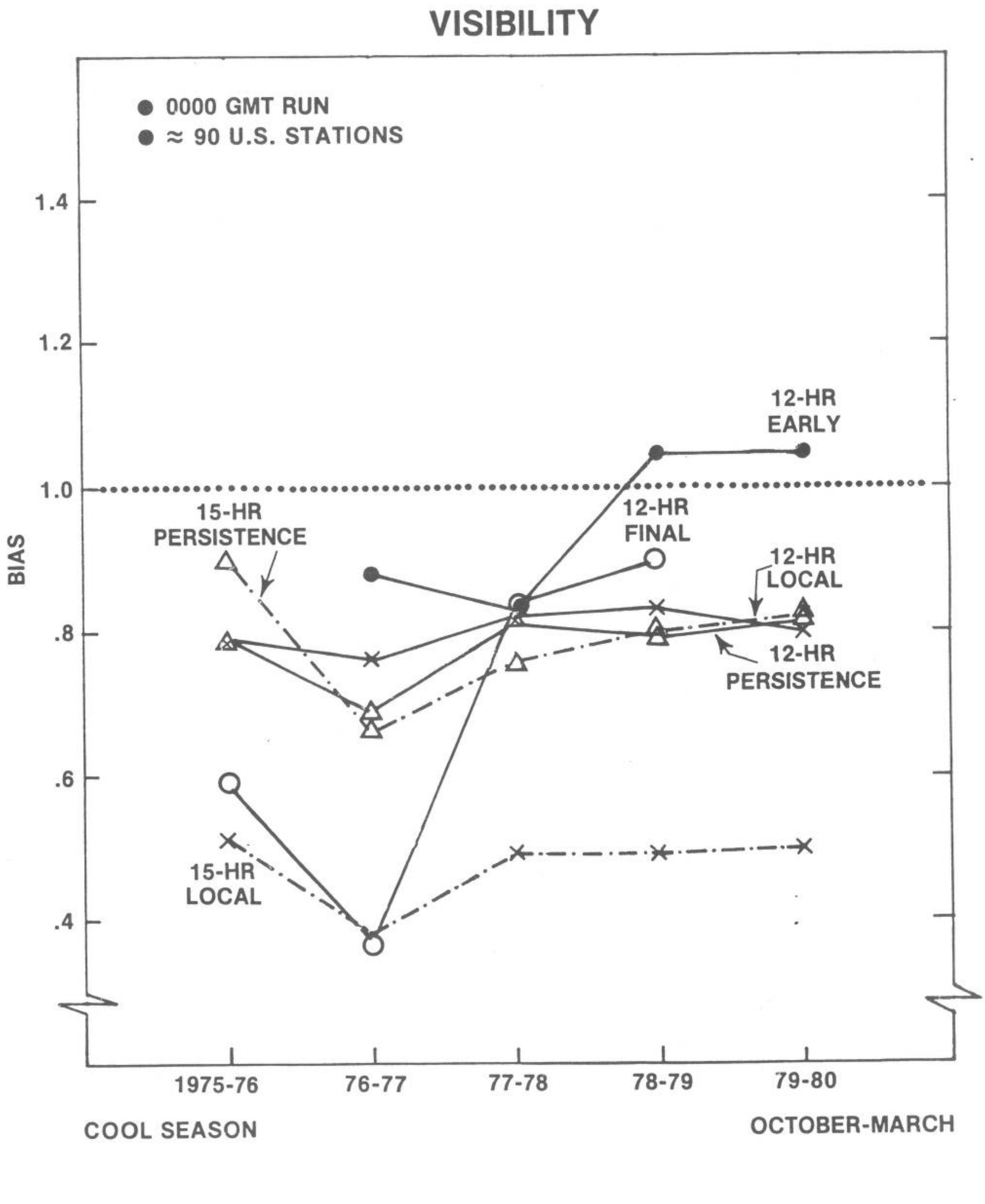

Fig. 6.7. Same as Fig. 6.5 except for visibility forecasts.

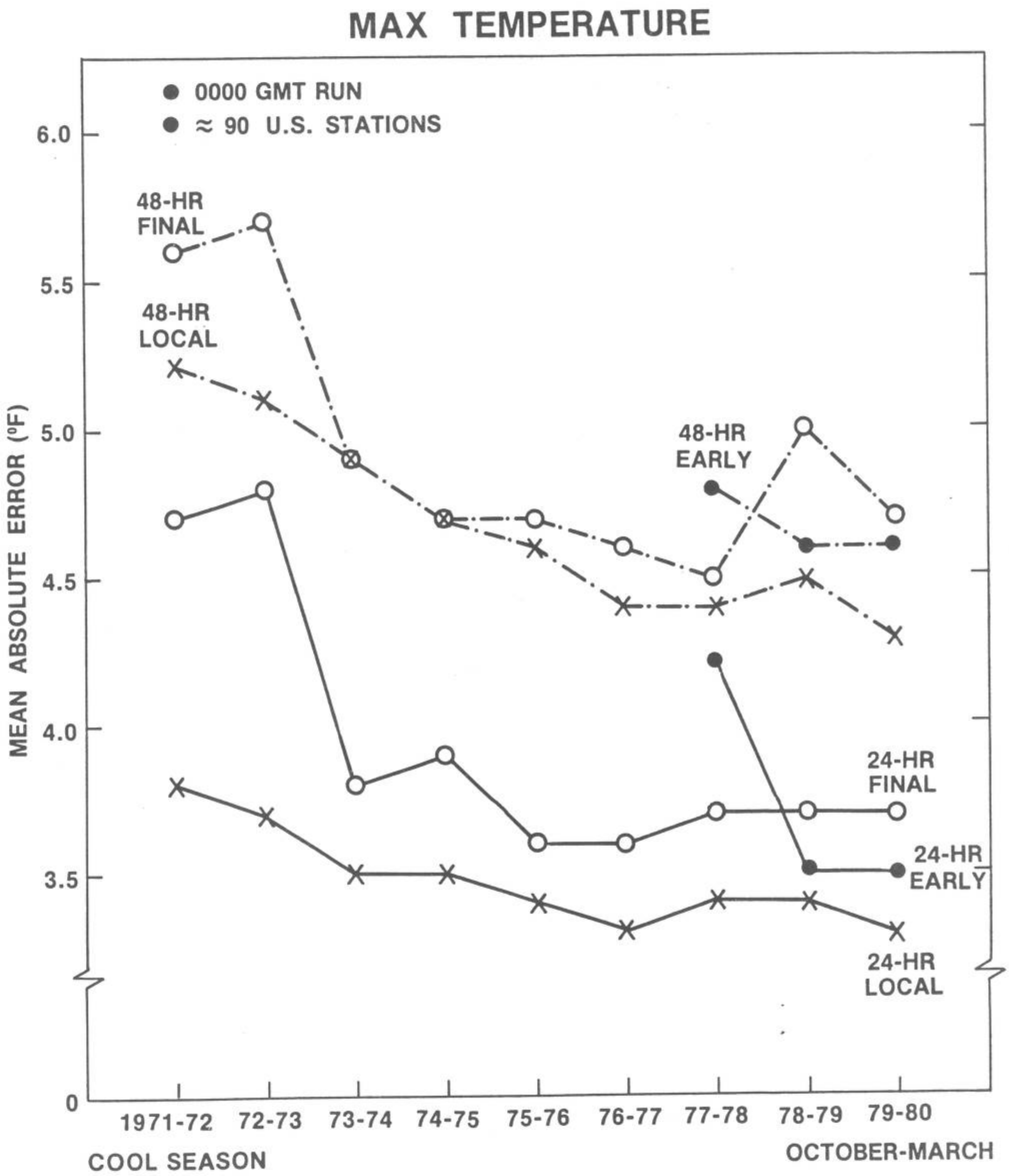

Fig. 7.1. Mean absolute errors of the local and guidance max temperature forecasts during the cool season.