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COMPARATIVE VERIFICATION OF GUIDANCE AND LOCAL AVIATION/PUBLIC WEATHER FORECASTS--NO. 11 (OCTOBER 1980-MARCH 1981)

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1. INTRODUCTION

This is the eleventh 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. In this report, we present verification statistics for the cool season months of October 1980 through March 1981 for probability of precipitation (PoP), precipitation type (rain, freezing rain, or snow), surface wind, opaque sky cover (cloud amount), ceiling height, visibility, and maximum/minimum (max/min) temperature. For the first time, the PoP and max/min temperature verification results are provided for both forecast cycles (0000 GMT and 1200 GMT).

The objective guidance is based on equations developed through application of 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 Trajectory (TJ) model (Reap, 1972), and/or the 6-layer coarse mesh Primitive Equation (6LPE) model (Shuman and Hovermale, 1968). In operations, forecast fields from the LFM-II model (National Weather Service, 1977) and the Spectral model (National Weather Service, 1980a; Sela, 1980) 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 model as "early" guidance; "final" guidance indicates the objective forecasts were produced from PE data. Also, the observation times of surface weather elements used as predictors in the early and final guidance generally differ. The final guidance is no longer disseminated operationally due to the superiority of the early guidance; however, comparative results are included for PoP, precipitation type, and max/min temperature since, for these elements, the final guidance was operational until December 23, 1980. We have not verified the final surface wind guidance since the start of the 1979 warm season nor the final opaque sky cover, ceiling, and visibility guidance since the start of the 1979-80 cool season.

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). The aviation forecasts were recorded for verification according to the direction that they be "... not inconsistent with ..." the official weather prognosis. The public weather max/min and PoP forecasts used for verification were official forecasts taken from the Coded City Forecast (FPUS4) bulletin. 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

Objective PoP forecasts were produced by the new set of cool season prediction equations described in Technical Procedures Bulletin No. 289 (National Weather Service, 1980c). Guidance was available for the first, second, and third periods, which correspond to 12-24 hours, 24-36 hours, and 36-48 hours, respectively, after 0000 GMT or 1200 GMT. The predictors for the first period equations were forecast fields from the LFM-II model and surface variables observed at the forecast site at 0300 GMT or 1500 GMT. While both early and final objective PoP forecasts were produced for the second and third periods, only the early guidance was available for the first period. All of the early guidance was based on LFM-II model output. The final guidance for the second and third periods was based on output from the Spectral model.

The PoP forecasts were verified by computing Brier scores (Brier, 1950) for the 85 stations shown in Table 2.1. Please note that we used the standard NWS Brier score which is one-half the original score defined by Brier. Brier scores will vary from one station to the next and from one year to the next because of changes in the relative frequency of precipitation; in particular, the scores usually are better for periods of below normal precipitation. Therefore, we also computed the percent improvement over climatology, that is, the percent improvement of Brier scores obtained from the local or guidance forecasts over analogous Brier scores produced by climatic forecasts. Climatic forecasts are defined as relative frequencies of precipitation by month and by station determined from a 15-year sample (Jorgensen, 1967).

Tables 2.2 and 2.7 present the results for all 85 stations for the 0000 GMT and 1200 GMT cycle forecasts, respectively, for October 1980 through March 1981. Tables 2.3-2.6 and Tables 2.8-2.11 show scores for the NWS Eastern, Southern, Central, and Western Regions, for the 0000 GMT and 1200 GMT cycles, respectively. This is the first report in which PoP verification results are given for both forecast cycles. Also, please note that the second and third-period verification results are a three-way comparison among the early guidance, final guidance, and subjective local forecasts. In comparison to the 1979-80 cool season (Bocchieri et al., 1981), the 0000 GMT cycle early and final guidance and local forecasts generally showed improved Brier scores for all three periods. Most likely, this is related to the dry winter throughout most of the United States. Some exceptions include all second-period forecasts for the Eastern Region and the third-period early guidance and local forecasts for the Southern Region.

Comparison of the Brier scores and percent improvement over climatology in Table 2.2 indicates, overall, the 0000 GMT cycle local forecasts were superior to the guidance for the first and third periods. This result also applies on the regional level (Tables 2.3-2.6), although for the Western Region the local forecasts were superior at all three periods. For all regions but the Western, the second-period early guidance was more accurate than both the local forecasts and final guidance.

As shown in Table 2.7, overall, the 1200 GMT cycle local forecasts were as good as, or better than, both the early and final guidance for the first two periods. Regionally (Tables 2.8-2.11), the early guidance usually was superior to the local forecasts for all 3 periods in the Eastern and Central Regions; in the Southern and Western Regions, the local forecasts generally were better than the guidance.

Fig. 2.1 shows the trend since 1970-71 in skill (expressed in terms of percent improvement over climatology) of the first and third-period 0000 GMT cycle PoP forecasts. For the first period, the 1980-81 local forecasts and early guidance decreased in skill. For the third period, the skill of both types of guidance and the local forecasts also deteriorated; however, the third-period early guidance was about as accurate as the first-period final guidance for the cool seasons of 1970-71 through 1974-75. Note, results for the 1975-76 season are unavailable because of missing data, and results for 1973-74 are based on a much larger sample of 190 stations.

3. PRECIPITATION TYPE

The early guidance conditional probability of precipitation type (PoPT) forecast system (Bocchieri, 1979; National Weather Service, 1978b) provides 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. In this report, the frozen, freezing, and liquid categories will be referred to as snow, freezing rain, and rain, respectively.

In contrast, for the final guidance conditional probability of frozen precipitation (PoF) system (Glahn and Bocchieri, 1975; Bocchieri and Glahn, 1976; National Weather Service, 1976), freezing rain is included with rain. Another difference beteween the PoPT and PoF systems is that the operational PoPT predictions are transformed into "best category" forecasts. The manner in which the PoPT guidance best category forecast is calculated is described by Bocchieri (1979).

For verification purposes, local categorical forecasts of precipitation type (made at about 1000 GMT) are recorded for three valid times, 1800 GMT (today), 0600 GMT (tonight), and 1800 GMT (tomorrow). Note, this is a conditional forecast; that is, it`s a forecast of the type of precipitation if precipitation actually occurs. Therefore, a precipitation type forecast is always recorded. Similarly, the PoPT and PoF guidance forecasts are conditional and are available whether or not precipitation occurs.

Table 3.1 lists the 61 stations used for this verification study. Of course, the verification included only those cases in which precipitation actually occurred. Also, since we were concerned that some forecasters may not have put much effort into making the conditional forecasts when they considered precipitation to be unlikely we used cases only when the local PoP was $\geq$ 30%. These PoP forecasts were valid for 12-h periods centered on the 18-, 30-, and 42-h projections from 0000 GMT.

First, we compared the early PoPT guidance with local forecasts for the snow, freezing rain, and rain categories. Table 3.2 shows the verification results. Note that the scores for the freezing rain category are not shown because there weren`t enough cases to provide meaningful results. The scores for all stations combined indicate: (1) the guidance was better than the local forecasts for both skill score[1] and percent correct for the 18- and 30-h projections; (2) there was little difference between the two systems at 42 hours; and

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

(3) as shown by the bias-by-category[2] results, both systems tended at the 30- and 42-h projections to slightly overforecast the snow event. In the regional breakdown, the results show: (1) the guidance generally was better than the local forecasts in the Central and Western Regions for 18 hours, the Eastern and Central Region for 30 hours, and the Southern and Western Regions for 42 hours; and (2) the local forecasts generally were better than the guidance in the Eastern Region for 18 hours, the Western Region for 30 hours, and the Eastern and Central Regions for 42 hours.

The percent correct in these tables is high because the sample includes many "obvious" forecasts. For instance, on some days in the southern states, precipitation, if it occurred, would obviously be rain. Therefore, in order to isolate some of the more difficult forecasting situations, we verified cases in which the guidance and local forecasts differed. Again, we used only those cases for which local PoP was $\geq$ 30%. The results, presented in Table 3.3, indicate the 18- and 30-h guidance forecasts were correct 55.2% and 60.5% of the time, respectively, while the corresponding local forecasts were correct 44.8% and 36.8% of the time; however, the 42-h local forecasts were correct 52.1% of the time while the corresponding guidance was correct only 45.8% of the time.

In order to do a three-way verification among the early PoPT guidance, final PoF guidance, and local forecasts, and to compare scores from the 1980-81 season to those for previous seasons, only two categories of precipitation type (snow and rain) were verified. For this comparison, freezing rain was included in the rain category, and for PoF, a categorical forecast of snow was defined as a PoF $\geq$ 50%. Of course, for PoPT and the locals, categorical forecasts of snow already were available. In Table 3.4, the verification results for all stations combined show that, in general, the early PoPT guidance was better than the final PoF guidance for all scores and projections. The early guidance also was better than the local forecasts except for the 42-h projection where there was little difference between the two systems. Both guidance systems and the local forecasts tended to slightly overforecast the snow event except at 18 hours where the local forecasts underforecast the snow event. These results also generally apply for the regional breakdowns except in the Western Region where the final guidance was better than the early guidance for the 18- and 30-h projections.

The skill scores of the guidance and local forecasts for the past 8 seasons are shown in Fig. 3.1; only 18- and 42-h verification results are presented. During that time, two changes in the verification procedure took place: (1) the number of stations changed from around 90 for the first 2 years to approximately 60 thereafter; and (2) starting with the 1975-76 season, we used cases only where the local PoP was $\geq$ 30% in order to isolate those situations when the forecaster was more confident precipitation would occur. The results show the guidance was consistently better than the locals during these 8 years except for the 1977-78 season where the 18-h guidance and local forecasts scored the same and during the 1980-81 season when the 42-h local forecasts were better than the final guidance. Note that the PoPT system, which replaced the early

[2]In the discussion of precipitation type, surface wind, opaque sky cover, ceiling height, and visibility, bias-by-category refers to the number of forecasts of a particular category (event) divided by the number of observations of that category. A value of 1.0 denotes unbiased forecasts for that particular category.

PoF guidance operationally during the 1978-79 season, has been consistently better than the final PoF guidance. Also, the skill of both types of guidance deteriorated in 1980-81 as compared to the previous year except for the 18-h final guidance. In contrast, the skill of the 18-h local forecasts improved substantially during the 1980-81 cool season.

4. SURFACE WIND

Objective surface wind forecasts were generated by the cool season, LFM-based equations described in Technical Procedures Bulletin No. 288 (National Weather Service, 1980d). In addition to LFM-II forecasts, predictors in the equations for all projections included the sine and cosine of the day of the year and of twice the day of the year; also, surface weather observations were used as predictors for the 6- and 12-h projections. Prior to the 1980-81 cool season, a significant change occurred in the operational early guidance wind prediction system. New equations were developed without surface pressure or boundary layer fields as predictors. The impact of removal of the boundary layer fields as predictors in objective surface wind forecasting is described by Janowiak (1981). Also, the new developmental sample included several seasons of LFM-II model data which were unavailable previously.

For this study, we verifed the 18-, 30-, and 42-h forecasts from 0000 GMT. The objective surface wind forecast is defined to be the same as the observed wind, namely, the one-minute average wind 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, the wind forecasts were verified in two ways. First, for all those cases in which both the local and objective 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 automated forecasts were available, skill score, percent correct, and bias-by-category were computed from contingency tables of wind speed. The seven categories in the tables were: < 8, 8-12, 13-17, 18-22, 23-27, 28-32, and > 32 knots. Table 4.1 lists the 90 stations used in the verification. Tables 4.2-4.12 show comparative verification scores for the 18-, 30-, and 42-h projections. Note that all the objective forecasts of wind speed were adjusted in daily operations by an "inflation" technique (Klein et al., 1959) involving the multiple correlation coefficient and the mean value of wind speed for each particular station and forecast valid time.

The results for all 90 stations combined are shown in Tables 4.2 and 4.3. The direction MAE`s reveal an advantage for the guidance ranging from 5° for the 18-h projection to 6° at 30- and 42-h. Overall, the speed MAE`s, skill scores, and percent correct were also better for the guidance. The bias values in Table 4.2 indicate that for most of the seven categories, the guidance exhibited better bias characteristics (that is, biases closer to 1.0) than the local forecasts. The bias values, as well as the contingency tables in Table 4.3, indicate the local forecasts underestimated winds stronger than 22 knots (categories 5, 6, and 7) to a greater extent than did the objective forecasts. In fact, bias values for the guidance forecasts for the last three categories combined were the best of any previous cool season (see, for example, Bocchieri et al., 1981). This may be due, in part, to the new forecast equations that became operational during the 1980-81 cool season.

Tables 4.4-4.7 show scores for the NWS Eastern, Southern, Central, and Western Regions, respectively. The regional comparisons have the same general characteristics as those for the entire group of stations, except the advantage of the guidance over the local forecasts varies in magnitude from region to region.

Table 4.8 shows the distribution of wind direction absolute errors by categories--0-30°, 40-60°, 70-90°, 100-120°, 130-150°, and 160-180°--for all 90 stations combined. Note that the guidance had about 6%, 9%, and 8% fewer errors of 40° or more than did the local forecasts for the 18-, 30-, and 42-h projections, respectively.

Distributions of direction errors for the individual regions are given in Tables 4.9-4.12. In general, these results are much like those in Table 4.8 except, once again, the advantage of the guidance over local forecasts differs in magnitude from region to region.

A comparison of overall MAE`s and skill scores during the past 8 cool seasons for the 18- and 42-h guidance and local forecasts is presented in Figs. 4.1-4.4. The verification data throughout this period were relatively homogeneous; the number of stations varied only slightly from season to season, while the basic set of verification stations remained the same. The MAE`s and skill scores in these figures denote the consistent superiority of the early over the final guidance.

The MAE`s for direction are shown in Fig. 4.1. Except for a slight increase in some of the MAE`s during the 1977-78 and 1979-80 cool seasons, the guidance and local forecasts for both projections have improved over the span of these 8 seasons.

In contrast, the MAE`s for wind speed in Fig. 4.2 indicate a decrease in accuracy for the final guidance after the introduction of inflation in July 1975. We realized that inflation would have this effect; however, previous wind speed verifications indicated the bias values of inflated forecasts were somewhat closer to 1.0 compared to the bias values of uninflated forecasts (Carter and Hollenbaugh, 1976). As discussed before, the bias values of the objective forecasts were quite good during the 1980-81 cool season. Despite use of the inflation technique, the MAE`s for the 18-h early guidance were as good as the pre-inflation MAE`s for the 18-h final guidance. Note, too, the consistent superiority of the early guidance over the local forecasts for both the 18- and 42-h projections.

Fig. 4.3 is a comparison of guidance and local skill scores computed on five (instead of seven) categories of wind speed; the fifth category included all speeds > 22 knots. Of particular interest in Fig. 4.3 is the magnitude of the advantage in skill of the guidance over the locals for both projections. With the exception of the 1978-79 final guidance, the guidance out-performed the local forecasts throughout the entire period.

Fig. 4.4 depicts a comparison of guidance and local skill scores computed on two categories; the first category contained all speeds $\leq$ 22 knots, while the second category included speeds > 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. Once again, the skill scores for the early guidance were consistently superior to those for the local forecasts. Nevertheless, the skill scores for both the 18- and 42-h objective forecasts did decrease slightly from the 1979-80 to the 1980-81 cool season. These scores, however, were still better than the highest scores ever obtained by the final guidance.

5. OPAQUE SKY COVER

The early guidance equations used in forecasting opaque sky cover were unchanged for the 1980-81 cool season; LFM-II model output and 0300 (1500) GMT surface observations were used to make forecasts for eight projections at 6-h intervals from 6 to 48 hours after 0000 (1200) GMT. These regionalized equations produced probability forecasts for the four categories of opaque sky cover 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 the opaque sky cover guidance see Technical Procedures Bulletin No. 234 (National Weather Service, 1978a).

We compared the local forecasts with a matched sample of early guidance forecasts for the 90 stations listed in Table 4.1 for the 18-, 30-, and 42-h forecast projections from 0000 GMT. The local forecasts and the surface observations used for this verification were converted from amounts of opaque sky cover 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. For 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, differences at the 18-h projection were small. Examination of the bias-by-category scores indicates that the guidance forecasts were better than the local forecasts for each projection and category. Also, 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.

Verification scores for stations in the NWS Eastern, Southern, Central, and Western Regions are given in Tables 5.3-5.6, respectively. The percent correct and skill scores for the guidance forecasts were superior, for the most part, to those of the local forecasts except in the Western Region where the local skill scores were superior to the guidance for all three projections. In the regional breakdown, the bias scores for the guidance forecasts also were better than those for the local forecasts. The most notable exception occurred in the Western Region where the locals had better bias scores for the clear and overcast categories for each projection and also for the broken category for the 42-h projection. The regional results also show the tendency of the locals to overforecast the scattered and broken categories.

The percent correct and skill scores over the past 7 cool seasons are depicted in Figs. 5.1 and 5.2, respectively, for the 18- and 42-h projections. These figures indicate departures in the percent correct and skill scores from the 1979-80 values were small.

Figs. 5.3-5.6 show trends in the bias-by-category for all stations combined for the 18- and 42-h projections. In all cases, the guidance bias scores are consistently superior to those for the local forecasts. Please note that 42-h early guidance was not implemented in operations until January 25, 1978. Therefore, the matched sample for 1977-78 covered only about 2 months. This small sample size may be responsible for the unusually high category 3 bias for the 42-h guidance during the 1977-78 cool season.

Fig. 5.3 indicates the bias of the early guidance category 1 forecasts for the 42-h projection has shown a tendency to move consistently away from 1.0 since the 1977-78 cool season. Although not as evident, this same trend is apparent for categories 2-4 (Figs. 5.4-5.6). The causes for this are probably due to a number of factors. One possibility is that the early guidance forecast equations beyond the 24-h projection were originally developed from 6LPE model output but were applied operationally to LFM-II model output. Modifications to the LFM-II model over the past few years also may have contributed to the trend. This continued poor performance is a factor which prompted the recent implementation of a new and improved set of opaque sky cover prediction equations (National Weather Service, 1981).

6. CEILING AND VISIBILITY

During the 1980-81 cool season, the guidance continued to rely on ceiling and visibility prediction equations first implemented in February 1977. Operationally, the early guidance was based on LFM-II output and used 0300 (1500) GMT surface observations. The guidance consisted of forecasts at 6-h intervals from 6 to 48 hours after 0000 (1200) GMT. For details concerning this particular version of the automated ceiling and visibility forecast system, see Technical Procedures Bulletin No. 234 (National Weather Service, 1978a).

Verification scores were computed for both the local and objective forecasts for the 90 stations listed in Table 4.1. In each case, persistence based on an observation taken at 0900 GMT for the 0000 GMT cycle and at 2100 (or 2200) GMT for the 1200 GMT cycle provided a standard of comparison. The guidance for 12-, 18-, 24-, 36-, and 48-h projections was verified for both cycles; the local forecasts for both cycles were verified for the 12-, 15-, and 21-h projections. Both the guidance forecast and the persistence observation for each station usually were available to the local forecaster on a daily basis.

We constructed six-category, forecast-observed contingency tables for all the forecasts involved in this comparative verification; definitions of the categories are given in Table 6.1. These tables were used for computing several different scores: bias-by-category, percent correct, and skill score. We then consolidated the data from these tables in order to create a reduced table containing only two categories (categories 1 and 2 combined versus categories 3 through 6 combined). Bias-by-category and threat scores for categories 1 and 2 combined, as well as skill score and percent correct, were calculated from the reduced tables. The results are summarized in Tables 6.2-6.9. Skill score and bias-by-category results for the previous 6 cool seasons for selected projections from the 0000 GMT forecast cycle are presented in Figs. 6.1-6.8.

Tables 6.2-6.5 show verification results for the six-category ceiling and visibility forecasts. For the 12-h projection (actually, a 3-h projection from the latest available surface observation for both the local and persistence forecasts, and a 9-h projection for the guidance for both forecast cycles), the skill of persistence exceeded that of the local forecasts and guidance for both ceiling and visibility. Also, the skill of the guidance was significantly lower than that of the local and persistence forecasts valid at the same time. With the exception of visibility forecasts for the 15-h projection, the local forecasts had higher skill scores than persistence for the 15- and 21-h projections for both ceiling and visibility. Generally, for both cycles, the 24-, 36-, and 48-h guidance forecasts had higher skill scores than persistence. For the 12-h projection, the six-category bias-by-category characteristics of the locals were generally worse than those of the guidance and persistence forecasts. For projections beyond 12 hours, the guidance bias characteristics were about as good as those for the persistence forecasts; however, the 0000 GMT cycle guidance greatly underforecast category 1 ceiling events for the 24- and 48-h projections and category 1 visibility events for the 48-h projection.

Tables 6.6-6.9 present comparative verification results for the two-category ceiling and visibility forecasts. The relative frequency of categories 1 and 2 combined (ceiling less than 500 feet and visibility less than 1 mile) ranged from 0.013 to 0.051. This fact, plus lower skill scores for the two-category tables as compared to the six-category tables, indicates these events are quite difficult to forecast. For the 12-h projection, the persistence skill scores were superior to those for the local and the guidance forecasts of ceiling and visibility; this also generally was true for the 15- and 18-h projections. In contrast, for most of the longer range projections, the local and guidance skill scores exceeded those of persistence.

Figs. 6.1-6.8 are graphs depicting skill score and bias results for the previous 6 cool seasons for 0000 GMT cycle 12-, 15-, 18-, and 21-h two-category ceiling and visibility forecasts. Figs. 6.1-6.4 indicate that the guidance skill score for the 12-h projection has remained level while the skill score for the 18-h projection has been variable. The sample size for the 1976-77 cool season was relatively small (February-March) which probably accounts for the wide fluctuation in the scores for that year. Although skill scores for the 18-h ceiling guidance improved during the 1980-81 cool season, the poor performance during prior years is one of the factors which prompted rederivation of the operational ceiling and visibility prediction equations (National Weather Service, 1981). Figs. 6.5-6.8 show that since the introduction of a threshold technique for category selection during the 1976-77 cool season, the guidance forecast bias characteristics for categories 1 and 2 combined generally have been better (closer to 1.0) than those for either the local or persistence forecasts. Furthermore, a consistent low bias for the 15- and 21-h local forecasts of categories 1 and 2 combined is quite evident.

7. MAXIMUM/MINIMUM TEMPERATURE

The objective max/min temperature guidance for October 1980 through March 1981 was generated by several different sets of regression equations. 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 the model input data times of 0000 GMT and 1200 GMT. The final guidance was 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 cool season. Station observations taken 6 hours after the initial model time also were used in the final guidance equations for the first two projections. The early guidance system depended on sets of prediction equations derived from LFM and LFM-II model output and the first two harmonics of the day of the year (Dallavalle et al., 1980; National Weather Service, 1980b). Surface observations 3 hours after the initial model time also were used as input to much of the early guidance for the first two periods. For all projections, forecast equations were available for the same 3-month seasons of fall, winter, and spring as the final guidance.

As mentioned earlier, the automated max/min forecasts are valid for the local calendar day; for example, the first period objective forecast of the max based on 0000 GMT model data is valid for the calendar day that starts at the following midnight. In contrast, the valid period of the local max/min forecast does not correspond to a calendar day since the local forecaster predicts a max for the 1200 to 0000 GMT interval and a min valid generally from 0000 to 1200 GMT. This latter time, however, is extended to 1800 GMT for forecasters in the Western Region and for others in the western parts of the Central and Southern Regions. Hence, caution is necessary in comparing verification scores for the local forecasts and the objective guidance.

We verified both the 0000 GMT and 1200 GMT cycle local and objective forecasts, using calendar day max and min temperatures obtained from the National Climatic Center as the verifying observations. Mean algebraic error (forecast minus observed temperature), mean absolute error (MAE), and the number of absolute errors $\geq$ 10°F were computed for 85 stations (Table 2.1) in the conterminous United States. Four forecast projections of approximately 24 (max), 36 (min), 48 (max), and 60 (min) hours after 0000 GMT were verified; for the 1200 GMT cycle, forecasts of approximately 24 (min), 36 (max), 48 (min), and 60 (max) hours were verified. Note that this is the first season for which we have verified the 1200 GMT cycle guidance.

The results for all stations combined for 0000 GMT are shown in Table 7.1. For all four projections, the early guidance was considerably more accurate than the final in terms of mean algebraic error, MAE, and number of large errors ($\geq$ 10°F). Averaged over the four projections, the MAE of the early guidance was 0.7°F less than that of the final. This was the largest difference yet between these two types of guidance. Moreover, this discrepancy was a dramatic reversal of the 1980 cool season (Bocchieri et al., 1981) when the early and final guidance MAE's were about the same for all four projections. We attribute the superiority of the early guidance to two factors. The first is the development and implementation of new early guidance prediction equations (National Weather Service, 1980b); we found before (Hammons et al., 1976) that 3-month seasonal stratification improved the temperature guidance. Furthermore, we think that the new equations produce more accurate guidance because of the improved methods used in developing these equations (Dallavalle et al., 1980). The second contributing factor is the implementation of the Spectral model in August 1980. In preliminary tests (Stackpole, 1980), the Spectral model forecasts adversely affected Alaskan max/min temperature forecasts produced by 6LPE-derived equations. Because of differences between the Spectral and 6LPE models in the timing of synoptic features and the depth of the boundary layer, the Spectral model fields caused a similar deterioration in the final guidance for the conterminous United States to the point where this guidance became misleading. Thus, the final max/min guidance was terminated as an operational product in December 1980.

As Table 7.1 shows, for both the 36- and 60-h min forecasts, the early guidance was more accurate than the local forecasts in terms of mean algebraic error, MAE, and the number of large errors. For the 24- and 48-h max, the early guidance and local forecasts were about equal in accuracy. Note that this was the first cool season that the early guidance was as good as, or better than, the local forecasts for each projection (see, for example, Bocchieri et al., 1981).

Tables 7.2-7.5 give the 0000 GMT verification scores for the Eastern, Southern, Central, and Western Regions, respectively. As discussed before, the early guidance was more accurate than the final in all regions of the country and for all projections. The differences between the two types of guidance were especially noticeable in the Southern Region. In terms of MAE, the local forecasters in the Southern and Western Regions improved slightly upon the early guidance for both 24- and 48-h max forecasts.

Table 7.6 shows verification results for all stations combined for the 1200 GMT cycle. As with the 0000 GMT scores, the early guidance was more accurate than the final for all four projections, although the differences were not as great as at 0000 GMT. Again, for the min forecast projections (24 and 48 hours), the early guidance was more accurate than the local forecasters in terms of mean algebraic error, MAE, and number of large errors. For the 36- and 60-h max, the local forecasters were slightly better than the early guidance. The regional verification scores shown in Tables 7.7-7.10 generally follow the trends for all stations combined.

Max temperature forecast MAE`s (0000 GMT cycle only) are given in Fig. 7.1 for the last 10 cool seasons. For the local forecasts, there has been a steady increase in accuracy (decrease in MAE) since the 1971-72 season. The greatest improvement in the final guidance occurred during the 1973-74 cool season with the implementation of the first MOS forecast equations (Klein and Hammons, 1975). The performance of the final guidance in the 1980-81 cool season was the worst ever for the MOS forecasts. However, during this same season, the newly-derived early guidance equations produced the most accurate objective forecasts of the entire 10-year period. For both the 24- and 48-h max, the early guidance in 1980-81 was as accurate as the local forecasts, culminating a trend initiated during the 1978-79 cool season when introduction of LFM-derived equations (Carter et al., 1979) started to narrow the gap between the local forecasts and the guidance.

An analogous time series (0000 GMT only) is shown in Fig. 7.2 for min temperature forecasts. Verfications for the 60-h projections are available only for the last 4 seasons. For the 36-h projection, there has been an overall improvement in both the local forecasts and the objective guidance during the 10-year period; however, natural variability and the difficulty of predicting the min during the cool season results in an irregular pattern of improvement. The final min temperature guidance showed its greatest increase in accuracy during the 1975-76 cool season when we switched from 6-month to 3-month MOS forecast equations (Hammons et al., 1976). The early min guidance improved consistently during the past 4 cool seasons. The 1980-81 early guidance was slightly more accurate than the local forecasts for both the 36- and 60-h projections. In fact, the 60-h objective min forecast this season was more accurate than the 36-h final guidance in 1974-75. As data become available, similar curves will be plotted for the 1200 GMT forecast cycle.

8. CONCLUSIONS

Highlights of the 1980-81 cool season verification results, summarized by general type of weather element, are:

o Probability of Precipitation - The comparative verification involved 85 stations and forecast projections of 12-24, 24-36, and 36-48 hours from both 0000 GMT and 1200 GMT. With few exceptions, the LFM-based guidance was superior to the Spectral-based guidance for both forecast cycles. Brier scores for the 0000 GMT cycle forecasts indicate the local forecasts were slightly better than the LFM-based guidance for the first and third periods. For the 1200 GMT cycle, the local forecasts were better than LFM-based guidance for the first and second periods. As compared with 0000 GMT cycle results for the 1979-80 cool season, the skill (in terms of improvement over climatology) decreased slightly for both the local and guidance forecasts.

o Precipitation Type - Local and guidance forecasts for 61 stations and projections of 18, 30, and 42 hours from 0000 GMT comprised the comparative verification; only those cases where the local PoP was $\geq$ 30% were verified. Our results, for all stations combined, show: (1) the LFM-based probability of precipitation type guidance was better than the Spectral-based probability of frozen precipitation guidance; (2) the LFM-based guidance generally was better than the local forecasts; and (3) the skill of both types of guidance deteriorated slightly in 1980-81 while the skill of the local forecasts generally improved.

o Surface Wind - The comparative verifications were conducted for 90 stations and projections of 18, 30, and 42 hours from 0000 GMT. The overall results show the LFM-based surface wind guidance was consistently more accurate than the corresponding local forecasts. In addition, the guidance forecast bias-by-category results for the highest three categories of wind speed were better than those for any of the previous 7 cool seasons. We think this is related to recent changes in the operational forecast equations.

o Opaque Sky Cover - Verification results for all 90 stations combined indicate the LFM-based guidance was slightly better than the local forecasts in terms of percent correct, skill score, and bias-by-category (clear, scattered, broken, and overcast) for all three projections (18, 30, and 42 hours) from 0000 GMT. However, for the 42-h guidance, the category 1 bias values were worse than those associated with comparable forecasts for the previous cool season. This trend was one of the factors which prompted a recently completed effort to rederive the operational forecast equations for opaque sky cover.

o Ceiling and Visibility - The verification involved comparison of local forecasts, LFM-based guidance, and persistence forecasts for 90 stations, and for projections ranging from 12 to 48 hours from both 0000 GMT and 1200 GMT. However, direct comparison of local, MOS, and persistence forecasts was possible only for the 12-h projection. This projection is actually a 3-h projection from the latest available surface observation for the local and persistence forecasts, and in this sense it is a 9-h projection for the guidance. Most of the 12-h projection verification scores for both ceiling and visibility indicate that the local and persistence forecasts were superior to the guidance. In contrast, for the longer range projections, the local and guidance forecasts were better than persistence. Of further note were relatively poor skill scores associated with the 18-h guidance forecasts. As with opaque sky cover, new ceiling and visibility forecast equations have been derived and put into operation.

o Maximum/Minimum Temperature - Local and guidance max/min temperature forecasts for the 0000 GMT and 1200 GMT forecast cycles were verified for 85 stations. Both the LFM-based and Spectral-based max/min guidance are valid for calendar day periods. In contrast, the valid period for the local max/min forecasts does not correspond to a calendar day. All forecasts in this study were verified against calendar day max/min reports so caution is necessary when comparing scores for the local forecasts and the objective guidance. Overall, the mean absolute errors for the LFM-based guidance were better than those for any of the previous 10 cool seasons. Also, for the first time, the LFM-based guidance was as accurate as the local forecasts for all four forecast periods of approximately 24, 36, 48, and 60 hours from 0000 GMT. In contrast, the Spectral-based guidance performed quite poorly, justifying the termination of this product in December 1980.

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

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

Table 2.2 Comparative verification of early and final guidance and local PoP forecasts for 85 stations, 0000 GMT cycle.

Projection (h)	Type of Forecast	Brier Score	Improvement Over Guidance (%)	Improvement Over Climate (%)	Number of Cases
12-24 (1st period)	Early/Final	.0772		46.8	
	Local	.0733	5.1	49.5	12402
24-36 (2nd period)	Early	.0912		34.2	
	Final	.1001		27.9	12392
	Local	.0926	-1.4*(7.6)	33.4	
36-48 (3rd period)	Early	.0959		33.2	
	Final	.1024		28.9	12401
	Local	.0946	1.4*(7.0)	34.2	

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

Projection (h)	Type of Forecast	Brier Score	Improvement Over Guidance (%)	Improvement Over Climate (%)	Number of Cases
12-24	Early/Final	.0941		42.5	
(1st period)	Local	.0895	4.9	45.3	3612
24-36	Early	.1068		36.5	
(2nd period)	Final	.1180		29.9	3614
	Local	.1093	-2.3*(7.3)	35.0	
36-48	Early	.1133		30.7	
(3rd period)	Final	.1282		21.6	3612
	Local	.1126	0.7*(12.2)	31.2	

Table 2.4. Same as Table 2.2 except for 24 stations in the Southern Region.

Projection (h)	Type of Forecast	Brier Score	Improvement Over Guidance (%)	Improvement Over Climate (%)	Number of Cases
12-24	Early/Final	.0676		57.8	
(1st period)	Local	.0634	6.2	60.4	3612
24-36	Early	.0796		35.2	
(2nd period)	Final	.0874		28.8	3609
	Local	.0808	-1.5*(7.6)	34.2	
36-48	Early	.0861		47.2	
(3rd period)	Final	.0881		45.9	3611
	Local	.0850	1.2*(3.4)	47.8	

*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 20 stations in the Central Region.

Projection (h)	Type of Forecast	Brier Score	Improvement Over Guidance (%)	Improvement Over Climate (%)	Number of Cases
12-24 (1st period)	Early/Final	.0735		41.7	
	Local	.0714	2.8	43.4	3023
24-36 (2nd period)	Early	.0870		35.0	
	Final	.1019		23.9	3020
	Local	.0928	-6.8*(8.8)	30.6	
36-48 (3rd period)	Early	.0899		26.4	
	Final	.0989		19.1	3023
	Local	.0904	-0.6*(8.5)	26.0	

Table 2.6. Same as Table 2.2 except for 15 stations in the Western Region.

Projection (h)	Type of Forecast	Brier Score	Improvement Over Guidance (%)	Improvement Over Climate (%)	Number of Cases
12-24 (1st period)	Early/Final	.0701		42.6	
	Local	.0651	7.2	46.7	2155
24-36 (2nd period)	Early	.0906		27.4	
	Final	.0891		28.6	2149
	Local	.0837	7.6*(6.1)	33.0	
36-48 (3rd period)	Early	.0914		23.6	
	Final	.0879		26.5	2155
	Local	.0862	5.7*(1.9)	27.9	

*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 2.7. Comparative verification of early and final guidance and local PoP forecasts for 85 stations, 1200 GMT cycle.

Projection (h)	Type of Forecast	Brier Score	Improvement Over Guidance (%)	Improvement Over Climate (%)	Number of Cases
12-24 (1st period)	Early/Final	.0808		42.0	12095
	Local	.0798	1.4	42.9	
24-36 (2nd period)	Early	.0884		39.5	12096
	Final	.0952		34.6	
	Local	.0881	0.2*(7.0)	39.5	
36-48 (3rd period)	Early	.1036		24.9	12005
	Final	.1120		19.2	
	Local	.1046	-1.0*(6.1)	24.2	

*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 2.8. Same as Table 2.7 except for 26 stations in the Eastern Region.

Projection (h)	Type of Forecast	Brier Score	Improvement Over Guidance (%)	Improvement Over Climate (%)	Number of Cases
12-24	Early/Final	.0968		43.4	
(1st period)	Local	.0970	-0.2	43.2	3421
24-36	Early	.1084		34.5	
(2nd period)	Final	.1187		28.3	3419
	Local	.1071	1.2*(9.8)	35.3	
36-48	Early	.1223		26.4	
(3rd period)	Final	.1386		16.6	3399
	Local	.1236	-1.1*(10.8)	25.6	

Table 2.9. Same as Table 2.7 except for 24 stations in the Southern Region.

Projection (h)	Type of Forecast	Brier Score	Improvement Over Guidance (%)	Improvement Over Climate (%)	Number of Cases
12-24	Early/Final	.0721		41.8	
(1st period)	Local	.0699	3.1	43.6	3598
24-36	Early	.0806		49.9	
(2nd period)	Final	.0811		49.7	3598
	Local	.0800	0.8*(1.3)	50.3	
36-48	Early	.0926		24.8	
(3rd period)	Final	.0968		21.3	3570
	Local	.0944	-2.0*(2.5)	23.3	

*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 2.10. Same as Table 2.7 except for 20 stations in the Central Region.

Projection (h)	Type of Forecast	Brier Score	Improvement Over Guidance (%)	Improvement Over Climate (%)	Number of Cases
12-24	Early/Final	.0776		42.2	
(1st period)	Local	.0795	-2.5	40.7	2977
24-36	Early	.0788		36.8	
(2nd period)	Final	.0915		26.6	2980
	Local	.0812	-3.0*(11.3)	34.9	
36-48	Early	.0996		24.5	
(3rd period)	Final	.1101		16.5	2958
	Local	.1014	-1.9*(7.9)	23.1	

Table 2.11. Same as Table 2.7 except for 15 stations in the Western Region.

Projection (h)	Type of Forecast	Brier Score	Improvement Over Guidance (%)	Improvement Over Climate (%)	Number of Cases
12-24	Early/Final	.0741		39.8	
(1st period)	Local	.0691	6.8	43.9	2099
24-36	Early	.0826		33.3	
(2nd period)	Final	.0862		30.4	2099
	Local	.0811	1.8*(6.0)	34.5	
36-48	Early	.0975		23.5	
(3rd period)	Final	.0974		23.6	2078
	Local	.0957	1.9*(1.7)	24.9	

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

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

Table 3.2 Comparative verification of early PoPT guidance and local forecasts for 61 stations, 0000 GMT cycle. Only cases where the local PoP was ≥ 30% are included.

Projection (h)	Region (No. Stns)	Type of Forecast	Bias Snow	Bias Rain	Percent Correct	Skill Score	Number of Cases
18	Eastern (17)	Early	1.04	.92	89.2	.79	316
		Local	.97	1.03	90.8	.82	
	Southern (16)	Early	1.29	.98	91.8	.52	97
		Local	.71	1.03	92.8	.43	
	Central (16)	Early	.96	1.06	95.2	.91	189
		Local	.88	1.06	88.9	.79	
	Western (12)	Early	1.07	1.00	93.5	.82	124
		Local	.74	1.07	92.7	.78	
	All Stations	Early	1.02	.98	91.9	.84	726
		Local	.91	1.05	90.9	.81	
30	Eastern (17)	Early	1.05	.97	92.3	.85	298
		Local	1.08	.93	89.3	.79	
	Southern (16)	Early	1.50	.99	97.4	.39	117
		Local	1.00	.99	97.4	.39	
	Central (16)	Early	1.00	1.02	85.1	.70	134
		Local	1.08	.91	83.6	.67	
	Western (12)	Early	1.18	.97	88.7	.64	97
		Local	1.06	1.00	90.7	.70	
	All Stations	Early	1.04	.98	91.2	.82	646
		Local	1.08	.96	89.8	.79	
42	Eastern (17)	Early	1.20	.82	87.2	.75	282
		Local	1.10	.90	87.9	.76	
	Southern (16)	Early	.67	1.02	95.6	.55	68
		Local	0.00	1.03	94.1	.32	
	Central (16)	Early	1.10	.92	87.1	.74	139
		Local	1.08	.94	89.9	.80	
	Western (12)	Early	1.33	.97	91.3	.72	104
		Local	.93	1.03	89.4	.61	
	All Stations	Early	1.17	.91	88.9	.78	593
		Local	1.07	.96	89.4	.78	

Table 3.3. Comparative verification of early PoPT guidance and local forecasts for 61 stations, 0000 GMT cycle. Only those cases in which the locals and guidance differed, and the local PoP was ≥ 30%, are included.

Projection (h)	Type of Forecast	Percent Correct	Number of Cases
18	Early	55.2	67
	Local	44.8	
30	Early	60.5	38
	Local	36.8	
42	Early	45.8	48
	Local	52.1	

Table 3.4 Comparative verification of early PoPT guidance, final PoF guidance, and local forecasts for 61 stations, 0000 GMT cycle. Only cases where the local PoP was ≥ 30% are included.

Projection (h)	Region (No. Stns)	Type of Forecast	Bias Snow	Bias Rain	Percent Correct	Skill Score	Number of Cases
18	Eastern (17)	Early	1.04	.96	90.8	.82	316
		Final	1.17	.84	88.0	.76	
		Local	.97	1.03	90.8	.82	
	Southern (16)	Early	1.29	.98	93.8	.59	97
		Final	.86	1.01	94.8	.59	
		Local	.71	1.02	93.8	.47	
	Central (16)	Early	.96	1.05	95.8	.92	189
		Final	.98	1.02	94.7	.89	
		Local	.88	1.14	89.4	.79	
	Western (12)	Early	1.07	.98	95.2	.86	124
		Final	1.11	.97	96.0	.89	
		Local	.74	1.07	92.7	.76	
	All Stations	Early	1.02	.98	93.3	.86	726
		Final	1.09	.94	92.0	.84	
		Local	.91	1.06	91.2	.82	
30	Eastern (17)	Early	1.05	.95	93.0	.86	298
		Final	1.10	.90	90.3	.80	
		Local	1.08	.92	89.9	.80	
	Southern (16)	Early	1.50	.99	97.4	.39	117
		Final	1.50	.99	97.4	.39	
		Local	1.00	1.00	98.3	.49	
	Central (16)	Early	1.00	1.00	86.6	.72	134
		Final	.88	1.16	85.8	.72	
		Local	1.08	.89	85.1	.69	
	Western (12)	Early	1.18	.96	88.7	.63	97
		Final	1.18	.96	90.7	.70	
		Local	1.06	.99	90.7	.69	
	All Stations	Early	1.04	.97	91.8	.83	646
		Final	1.04	.98	90.7	.80	
		Local	1.08	.95	90.6	.80	
42	Eastern (17)	Early	1.20	.81	87.6	.75	282
		Final	1.23	.79	86.2	.72	
		Local	1.10	.90	87.9	.76	
	Southern (16)	Early	.67	1.02	98.5	.79	68
		Final	.67	1.02	98.5	.79	
		Local	0.00	1.05	95.6	.00	
	Central (16)	Early	1.10	.90	87.8	.75	139
		Final	1.04	.96	87.8	.76	
		Local	1.08	.91	89.9	.80	
	Western (12)	Early	1.33	.94	95.2	.83	104
		Final	1.60	.90	89.4	.66	
		Local	.93	1.01	91.3	.64	
	All Stations	Early	1.17	.90	90.2	.80	593
		Final	1.19	.89	88.5	.77	
		Local	1.07	.96	89.9	.79	

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

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

Table 4.2. Comparative verification of early guidance and local surface wind forecasts for 90 stations, 0000 GMT cycle.

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	25	7655	3.2	12.8	12.3	7680	.35	56.0	1.07	0.99	0.90	0.93	0.87	1.44	0.67	14546
	Local	30		3.4	13.3			.31	52.3	0.79 (5725)	1.20 (5065)	1.11 (2716)	0.97 (812)	0.68 (186)	1.30 (27)	0.60 (15)	
30	Early	28	4458	3.6	11.9	10.5	4532	.34	64.3	1.03	0.96	0.99	0.86	0.81	1.56	0.00	14760
	Local	34		4.0	12.5			.28	59.1	0.89 (8972)	1.21 (4059)	1.14 (1308)	0.96 (336)	0.73 (75)	1.78 (9)	5.00 (1)	
42	Early	34	7433	3.8	13.0	11.9	7475	.26	49.0	1.05	0.97	0.95	1.03	1.08	1.48	0.53	14513
	Local	40		3.9	12.9			.22	46.5	0.84 (5635)	1.24 (5126)	0.99 (2689)	0.74 (819)	0.53 (196)	1.06 (33)	0.33 (15)	

Table 4.3. Contingency tables for early guidance and local surface wind speed forecasts for 90 stations, 0000 GMT cycle.

18-h Forecasts

Guidance

OBS	1	2	3	4	5	6	7	T
1	4188	1343	176	17	1	0	0	5725
2	1708	2502	745	101	5	3	1	5065
3	189	1032	1149	305	32	7	2	2716
4	13	138	322	258	69	11	1	812
5	1	18	51	58	43	14	1	186
6	0	1	6	9	6	2	3	27
7	0	0	1	4	6	2	2	15
T	6099	5034	2450	752	162	39	10	14546

Local

OBS	1	2	3	4	5	6	7	T
1	3286	2083	319	33	4	0	0	5725
2	1065	2806	1049	131	11	2	1	5065
3	140	1011	1228	289	39	7	2	2716
4	17	142	351	255	35	10	2	812
5	3	14	66	65	28	9	1	186
6	0	2	5	9	5	6	0	27
7	1	0	1	5	4	1	3	15
T	4512	6058	3019	787	126	35	9	14546

30-h Forecasts

Guidance

OBS	1	2	3	4	5	6	7	T
1	7245	1519	190	15	3	0	0	8972
2	1753	1725	501	72	8	0	0	4059
3	200	540	436	109	16	7	0	1308
4	16	96	127	70	22	5	0	336
5	0	12	31	21	10	1	0	75
6	0	0	3	3	2	1	0	9
7	0	0	1	0	0	0	0	1
T	9214	3892	1289	290	61	14	0	14760

Local

OBS	1	2	3	4	5	6	7	T
1	6301	2292	346	29	2	1	1	8972
2	1441	1933	568	106	8	3	0	4059
3	214	562	408	103	15	5	1	1308
4	24	93	127	67	19	4	2	336
5	0	16	34	11	10	3	1	75
6	1	1	2	4	1	0	0	9
7	0	0	0	1	0	0	0	1
T	7981	4897	1485	321	55	16	5	14760

42-h Forecasts

Guidance

OBS	1	2	3	4	5	6	7	T
1	3722	1513	346	48	5	1	0	5635
2	1786	2242	905	158	30	3	2	5126
3	335	1015	911	351	64	13	0	2689
4	47	167	324	202	64	13	2	819
5	9	18	50	67	36	12	4	196
6	4	3	4	10	8	4	0	33
7	0	0	3	5	4	3	0	15
T	5903	4958	2543	841	211	49	8	14513

Local

OBS	1	2	3	4	5	6	7	T
1	3027	2149	415	42	1	1	0	5635
2	1343	2704	940	113	22	4	0	5126
3	299	1235	863	244	38	9	1	2689
4	60	231	353	141	24	8	2	819
5	9	43	70	54	12	6	2	196
6	6	2	7	7	6	5	0	33
7	1	2	2	8	0	2	0	15
T	4745	6366	2650	609	103	35	5	14513

Table 4.4. Same as Table 4.2 except for 22 stations in the Eastern Region.

		Direction		Speed														
								Contingency Table										
										Bias by Category								
Fcst. Proj. (h)	Type of Fcst.	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	25	2294	3.0	12.9	12.3	2297	.32	52.2	1.01	1.04	0.89	1.09	0.93	2.40	1.50	3526
	Local	29		3.4	13.8			.25	46.9	0.70 (1028)	1.10 (1381)	1.12 (842)	1.21 (223)	0.98 (45)	4.40 (5)	3.00 (2)	
30	Early	26	1382	3.4	12.1	10.8	1403	.36	62.7	1.00	1.02	0.96	0.94	0.85	2.00	0.00	3584
	Local	32		4.1	13.4			.28	54.6	0.78 (2016)	1.24 (1031)	1.38 (398)	1.20 (105)	1.31 (26)	3.33 (3)	3.00 (1)	
42	Early	30	2299	3.5	13.0	12.0	2300	.23	46.0	0.97	1.04	0.92	1.05	1.42	2.17	1.00	3519
	Local	36		3.9	13.5			.16	41.5	0.74 (1008)	1.13 (1395)	1.07 (832)	1.06 (228)	1.00 (48)	3.67 (6)	1.50 (2)	

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	26	2006	3.1	12.1	11.6	2007	.31	54.9	1.17	0.92	0.81	0.89	1.19	**	0.00	3911
	Local	30		3.1	12.6			.27	51.4	0.73 (1476)	1.24 (1580)	1.05 (667)	1.01 (155)	0.45 (31)	** (0)	0.00 (2)	
30	Early	29	965	3.5	11.5	10.4	982	.35	68.0	1.05	0.92	0.96	0.66	0.92	1.33	*	3958
	Local	35		3.8	11.8			.28	62.3	0.90 (2589)	1.31 (999)	0.95 (281)	0.51 (73)	0.54 (13)	1.33 (3)	* (0)	
42	Early	34	1843	3.7	12.5	11.2	1852	.22	48.1	1.18	0.84	0.92	1.24	0.97	4.00	0.50	3868
	Local	41		3.7	12.3			.16	45.2	0.86 (1441)	1.22 (1591)	0.91 (650)	0.64 (148)	0.09 (34)	0.50 (2)	0.50 (2)	

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

Table 4.6. Same as Table 4.2 except for 27 stations in the Central Region.

		Direction		Speed													
								Contingency Table									
										Bias by Category							
Fcst. Proj. (h)	Type of Fcst.	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	22	2665	3.1	13.2	13.0	2671	.34	52.7	1.17	0.95	0.92	0.87	0.86	0.93	0.88	4266
	Local	26		3.4	13.5			.27	48.5	0.76 (1225)	1.17 (1594)	1.13 (1000)	0.81 (351)	0.77 (73)	0.53 (15)	0.25 (8)	
30	Early	26	1613	3.5	12.0	10.6	1635	.31	58.8	1.08	0.88	1.04	0.88	0.91	4.00	*	4388
	Local	32		3.8	12.3			.25	53.8	0.90 (2279)	1.10 (1508)	1.15 (465)	1.04 (112)	0.35 (23)	2.00 (1)	** (0)	
42	Early	33	2695	3.9	13.5	12.5	2708	.21	43.5	1.10	0.95	0.96	0.94	1.23	1.39	0.63	4339
	Local	38		3.9	12.9			.18	42.8	0.82 (1238)	1.29 (1635)	0.94 (1004)	0.62 (357)	0.56 (79)	0.56 (18)	0.13 (8)	

*This category was neither forecast nor observed.
**This category was forecast once but not observed.

Table 4.7. Same as Table 4.2 except for 17 stations in the Western 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	40	690	4.4	12.8	11.5	705	.32	67.0	0.95	1.21	1.17	0.80	0.54	1.00	0.00	2843
	Local	43		4.5	13.1			.33	66.0	0.89 (1996)	1.40 (510)	1.22 (207)	0.93 (83)	0.32 (37)	0.43 (7)	0.33 (3)	
30	Early	39	498	4.3	11.9	9.9	512	.29	69.6	0.98	1.14	0.93	0.95	0.46	0.00	*	2830
	Local	43		4.5	12.0			.27	68.4	0.96 (2088)	1.24 (521)	0.80 (164)	0.86 (42)	0.46 (13)	0.00 (2)	* (0)	
42	Early	49	596	4.9	12.6	10.8	615	.24	62.7	0.95	1.22	1.07	0.94	0.37	0.43	0.00	2787
	Local	54		5.0	12.4			.22	60.4	0.90 (1948)	1.49 (505)	1.11 (203)	0.59 (86)	0.23 (35)	0.29 (7)	0.00 (3)	

*This category was neither forecast nor observed.

Table 4.8. Distribution of absolute errors associated with early guidance and local forecasts of surface wind direction for 90 stations, 0000 GMT cycle.

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	77.9	14.7	3.7	1.7	1.2	0.7
	Local	72.0	17.7	5.4	2.3	1.6	1.1
30	Early	74.6	15.7	4.4	2.4	1.7	1.2
	Local	65.6	19.8	7.8	3.5	2.0	1.3
42	Early	67.5	18.5	6.6	3.1	2.6	1.7
	Local	59.3	22.3	8.5	4.5	3.1	2.2

Table 4.9. Same as Table 4.8 except for 22 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	16.5	3.1	1.4	1.1	0.4
	Local	71.3	18.7	5.8	2.0	1.1	1.1
30	Early	75.2	17.6	3.9	1.6	1.2	0.6
	Local	66.8	21.1	7.1	2.8	1.3	0.8
42	Early	70.6	18.8	5.3	2.7	1.6	1.0
	Local	62.8	21.7	7.8	3.8	2.3	1.5

Table 4.10. Same as Table 4.8 except for 24 stations in the Southern 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	75.9	16.6	4.5	1.5	1.0	0.5
	Local	70.7	18.6	5.7	2.5	1.6	0.8
30	Early	75.6	13.9	4.5	2.3	2.0	1.8
	Local	64.8	18.3	9.1	3.9	2.4	1.5
42	Early	65.5	20.5	7.2	3.1	2.6	1.0
	Local	55.7	25.1	9.5	4.4	3.2	2.1

Table 4.11. Same as Table 4.8 except for 27 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	83.4	11.6	2.7	1.0	0.8	0.5
	Local	76.0	16.7	4.1	1.5	1.1	0.6
30	Early	76.3	15.9	3.5	2.1	1.2	0.9
	Local	67.4	20.3	6.8	2.7	1.5	1.2
42	Early	68.8	17.3	6.4	3.2	2.6	1.8
	Local	60.3	22.1	8.7	4.0	3.0	1.9

Table 4.12. Same as Table 4.8 except for 17 stations in the Western 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	64.1	15.9	7.1	5.4	4.1	3.5
	Local	62.2	15.4	7.8	5.2	5.2	4.2
30	Early	65.1	13.9	8.4	5.4	4.8	2.4
	Local	58.4	17.5	10.0	6.8	4.4	2.8
42	Early	55.2	17.0	10.6	4.7	6.2	6.4
	Local	52.0	16.4	7.6	10.0	6.9	7.2

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

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

Table 5.2. Comparative verification of early guidance and local forecasts of four categories of cloud amount (clear, scattered, broken, and overcast) for 90 stations, 0000 GMT cycle.

Projection (h)	Type of Forecast	Bias by Category				Percent Correct	Skill Score	Number of Cases
		1	2	3	4			
18	Early	1.15	0.78	0.95	1.02	52.2	.345	14497
	Local	0.70	1.47	1.33	0.80	50.4	.343	
	No. Obs.	4685	3014	2583	4215			
30	Early	1.20	0.80	0.79	0.88	57.1	.345	14144
	Local	0.66	2.16	1.94	0.66	46.8	.285	
	No. Obs.	6206	1935	1497	4506			
42	Early	1.38	0.75	0.82	0.88	46.2	.260	14068
	Local	0.58	1.88	1.35	0.61	39.6	.209	
	No. Obs.	4492	2960	2537	4079			

Table 5.3. Same as Table 5.2 except for 22 stations in the Eastern Region.

Projection (h)	Type of Forecast	Bias by Category 1	2	3	4	Percent Correct	Skill Score	Number of Cases
18	Early	1.08	0.66	1.04	1.11	51.1	.328	3421
	Local	0.59	1.47	1.44	0.75	47.2	.298	
	No. Obs.	812	684	714	1211			
30	Early	1.14	0.66	1.20	0.91	57.3	.364	3390
	Local	0.66	2.35	2.08	0.63	46.0	.281	
	No. Obs.	1216	380	392	1402			
42	Early	1.29	0.69	1.11	0.92	45.8	.265	3320
	Local	0.51	1.76	1.45	0.60	40.8	.219	
	No. Obs.	759	676	714	1171			

Table 5.4. Same as Table 5.2 except for 24 stations in the Southern Region.

Projection (h)	Type of Forecast	Bias by Category 1	2	3	4	Percent Correct	Skill Score	Number of Cases
18	Early	1.17	0.84	0.79	0.99	56.5	.379	3905
	Local	0.78	1.55	1.35	0.70	52.5	.358	
	No. Obs.	1555	786	595	969			
30	Early	1.23	0.95	0.37	0.79	62.7	.372	3860
	Local	0.73	2.35	1.88	0.57	50.7	.304	
	No. Obs.	2018	487	355	1000			
42	Early	1.44	0.73	0.55	0.80	49.9	.265	3787
	Local	0.70	2.07	1.27	0.45	40.3	.202	
	No. Obs.	1504	762	579	942			

Table 5.5. Same as Table 5.2 except for 27 stations in the Central Region.

Projection (h)	Type of Forecast	Bias by Category 1	2	3	4	Percent Correct	Skill Score	Number of Cases
18	Early	1.03	0.78	1.09	1.09	50.9	.329	4433
	Local	0.60	1.57	1.29	0.86	49.4	.330	
	No. Obs.	1483	970	748	1232			
30	Early	1.09	0.69	1.01	1.00	56.1	.331	4158
	Local	0.55	2.35	2.10	0.71	44.2	.258	
	No. Obs.	1878	586	384	1310			
42	Early	1.15	0.82	0.91	1.03	45.2	.248	4266
	Local	0.42	2.05	1.30	0.66	37.1	.178	
	No. Obs.	1417	946	734	1169			

Table 5.6. Same as Table 5.2 except for 17 stations in the Western Region.

Projection (h)	Type of Forecast	Bias by Category 1	2	3	4	Percent Correct	Skill Score	Number of Cases
18	Early	1.38	0.86	0.84	0.81	49.7	.314	2738
	Local	0.82	1.20	1.22	0.90	53.2	.374	
	No. Obs.	835	574	526	803			
30	Early	1.40	0.89	0.54	0.72	50.2	.265	2736
	Local	0.70	1.61	1.68	0.73	46.1	.278	
	No. Obs.	1094	482	366	794			
42	Early	1.75	0.72	0.62	0.68	43.4	.221	2695
	Local	0.70	1.50	1.35	0.72	41.3	.224	
	No. Obs.	812	576	510	797			

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 6.2. Comparative verification of early guidance, persistence, and local ceiling forecasts for 90 stations, 0000 GMT cycle.

Projection (h)	Type of Forecast	Bias by Category 1	2	3	4	5	6	Percent Correct	Skill Score
12	Early	0.82	0.86	0.93	1.06	1.03	1.00	67.6	.406
	Local	0.67	0.90	0.91	1.14	1.09	0.97	76.8	.581
	Persistence	0.86	0.87	0.93	0.93	1.04	1.02	79.0	.610
	No. Obs.	263	498	712	1859	1975	9646		
15	Local	0.44	0.67	0.73	1.22	1.23	0.97	70.2	.456
	Persistence	1.07	0.82	0.85	0.91	1.11	1.02	70.5	.447
	No. Obs.	214	533	785	1918	1887	9996		
18	Early	0.58	0.85	0.95	1.05	0.99	1.00	67.9	.384
	Persistence	2.43	1.29	0.98	0.83	1.11	0.99	66.1	.358
	No. Obs.	95	341	688	2130	1896	10114		
21	Local	0.16	0.42	0.60	1.12	1.21	0.97	69.7	.403
	Persistence	4.53	1.74	1.28	0.91	0.98	0.97	64.1	.301
	No. Obs.	49	254	519	1912	2144	10395		
24	Early	0.17	0.73	0.88	1.03	0.88	1.04	70.4	.373
	Persistence	3.50	1.57	1.29	1.08	0.96	0.95	61.8	.252
	No. Obs.	66	280	521	1638	2192	10567		
36	Early	0.49	0.70	0.69	1.03	0.82	1.08	63.5	.294
	Persistence	0.88	0.88	0.93	0.93	1.04	1.02	55.2	.169
	No. Obs.	262	500	727	1900	2028	9846		
48	Early	0.14	0.66	0.62	0.78	0.68	1.13	67.6	.254
	Persistence	3.55	1.59	1.33	1.08	0.95	0.95	54.2	.103
	No. Obs.	65	277	508	1640	2218	10556		

Table 6.3. Same as Table 6.2 except for visibility.

Projection (h)	Type of Forecast	Bias by Category						Percent Correct	Skill Score
		1	2	3	4	5	6		
12	Early	0.97	0.86	0.88	1.11	0.88	1.01	75.6	.286
	Local	0.70	1.01	0.80	1.43	1.26	0.97	79.6	.448
	Persistence	0.76	0.83	0.85	0.84	0.92	1.04	83.7	.503
	No. Obs.	321	196	665	803	977	11866		
15	Local	0.46	0.64	0.44	1.15	0.92	1.06	75.5	.312
	Persistence	0.82	0.71	0.61	0.85	0.76	1.08	76.2	.321
	No. Obs.	306	239	945	798	1188	11714		
18	Early	0.87	0.87	0.80	1.11	1.06	1.01	78.4	.282
	Persistence	1.80	1.10	0.76	1.02	1.09	1.00	77.1	.254
	No. Obs.	144	155	767	682	855	12617		
21	Local	0.33	0.43	0.37	1.09	1.12	1.03	83.1	.274
	Persistence	3.92	1.17	0.88	1.27	1.24	0.96	78.0	.216
	No. Obs.	64	146	650	536	725	13016		
24	Early	0.48	0.91	0.72	1.19	0.74	1.02	83.7	.292
	Persistence	3.16	1.41	1.04	1.31	1.22	0.96	77.5	.192
	No. Obs.	82	121	565	529	764	13159		
36	Early	0.59	0.63	0.74	1.07	0.74	1.05	74.0	.193
	Persistence	0.78	0.79	0.84	0.85	0.93	1.03	71.9	.150
	No. Obs.	332	216	693	819	995	12164		
48	Early	0.17	0.65	0.62	0.96	0.72	1.04	82.4	.188
	Persistence	3.12	1.39	1.04	1.32	1.21	0.96	74.5	.085
	No. Obs.	83	123	561	525	768	13160		

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

Projection (h)	Type of Forecast	Bias by Category 1	2	3	4	5	6	Percent Correct	Skill Score
12	Early	0.40	0.97	1.08	1.06	0.89	1.01	71.6	.409
	Local	0.52	0.73	0.89	1.30	1.00	0.97	79.3	.584
	Persistence	0.83	0.86	1.03	1.18	0.96	0.99	80.1	.595
	No. Obs.	65	257	493	1545	2134	10170		
15	Local	0.31	0.70	0.89	1.36	0.93	0.98	74.5	.485
	Persistence	0.51	0.77	0.96	1.16	1.00	0.99	72.8	.447
	No. Obs.	112	292	534	1584	2097	10333		
18	Early	0.90	0.65	1.03	1.22	0.96	0.99	68.1	.372
	Persistence	0.40	0.58	0.89	1.17	1.00	1.00	67.9	.359
	No. Obs.	138	387	591	1594	2077	10198		
21	Local	0.26	0.69	0.92	1.41	0.92	0.98	68.1	.396
	Persistence	0.25	0.53	0.80	1.10	1.02	1.03	64.2	.298
	No. Obs.	217	419	636	1670	2035	9896		
24	Early	0.71	0.79	1.11	1.14	0.97	0.99	64.0	.339
	Persistence	0.22	0.47	0.74	1.02	1.05	1.05	60.9	.249
	No. Obs.	248	478	705	1833	1980	9740		
36	Early	0.65	1.26	0.73	0.86	0.79	1.07	68.3	.303
	Persistence	0.87	0.86	1.07	1.18	0.96	0.98	58.2	.150
	No. Obs.	63	262	491	1584	2162	10336		
48	Early	0.64	0.74	0.71	0.80	0.88	1.10	62.3	.250
	Persistence	0.22	0.47	0.74	1.03	1.06	1.05	52.7	.092
	No. Obs.	249	476	709	1810	1960	9692		

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	0.44	0.70	0.87	1.27	0.77	1.01	84.1	.320
	Local	0.56	0.86	0.73	1.54	1.31	0.98	86.3	.474
	Persistence	0.81	1.32	1.17	1.01	1.03	0.99	88.0	.523
	No. Obs.	78	118	517	489	736	12565		
15	Local	0.57	1.05	0.85	1.66	1.40	0.96	83.8	.371
	Persistence	0.70	1.50	1.28	0.97	1.17	0.98	84.9	.379
	No. Obs.	91	107	470	515	660	12941		
18	Early	0.75	0.92	0.88	1.14	0.86	1.01	81.9	.284
	Persistence	0.41	1.75	1.26	0.87	1.01	1.00	81.6	.301
	No. Obs.	174	113	495	592	775	12830		
21	Local	0.55	1.12	0.92	1.85	1.20	0.95	77.2	.290
	Persistence	0.30	1.30	1.10	0.77	0.95	1.02	79.0	.240
	No. Obs.	237	151	555	650	809	12456		
24	Early	0.80	0.86	1.16	0.95	0.92	1.01	74.9	.266
	Persistence	0.22	0.94	0.94	0.63	0.81	1.07	74.8	.182
	No. Obs.	316	211	669	814	964	12004		
36	Early	0.42	0.70	0.95	0.91	0.76	1.03	82.5	.223
	Persistence	0.89	1.67	1.15	1.01	1.05	0.99	78.2	.141
	No. Obs.	80	118	542	502	740	12929		
48	Early	0.73	0.84	0.67	0.75	0.77	1.06	74.6	.175
	Persistence	0.22	0.95	0.94	0.63	0.82	1.06	71.6	.077
	No. Obs.	322	208	661	799	951	11947		

Table 6.6. Comparative verification for early guidance, persistence, and local ceiling forecasts for 90 stations, 0000 GMT cycle. 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	Skill Score	Threat Score
12	Early	0.051	0.84	94.3	.365	.246
	Local		0.82	96.0	.553	.402
	Persistence		0.86	96.4	.601	.449
15	Local	0.049	0.61	95.2	.362	.239
	Persistence		0.89	95.1	.446	.308
18	Early	0.029	0.79	96.2	.229	.142
	Persistence		1.54	95.1	.299	.193
21	Local	0.020	0.38	97.7	.159	.092
	Persistence		2.19	95.0	.189	.118
24	Early	0.023	0.62	97.0	.174	.104
	Persistence		1.94	94.7	.174	.110
36	Early	0.050	0.63	93.5	.167	.111
	Persistence		0.88	92.5	.157	.109
48	Early	0.022	0.56	96.8	.083	.051
	Persistence		1.96	93.9	.061	.046

Table 6.7. Same as Table 6.6 except for visibility.

Projection (h)	Type of Forecast	Rel. Freq. Cats. 1&2 combined	Bias Cats. 1&2 combined	Percent Correct	Skill Score	Threat Score
12	Early	0.035	0.92	95.3	.277	.178
	Local		0.82	97.3	.562	.404
	Persistence		0.79	97.4	.577	.419
15	Local	0.036	0.54	96.5	.341	.218
	Persistence		0.77	96.2	.388	.255
18	Early	0.020	0.87	97.4	.269	.165
	Persistence		1.44	96.5	.257	.159
21	Local	0.014	0.40	98.5	.198	.114
	Persistence		2.01	96.6	.158	.095
24	Early	0.013	0.73	98.2	.218	.128
	Persistence		2.12	96.6	.171	.103
36	Early	0.036	0.61	95.1	.135	.086
	Persistence		0.78	94.8	.164	.105
48	Early	0.014	0.46	98.3	.106	.060
	Persistence		2.09	96.3	.093	.058

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	Skill Score	Threat Score
12	Early	0.022	0.85	97.0	.236	.144
	Local		0.69	98.0	.438	.289
	Persistence		0.85	98.2	.541	.380
15	Local	0.027	0.59	97.3	.348	.220
	Persistence		0.70	97.3	.407	.266
18	Early	0.035	0.71	95.6	.240	.151
	Persistence		0.54	96.4	.306	.192
21	Local	0.043	0.55	95.5	.306	.196
	Persistence		0.43	95.4	.230	.143
24	Early	0.048	0.76	93.7	.233	.153
	Persistence		0.39	94.5	.164	.103
36	Early	0.022	1.14	96.2	.173	.107
	Persistence		0.86	96.4	.097	.061
48	Early	0.049	0.70	93.6	.191	.126
	Persistence		0.39	93.8	.052	.040

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

Projection (h)	Type of Forecast	Rel. Freq. Cats. 1&2 combined	Bias Cats. 1&2 combined	Percent Correct	Skill Score	Threat Score
12	Early	0.014	0.60	98.3	.209	.122
	Local		0.74	98.6	.416	.268
	Persistence		1.12	98.6	.494	.334
15	Local	0.013	0.83	98.3	.318	.195
	Persistence		1.13	98.1	.313	.192
18	Early	0.019	0.82	97.4	.248	.150
	Persistence		0.94	97.2	.238	.144
21	Local	0.026	0.77	96.6	.244	.151
	Persistence		0.69	96.4	.175	.107
24	Early	0.035	0.83	95.3	.242	.153
	Persistence		0.51	95.5	.125	.079
36	Early	0.013	0.59	98.2	.125	.071
	Persistence		1.35	97.4	.141	.084
48	Early	0.036	0.77	94.9	.170	.109
	Persistence		0.51	95.1	.060	.043

Table 7.1. Comparative verification of early and final guidance and local max/min temperature forecasts for 85 stations, 0000 GMT cycle.

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	3.3	466 (3.6)	12876
	Final	-2.0	4.2	918 (7.1)	
	Local	-0.2	3.3	459 (3.6)	
36 (Min)	Early	0.2	4.0	838 (6.5)	12865
	Final	-1.0	4.5	1273 (9.9)	
	Local	1.0	4.1	960 (7.5)	
48 (Max)	Early	-0.5	4.4	1162 (9.0)	12861
	Final	-2.9	5.4	2011 (15.6)	
	Local	-0.9	4.4	1193 (9.3)	
60 (Min)	Early	-0.2	4.8	1525 (11.8)	12875
	Final	-0.7	5.3	1906 (14.8)	
	Local	0.4	5.0	1655 (12.9)	

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	-0.0	3.3	128 (3.2)	3992
	Final	-1.7	3.9	231 (5.8)	
	Local	-0.7	3.4	151 (3.8)	
36 (Min)	Early	0.2	4.2	293 (7.3)	3988
	Final	-0.9	4.5	366 (9.2)	
	Local	1.2	4.4	364 (9.1)	
48 (Max)	Early	-1.1	4.3	326 (8.2)	3992
	Final	-1.9	4.6	420 (10.5)	
	Local	-1.7	4.5	367 (9.2)	
60 (Min)	Early	-0.2	5.0	510 (12.8)	3991
	Final	-0.3	5.2	564 (14.1)	
	Local	0.5	5.1	546 (13.7)	

Table 7.3. Same as Table 7.1 except for 24 stations in the Southern 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	0.1	3.3	125 (3.4)	3663
	Final	-2.4	4.3	250 (6.8)	
	Local	-0.1	3.2	116 (3.2)	
36 (Min)	Early	0.2	3.9	202 (5.5)	3655
	Final	-1.1	4.7	406 (11.1)	
	Local	0.8	3.9	200 (5.5)	
48 (Max)	Early	-0.1	4.2	270 (7.4)	3651
	Final	-4.0	5.8	680 (18.6)	
	Local	-0.3	4.1	269 (7.4)	
60 (Min)	Early	0.1	4.6	379 (10.3)	3664
	Final	-0.4	5.3	562 (15.3)	
	Local	0.5	4.7	423 (11.5)	

Table 7.4. Same as Table 7.1 except for 20 stations in the Central Region.

Forecast Projection (h)	Type of Forecast	Mean Algebraic Error (°F)	Mean Absolute Error (°F)	Number (%) of Absolute Errors ≥ 10°	Number of Cases
	Early	0.5	3.6	126 (4.1)	
24 (Max)	Final	-2.2	4.5	313 (10.2)	3072
	Local	0.1	3.6	137 (4.5)	
	Early	0.6	4.2	236 (7.7)	
36 (Min)	Final	-1.4	4.8	349 (11.4)	3070
	Local	1.3	4.5	290 (9.4)	
	Early	-0.5	4.9	368 (12.0)	
48 (Max)	Final	-3.1	5.9	630 (20.5)	3072
	Local	-0.7	4.9	390 (12.7)	
	Early	-0.0	5.2	433 (14.1)	
60 (Min)	Final	-1.0	5.6	507 (16.5)	3073
	Local	0.6	5.4	479 (15.6)	

Table 7.5. Same as Table 7.1 except for 15 stations in the Western Region.

Forecast Projection (h)	Type of Forecast	Mean Algebraic Error (°F)	Mean Absolute Error (°F)	Number (%) of Absolute Errors ≥ 10°	Number of Cases
	Early	0.5	3.1	87 (4.0)	
24 (Max)	Final	-1.9	3.9	124 (5.8)	2149
	Local	-0.0	3.0	55 (2.6)	
	Early	-0.3	3.5	107 (5.0)	
36 (Min)	Final	-0.7	4.0	152 (7.1)	2152
	Local	0.4	3.6	106 (4.9)	
	Early	0.1	4.3	198 (9.2)	
48 (Max)	Final	-2.4	5.1	281 (13.1)	2146
	Local	-0.4	4.0	167 (7.8)	
	Early	-1.0	4.4	203 (9.5)	
60 (Min)	Final	-1.7	4.8	273 (12.7)	2147
	Local	-0.1	4.4	207 (9.6)	

Table 7.6. Comparative verification of early and final guidance and local max/min temperature forecasts for 85 stations, 1200 GMT cycle.

Forecast Projection (h)	Type of Forecast	Mean Algebraic Error (°F)	Mean Absolute Error (°F)	Number (%) of Absolute Errors ≥ 10°	Number of Cases
24 (Min)	Early	0.4	3.8	646 (5.1)	12589
	Final	0.2	4.1	881 (7.0)	
	Local	0.9	3.9	825 (6.6)	
36 (Max)	Early	-0.2	4.0	894 (7.1)	12585
	Final	-1.5	4.4	1137 (9.0)	
	Local	-0.9	3.9	825 (6.6)	
48 (Min)	Early	-0.2	4.4	1148 (9.1)	12577
	Final	0.0	4.9	1577 (12.5)	
	Local	0.5	4.5	1251 (9.9)	
60 (Max)	Early	-0.5	4.9	1599 (12.8)	12489
	Final	-2.1	5.4	2012 (16.1)	
	Local	-0.9	4.9	1539 (12.3)	

Table 7.7. Same as Table 7.6 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
	Early	0.7	4.0	226 (5.8)	
24 (Min)	Final	0.7	4.0	261 (6.7)	3897
	Local	1.4	4.2	327 (8.4)	
	Early	-0.7	3.9	231 (5.9)	
36 (Max)	Final	-1.1	4.2	288 (7.4)	3899
	Local	-1.5	4.1	286 (7.3)	
	Early	-0.1	4.5	379 (9.7)	
48 (Min)	Final	0.0	5.1	512 (13.2)	3893
	Local	0.8	4.8	462 (11.9)	
	Early	-0.8	4.6	383 (9.9)	
60 (Max)	Final	-1.6	5.0	515 (13.3)	3867
	Local	-1.5	4.8	427 (11.0)	

Table 7.8. Same as Table 7.6 except for 24 stations in the Southern Region.

Forecast Projection (h)	Type of Forecast	Mean Algebraic Error (°F)	Mean Absolute Error (°F)	Number(%) of Absolute Errors ≥ 10°	Number of Cases
	Early	0.3	3.8	176 (4.9)	
24 (Min)	Final	0.1	4.1	264 (7.3)	3614
	Local	0.7	3.7	178 (4.9)	
	Early	-0.2	4.0	253 (7.0)	
36 (Max)	Final	-2.3	4.7	373 (10.3)	3610
	Local	-0.6	3.8	198 (5.5)	
	Early	-0.1	4.4	298 (8.3)	
48 (Min)	Final	0.8	4.9	441 (12.2)	3609
	Local	0.3	4.3	282 (7.8)	
	Early	-0.2	4.7	401 (11.2)	
60 (Max)	Final	-2.7	5.6	615 (17.2)	3586
	Local	-0.5	4.7	391 (10.9)	

Table 7.9. Same as Table 7.6 except for 20 stations in the Central Region.

Forecast Projection (h)	Type of Forecast	Mean Algebraic Error (°F)	Mean Absolute Error (°F)	Number (%) of Absolute Errors ≥ 10°	Number of Cases
24 (Min)	Early	0.4	3.9	169 (5.7)	2969
	Final	-0.0	4.4	255 (8.6)	
	Local	0.9	4.2	228 (7.7)	
36 (Max)	Early	-0.0	4.4	255 (7.1)	2974
	Final	-1.6	4.8	332 (9.2)	
	Local	-0.6	4.3	245 (6.8)	
48 (Min)	Early	-0.3	4.7	329 (11.1)	2971
	Final	-0.2	5.1	426 (14.3)	
	Local	0.5	4.9	354 (11.9)	
60 (Max)	Early	-1.1	5.8	547 (18.5)	2949
	Final	-2.2	6.0	596 (20.2)	
	Local	-0.9	5.6	505 (17.1)	

Table 7.10. Same as Table 7.6 except for 15 stations in the Western Region.

Forecast Projection (h)	Type of Forecast	Mean Algebraic Error (°F)	Mean Absolute Error (°F)	Number (%) of Absolute Errors ≥ 10°	Number of Cases
24 (Min)	Early	-0.1	3.2	75 (3.6)	2109
	Final	-0.0	3.5	101 (4.8)	
	Local	0.4	3.3	92 (4.4)	
36 (Max)	Early	0.3	3.8	155 (7.4)	2102
	Final	-0.9	4.0	144 (6.9)	
	Local	-0.4	3.4	96 (4.6)	
48 (Min)	Early	-0.5	4.0	142 (6.7)	2104
	Final	-0.9	4.4	198 (9.4)	
	Local	0.1	4.0	153 (7.3)	
60 (Max)	Early	0.1	4.7	268 (12.8)	2087
	Final	-1.9	5.1	286 (13.7)	
	Local	-0.5	4.5	216 (10.3)	

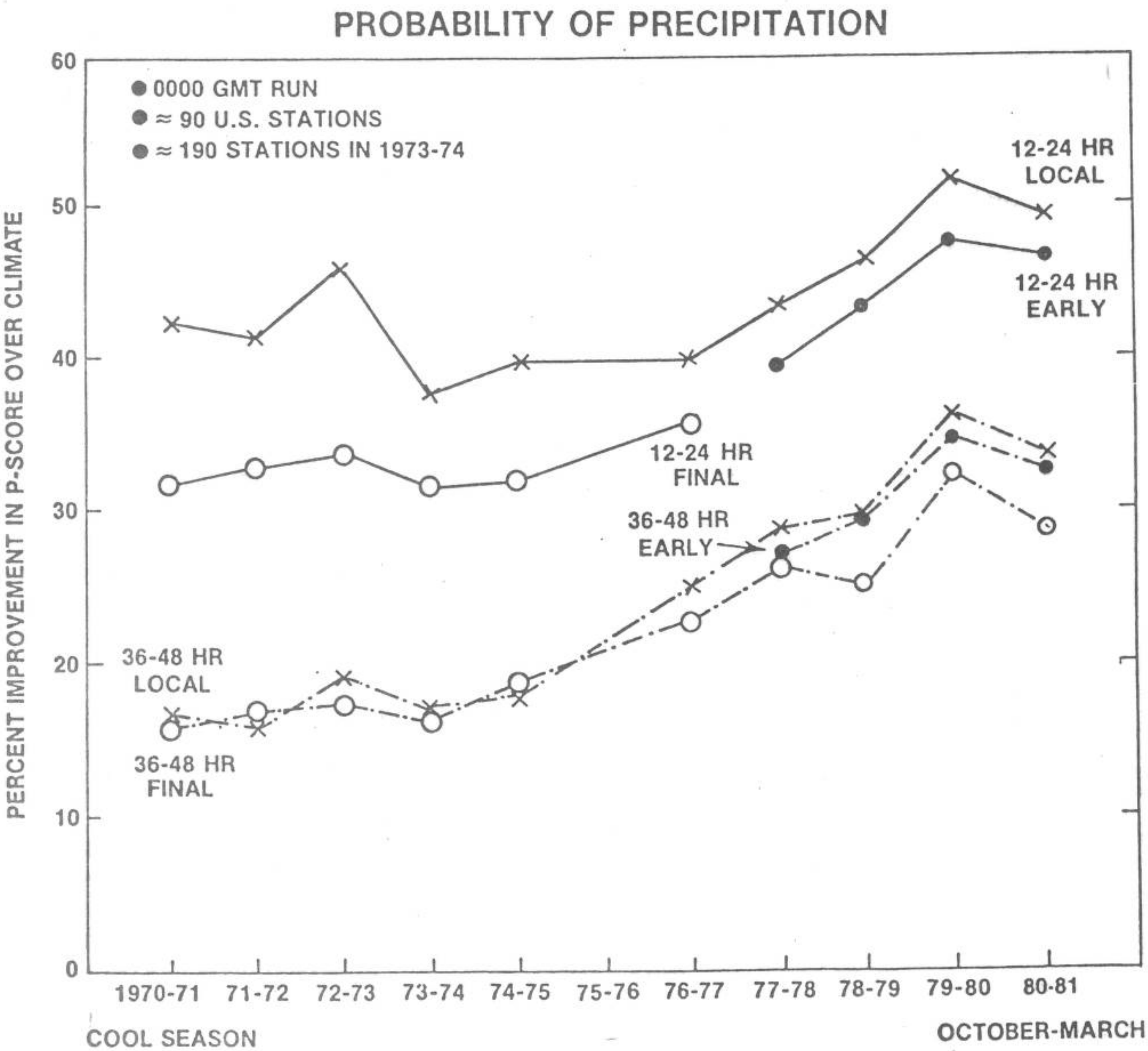

Figure 2.1. Percent improvement over climatology in the Brier score of the local and the early and final guidance PoP forecasts. Results for 1975-76 are unavailable because of missing data.

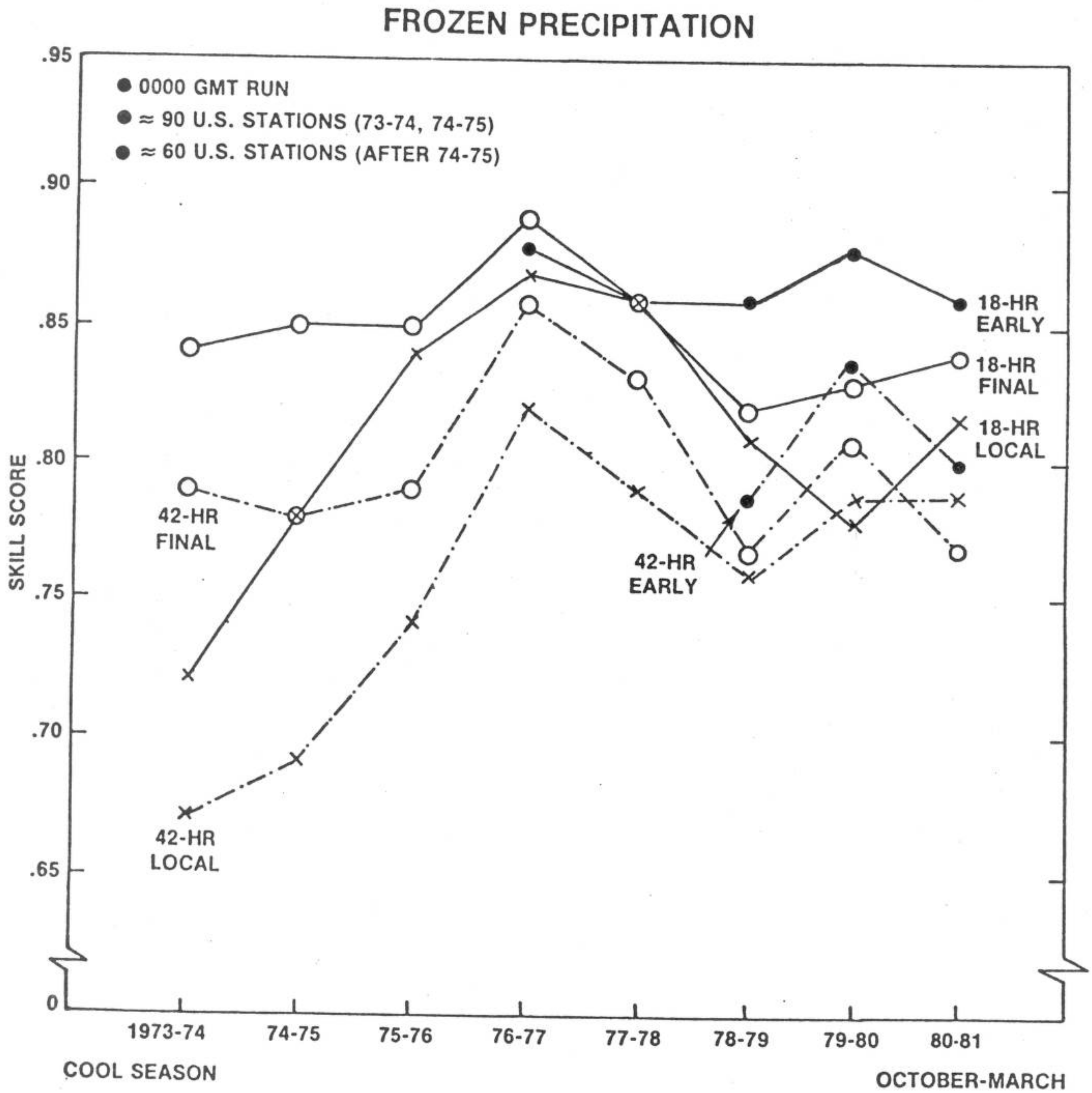

Figure 3.1. Skill score for the local and the early and final guidance frozen precipitation forecasts.

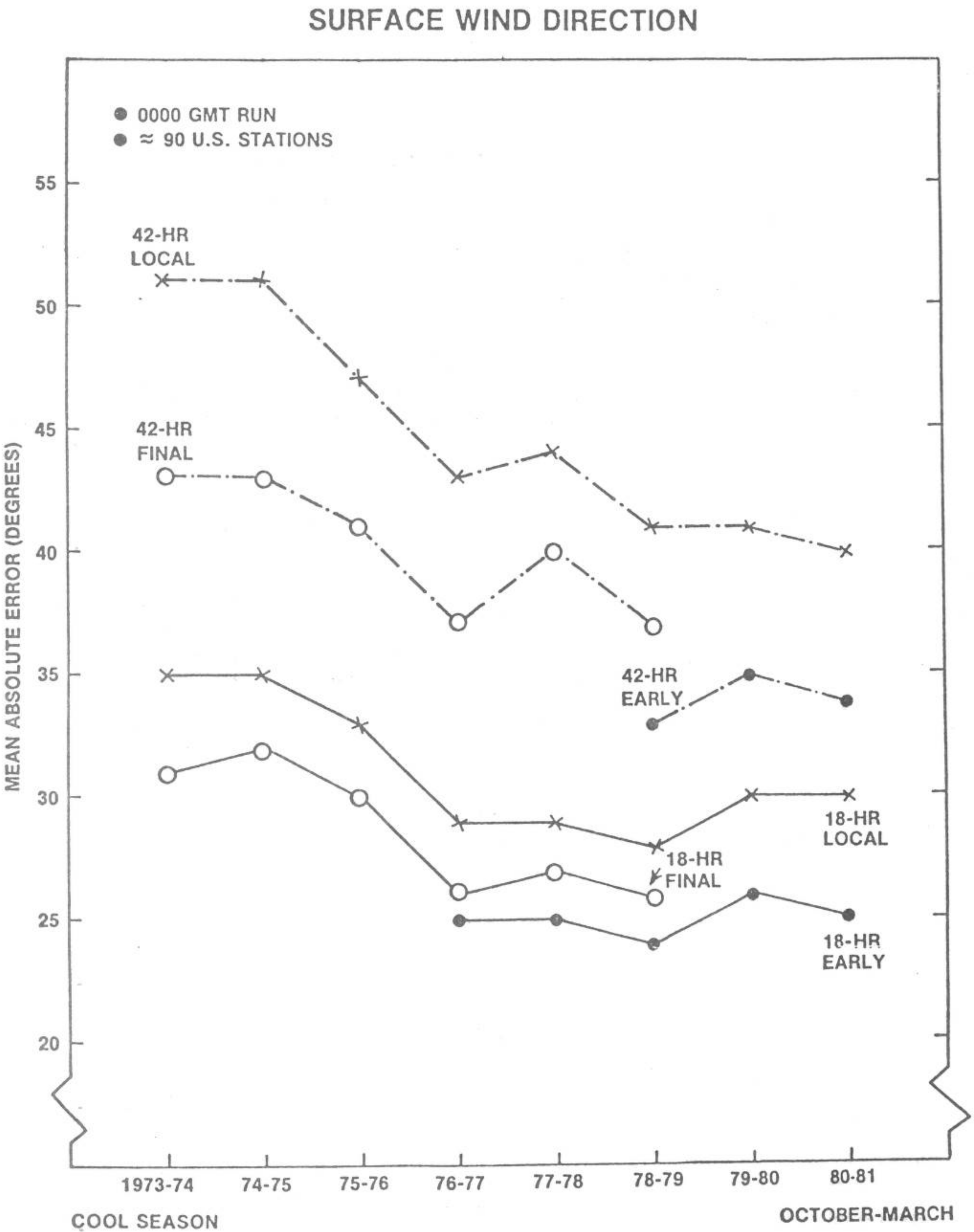

Figure 4.1. Mean absolute error for the local and the early and final guidance surface wind direction forecasts.

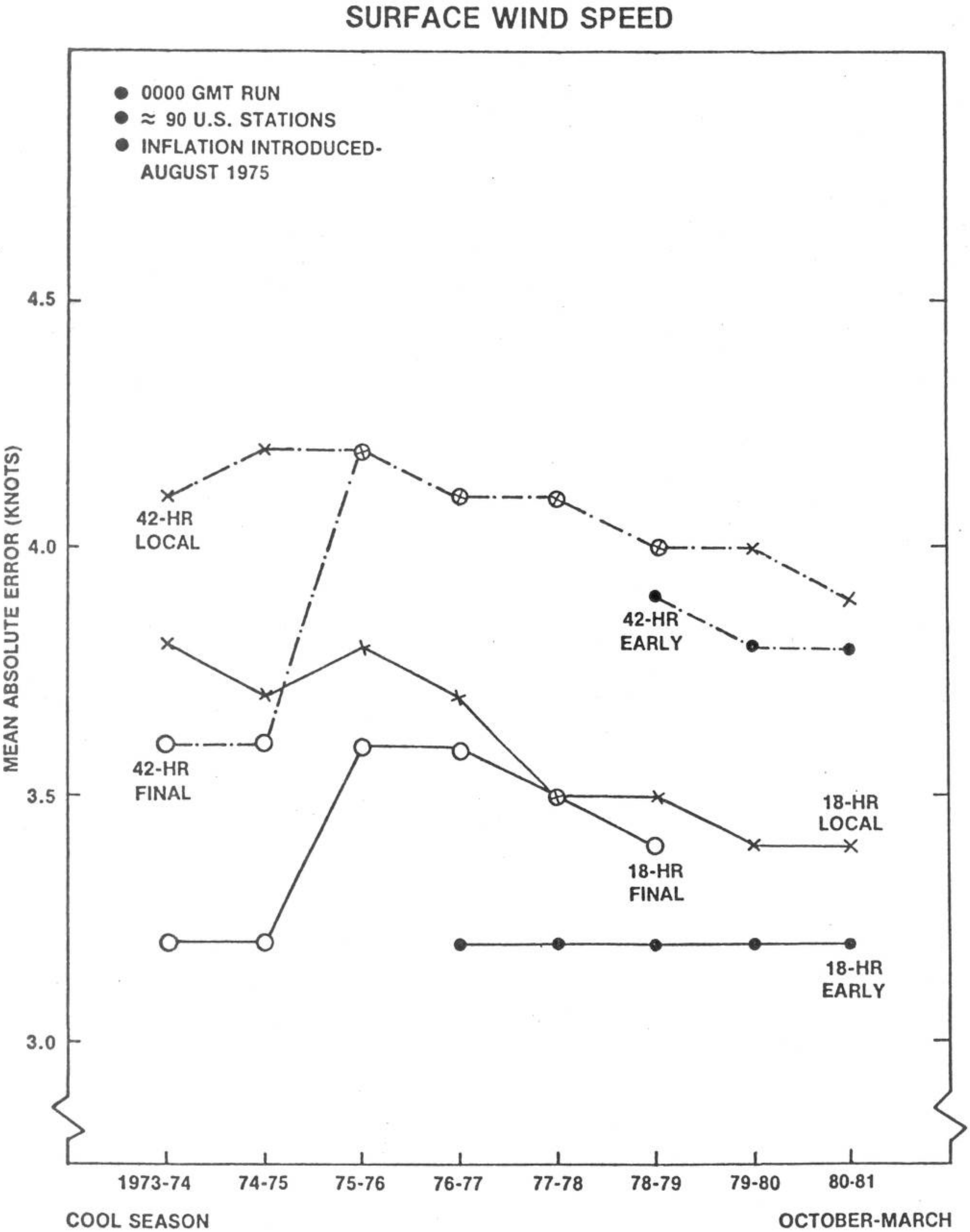

Figure 4.2. Same as Fig. 4.1 except for wind speed forecasts.

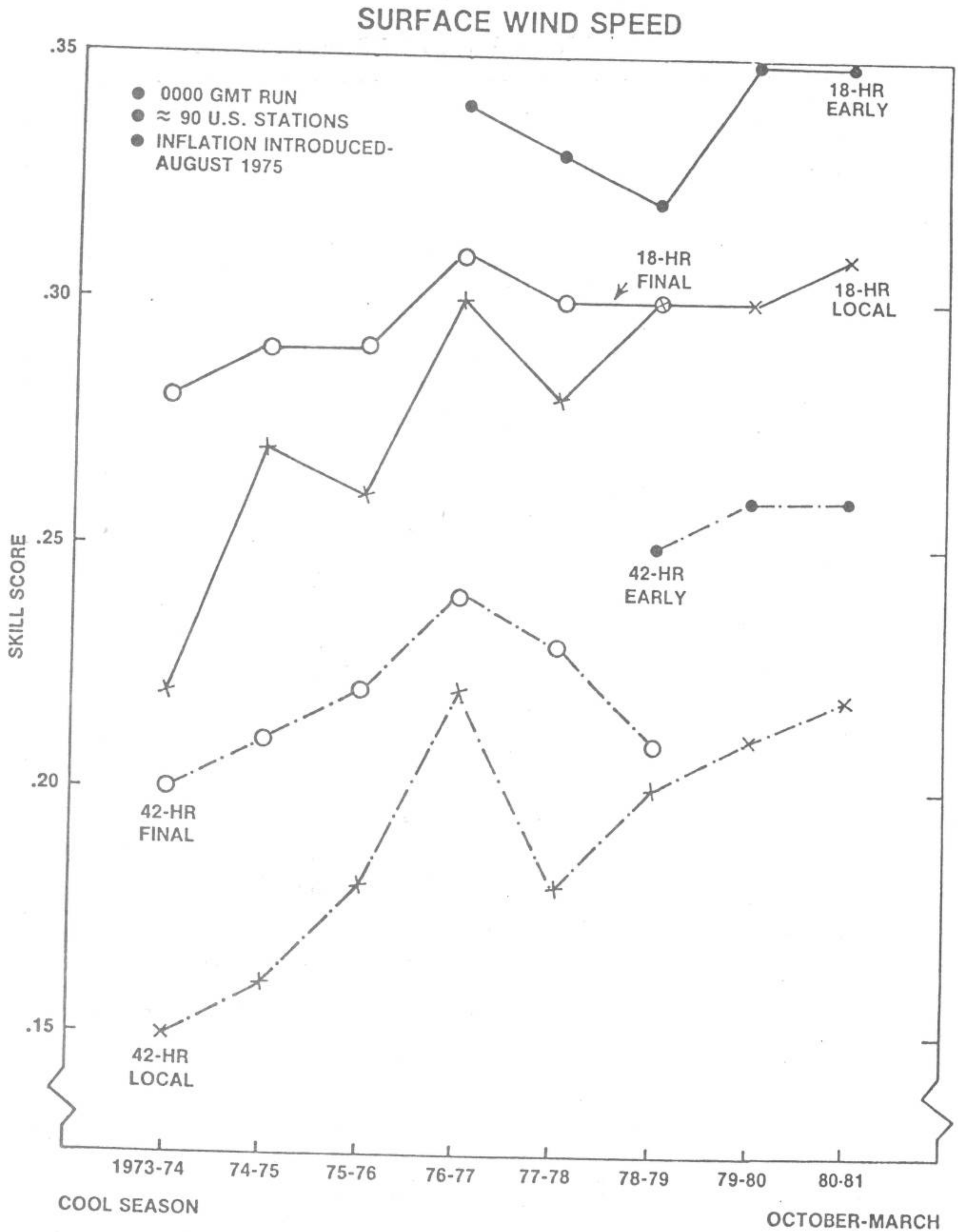

Figure 4.3. Skill score computed from five-category contingency tables for the local and the early and final guidance surface wind speed forecasts.

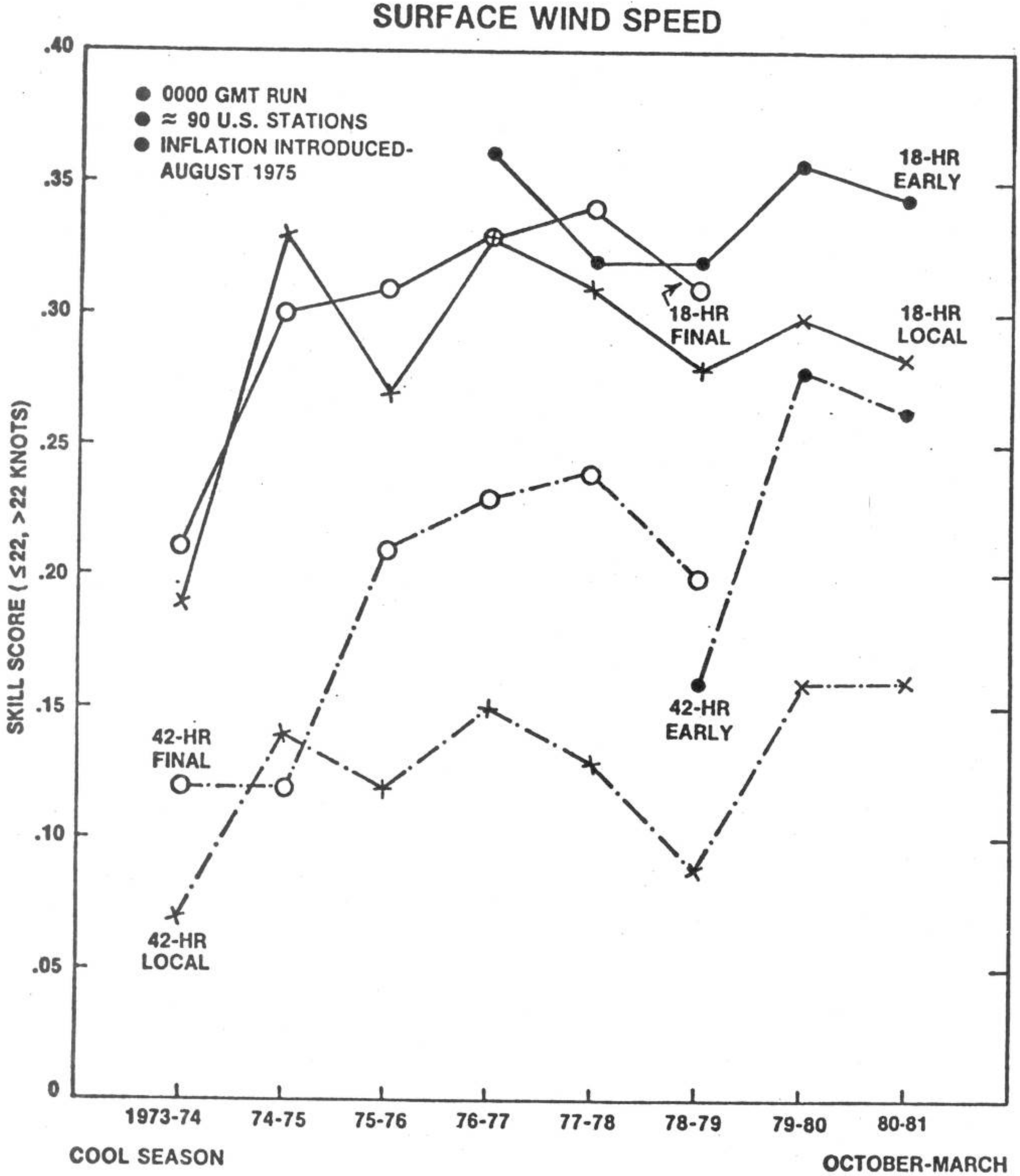

Figure 4.4. Same as Fig. 4.3 except for two-category contingency tables.

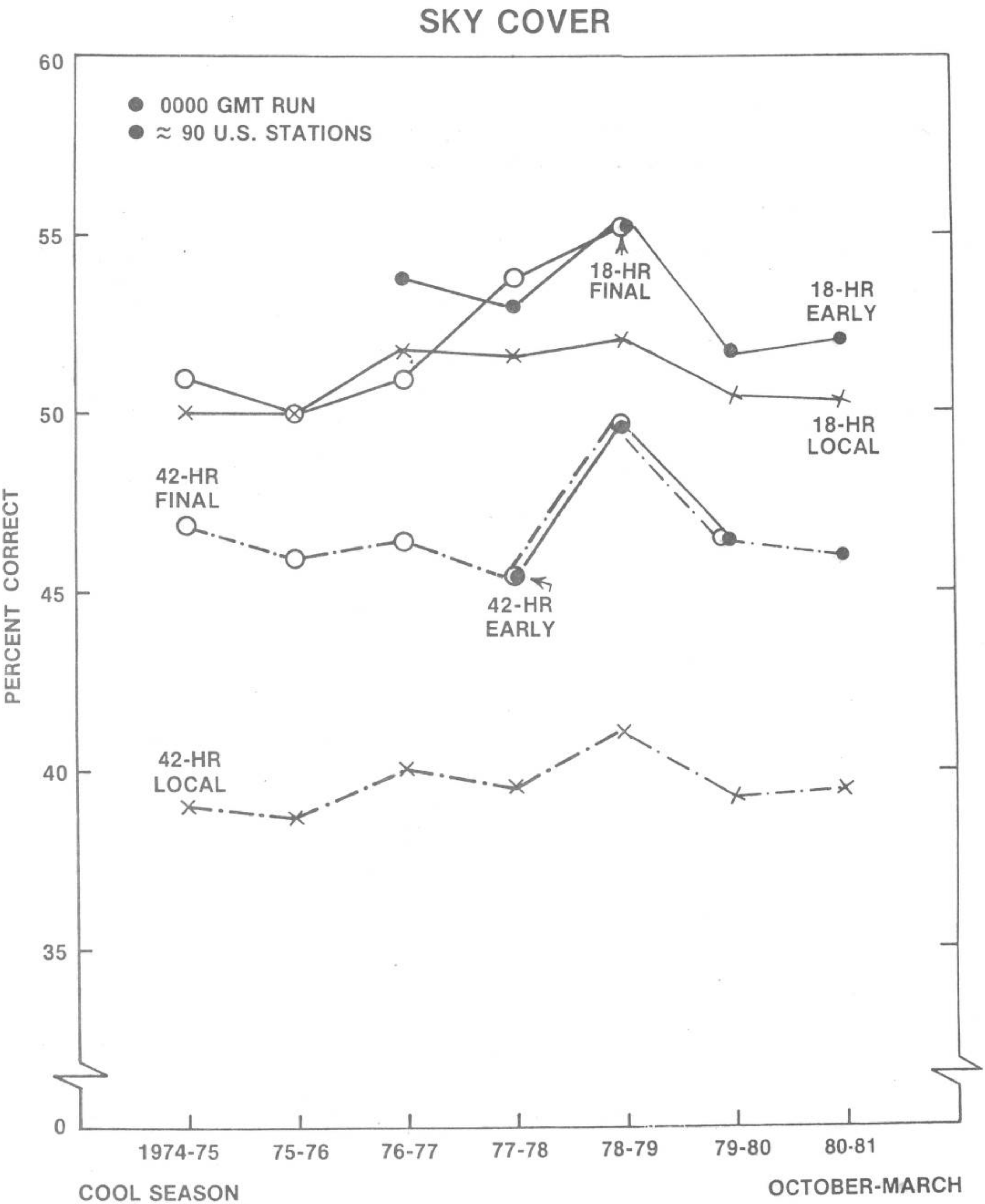

Figure 5.1. Percent correct for the local and the early and final guidance cloud amount forecasts.

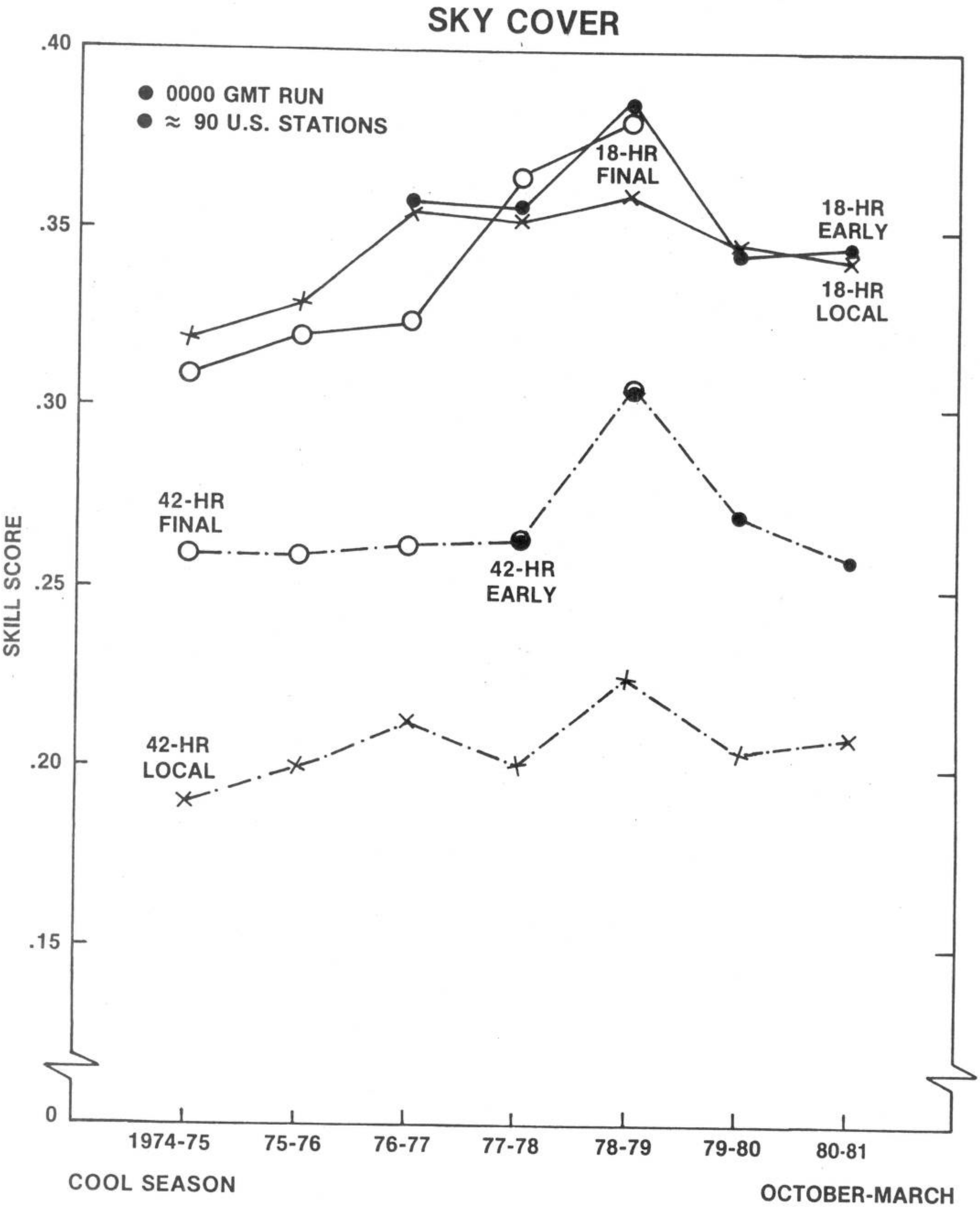

Figure 5.2. Skill score for the local and the early and final guidance cloud amount forecasts.

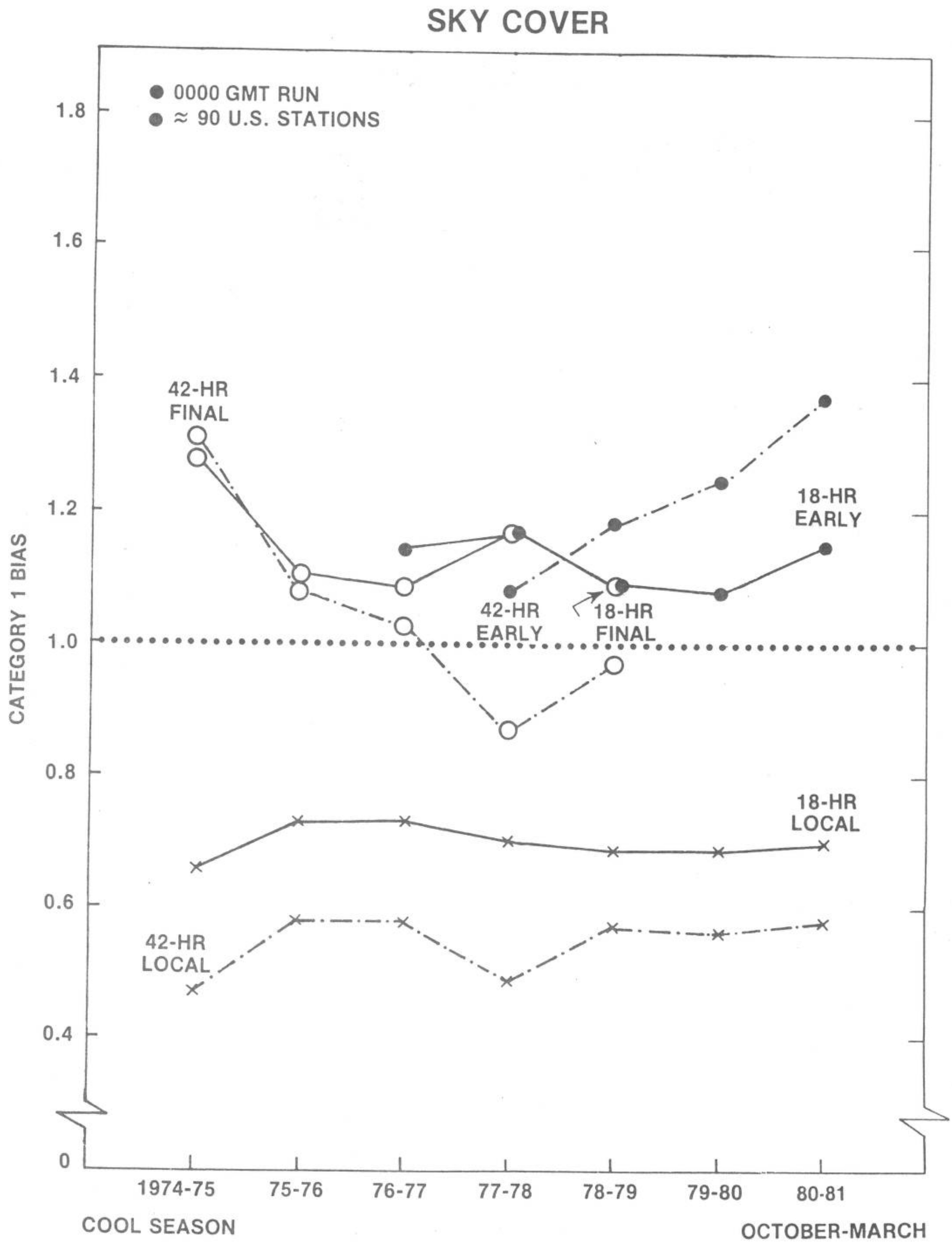

Figure 5.3. Category 1 bias for the local and the early and final guidance cloud amount forecasts.

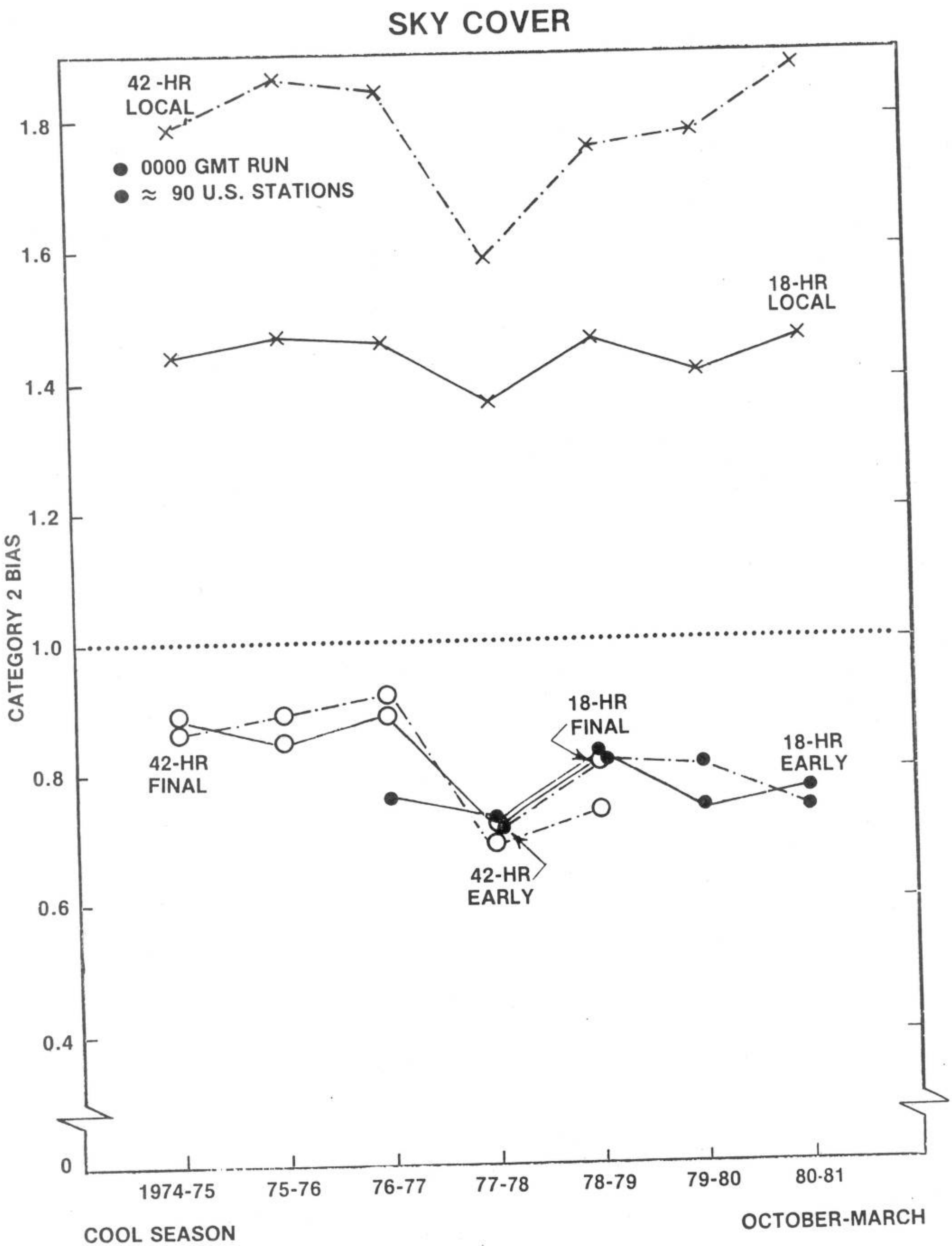

Figure 5.4. Same as Fig. 5.3 except for category 2 bias.

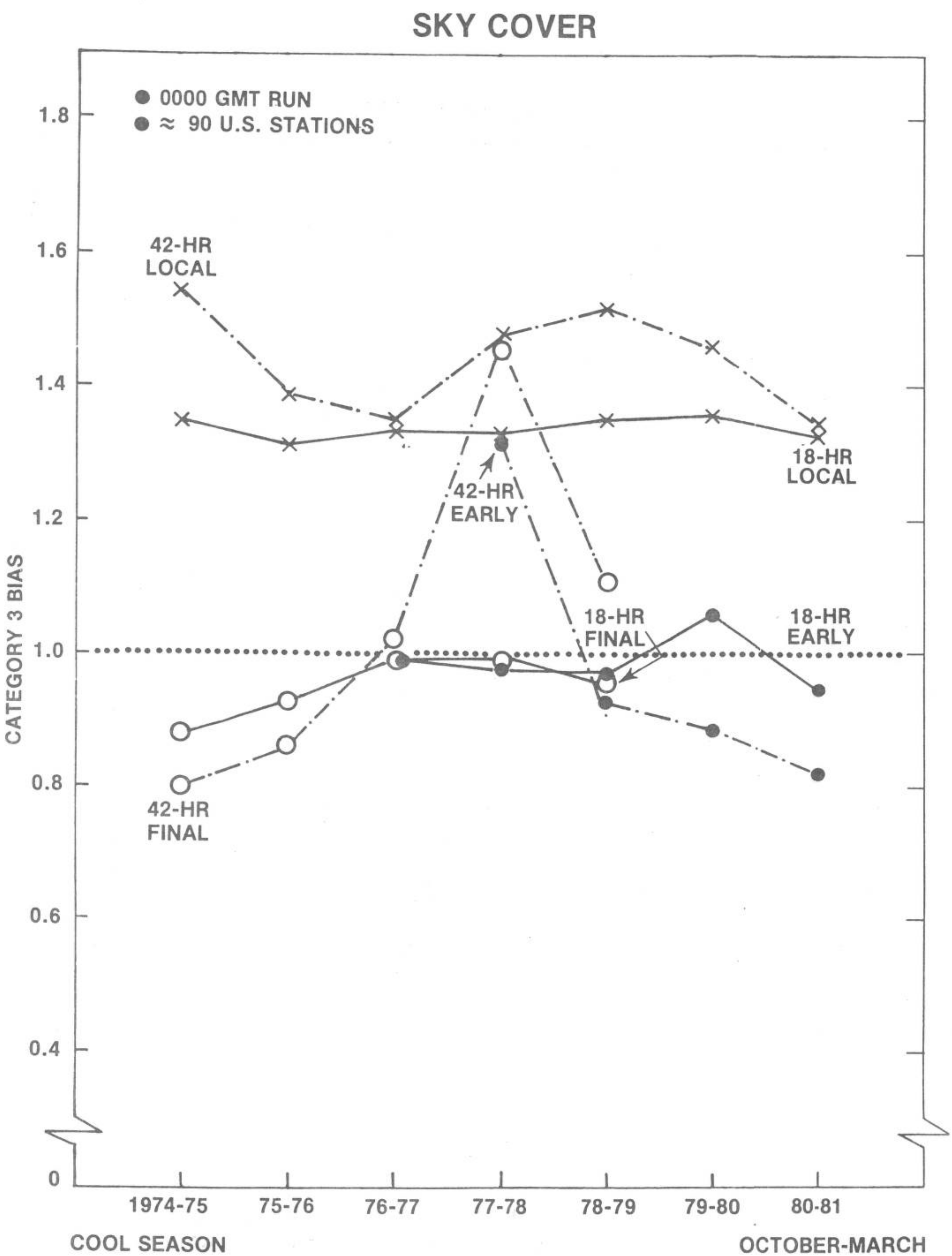

Figure 5.5. Same as Fig. 5.3 except for category 3 bias.

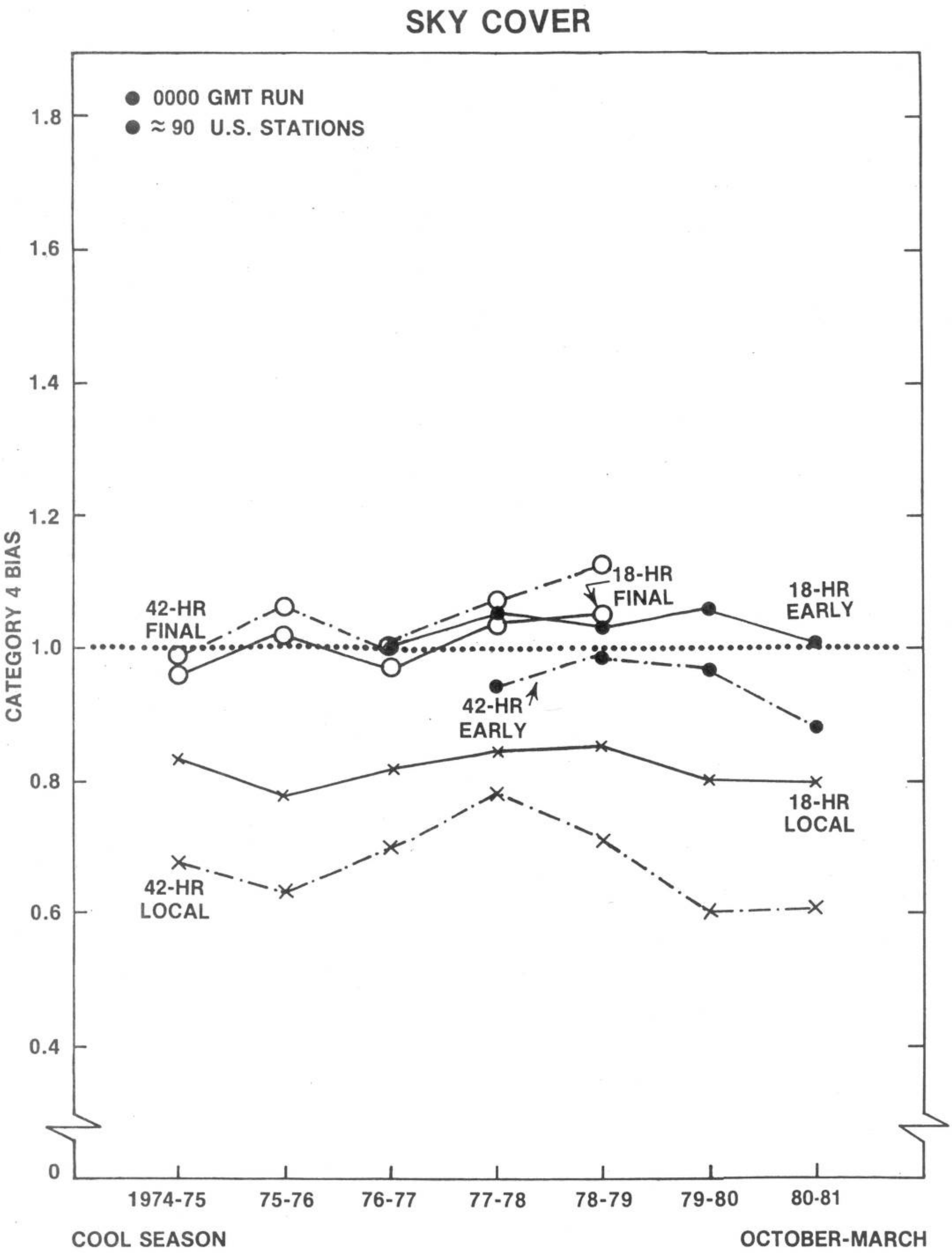

Figure 5.6. Same as Fig. 5.3 except for category 4 bias.

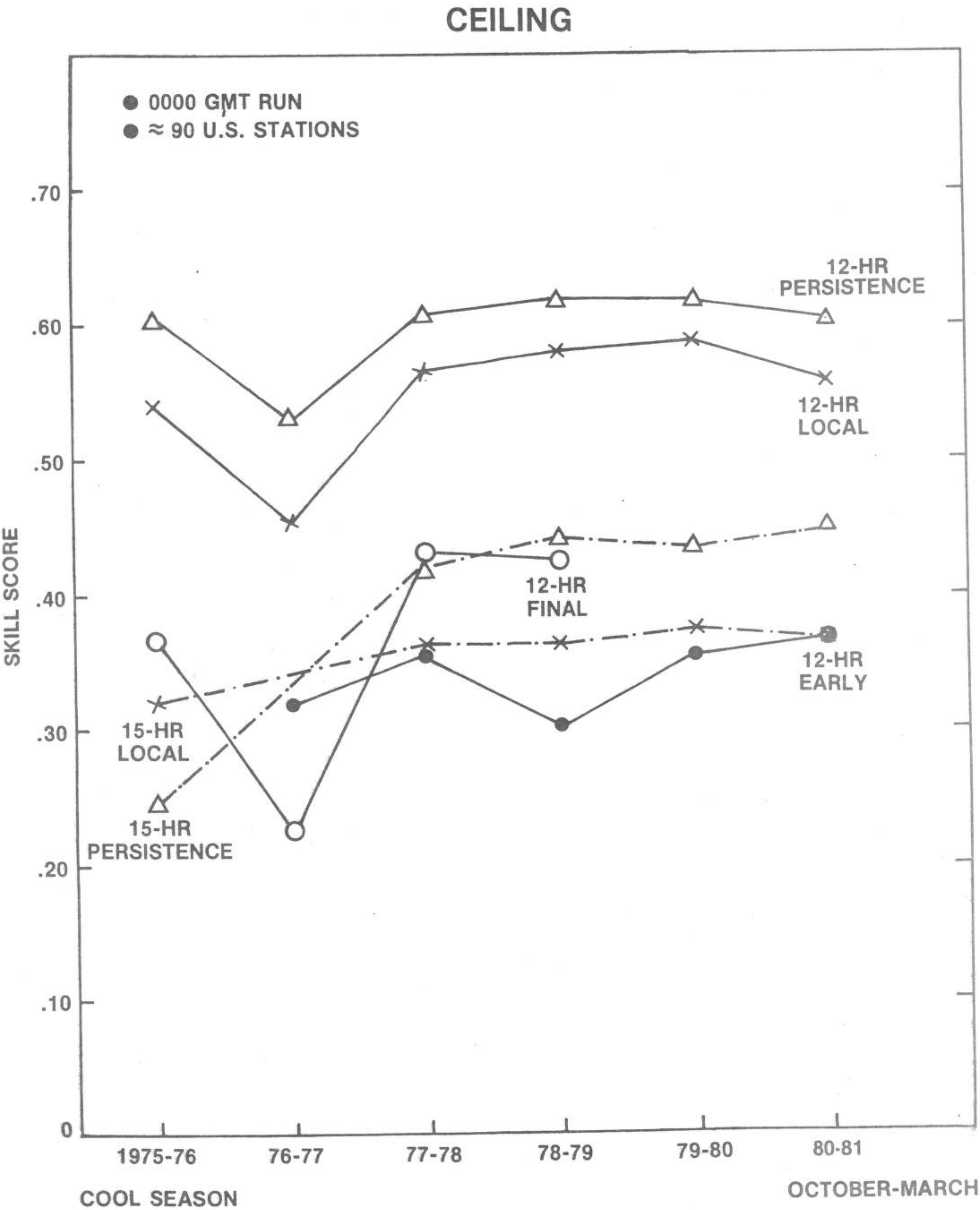

Figure 6.1. Skill score computed from two-category contingency tables for local, guidance, and persistence ceiling height forecasts.

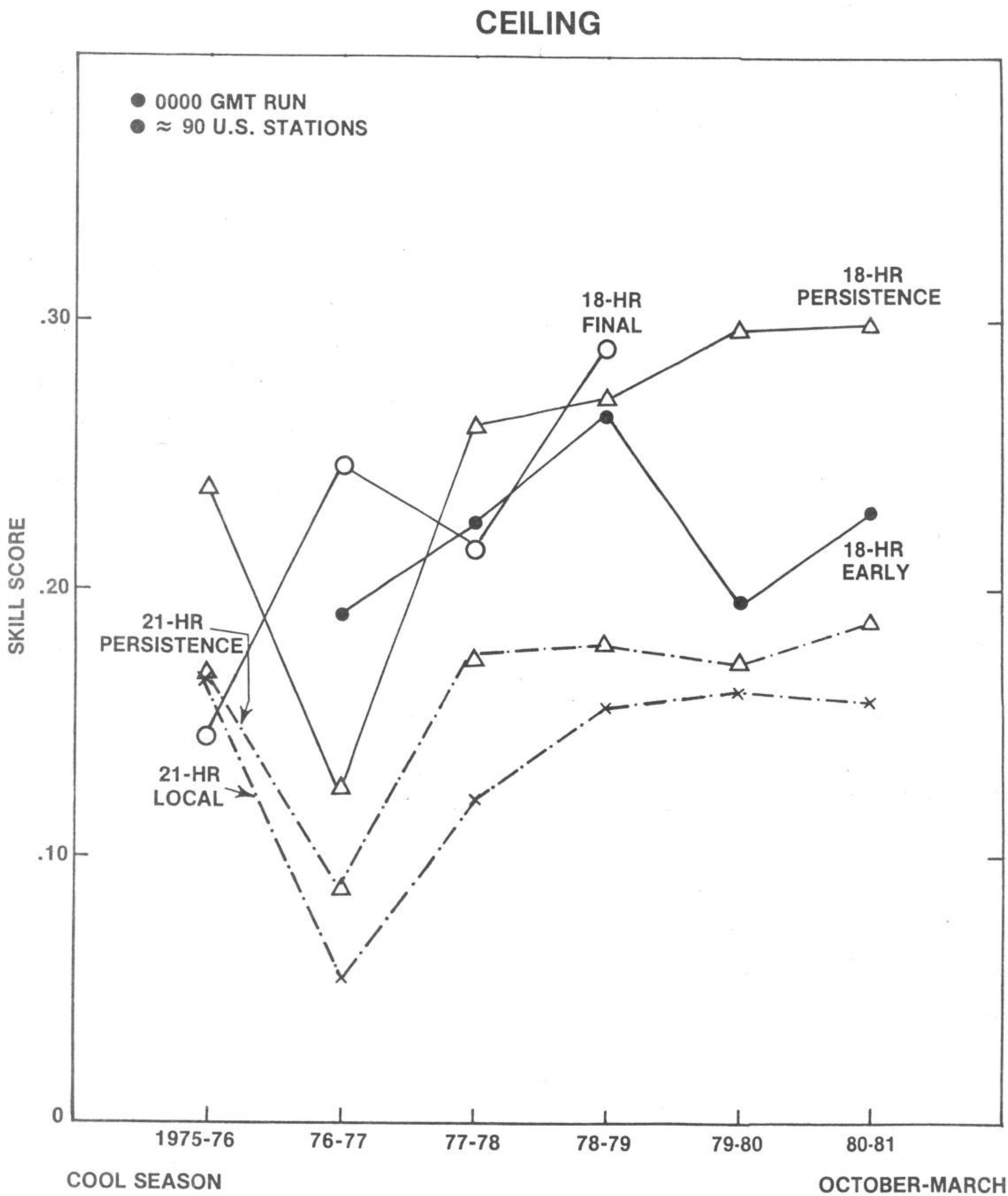

Figure 6.2. Same as Fig. 6.1 except for forecast projection.

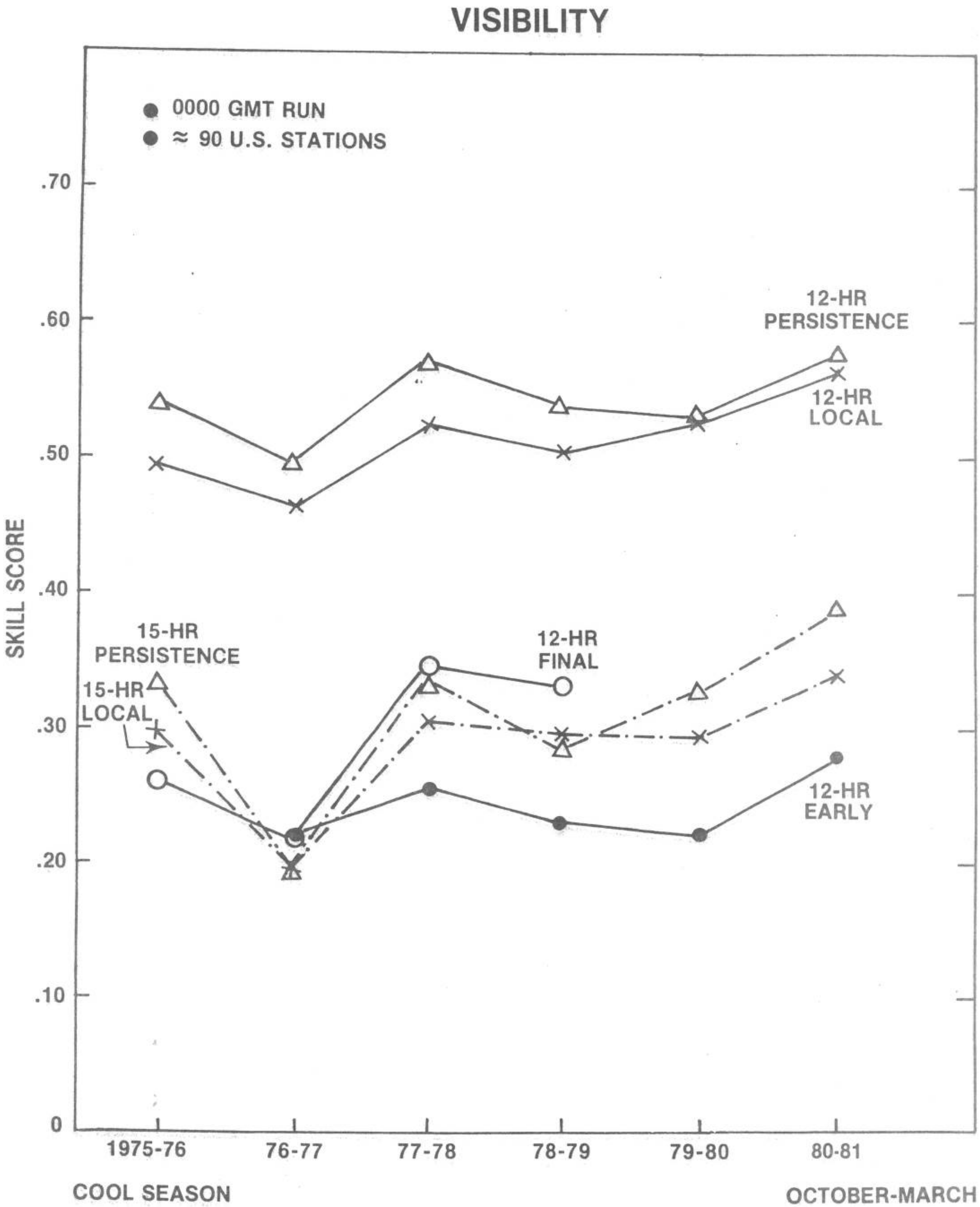

Figure 6.3. Same as Fig. 6.1 except for visibility forecasts.

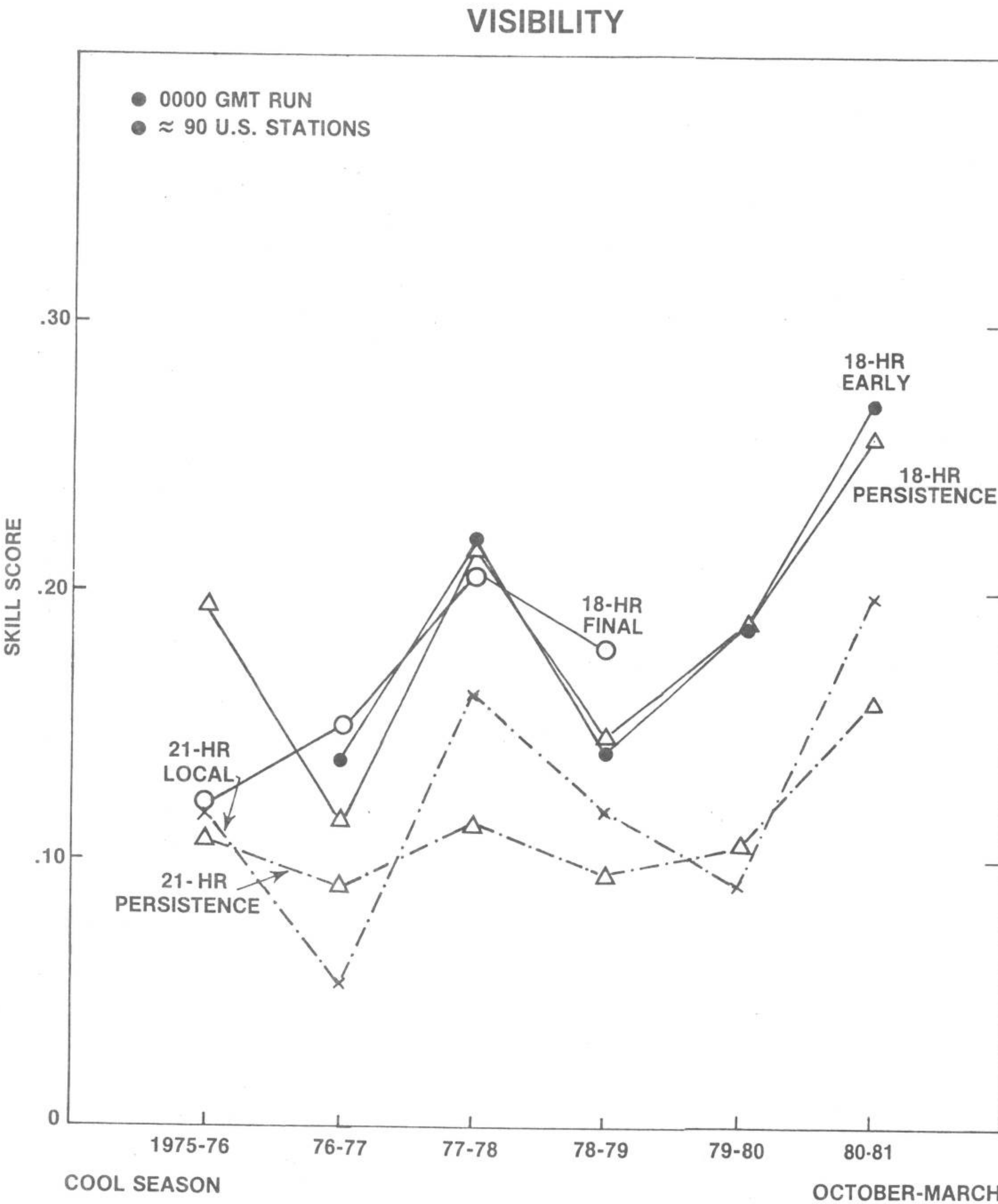

Figure 6.4. Same as Fig. 6.3 except for forecast projection.

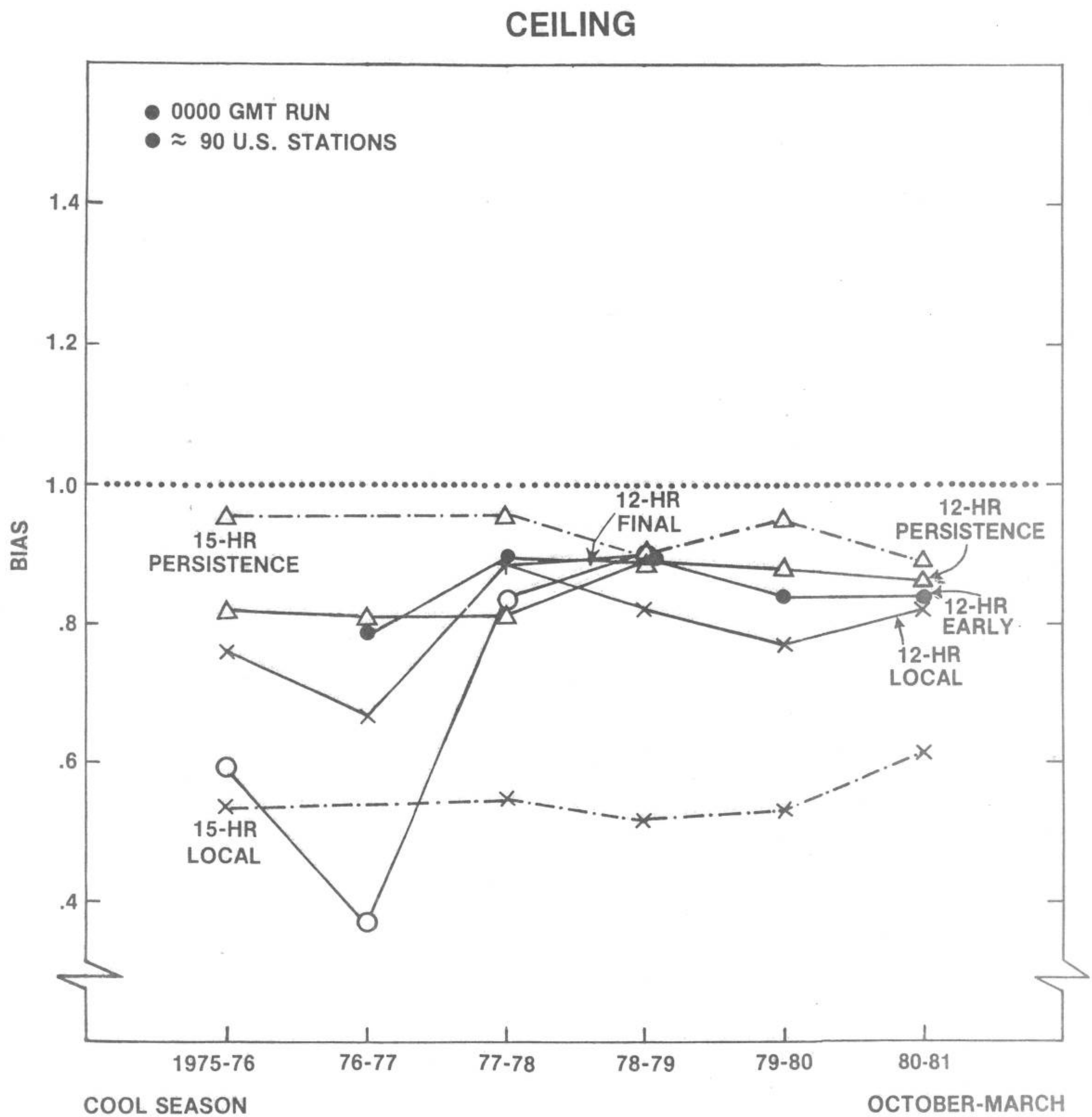

Figure 6.5. Bias for categories 1 and 2 combined for local, guidance, and persistence ceiling height forecasts.

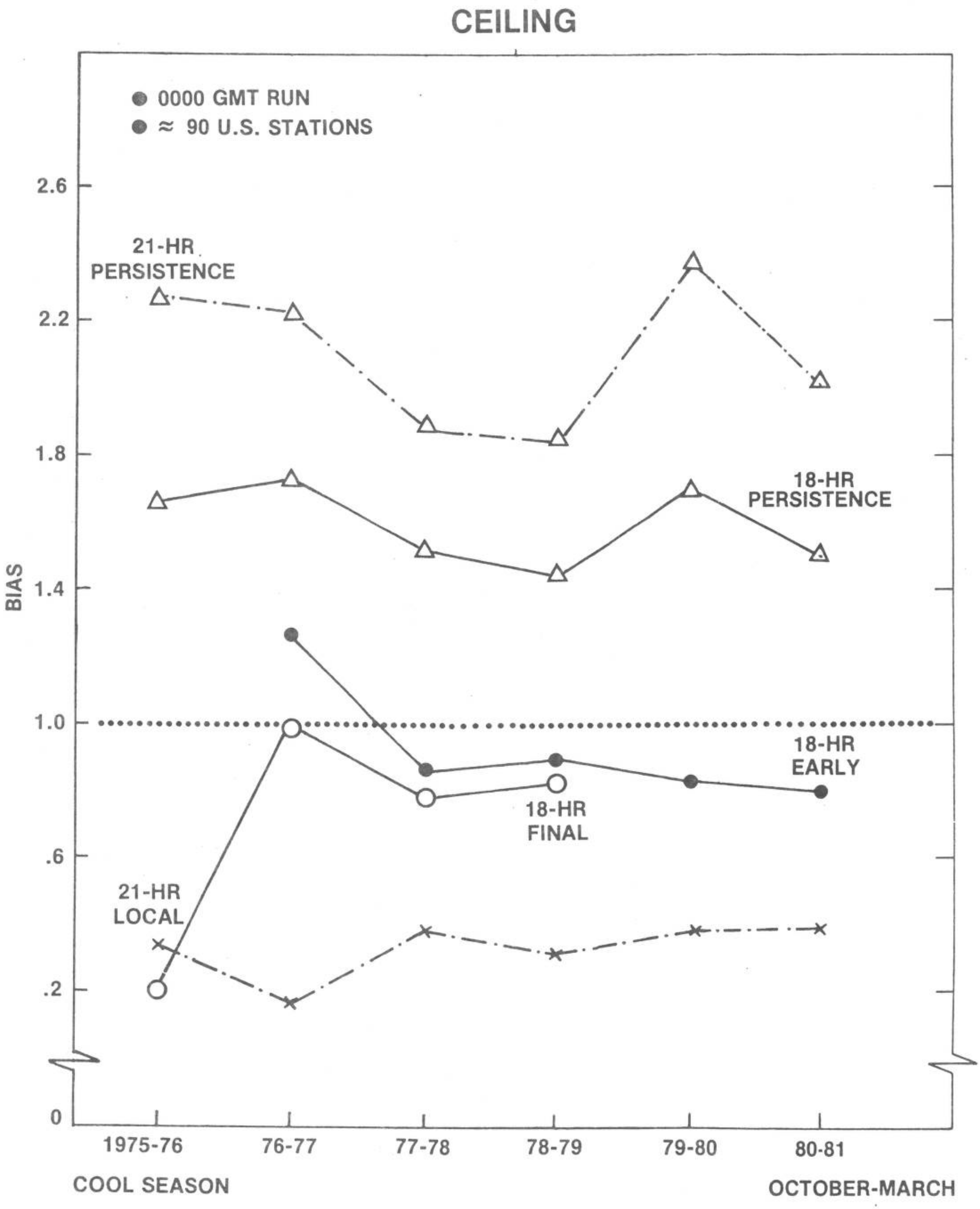

Figure 6.6. Same as Fig. 6.5 except for forecast projection.

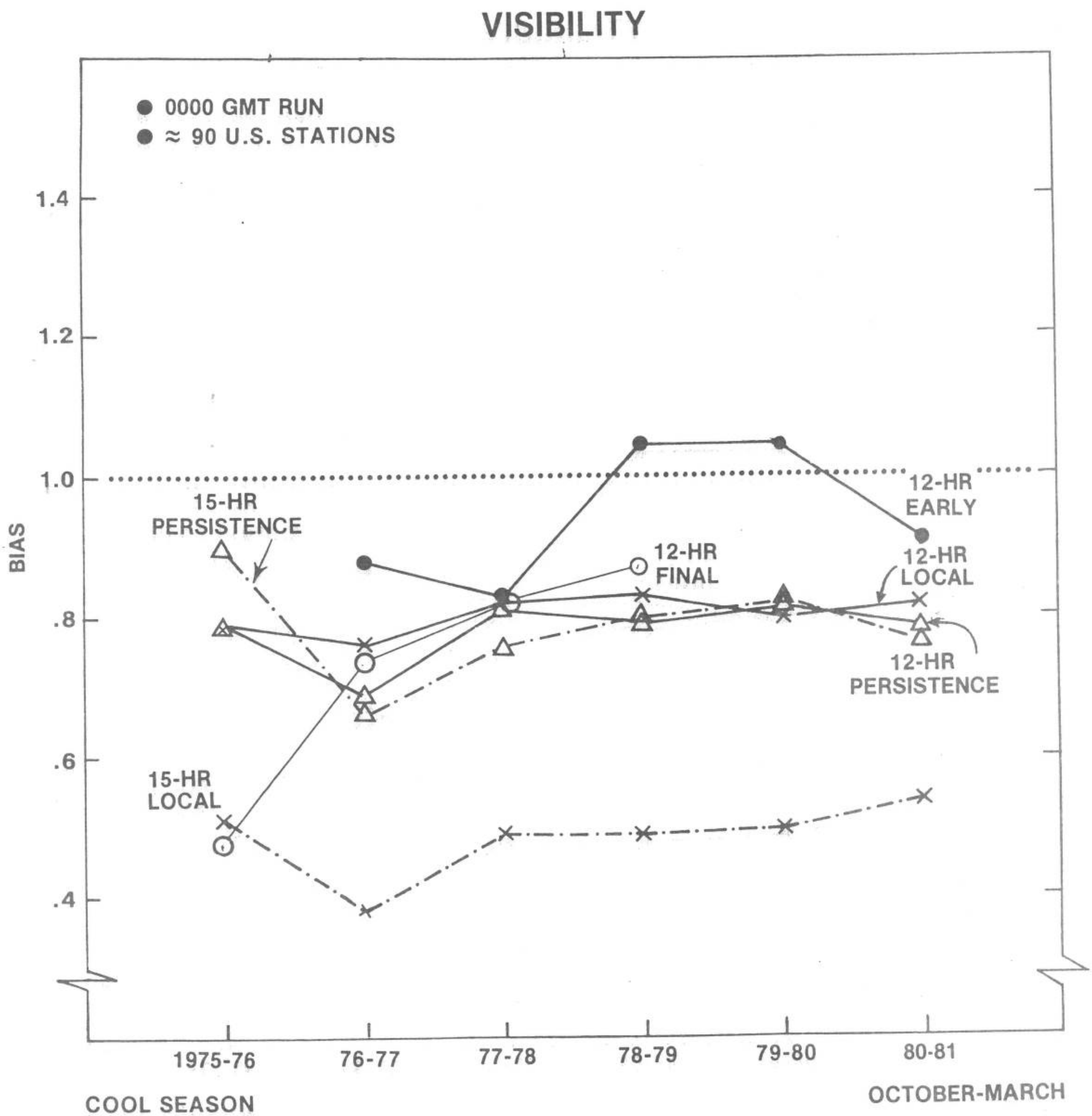

Figure 6.7. Same as Fig. 6.5 except for visibility forecasts.

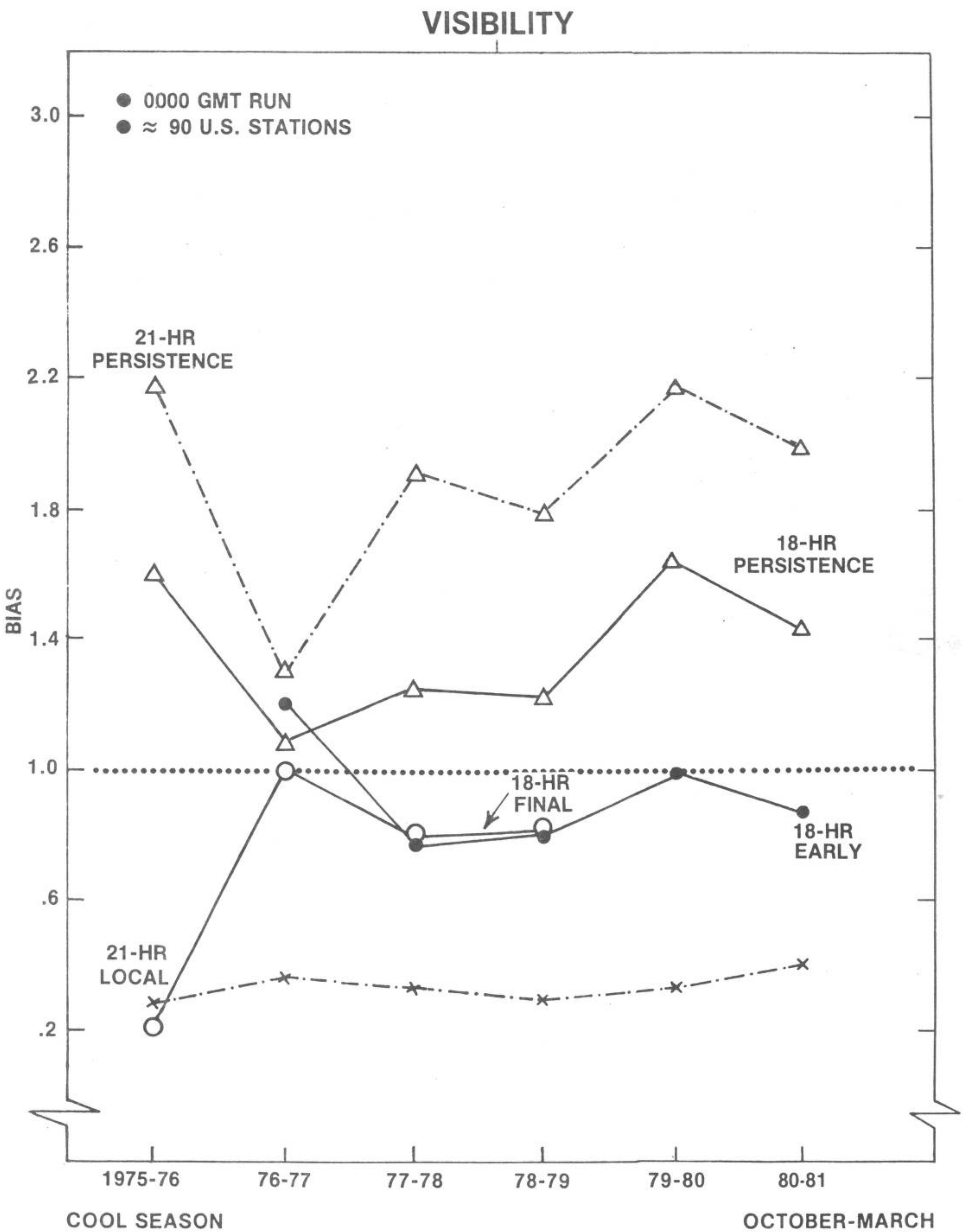

Figure 6.8. Same as Fig. 6.7 except for forecast projection.

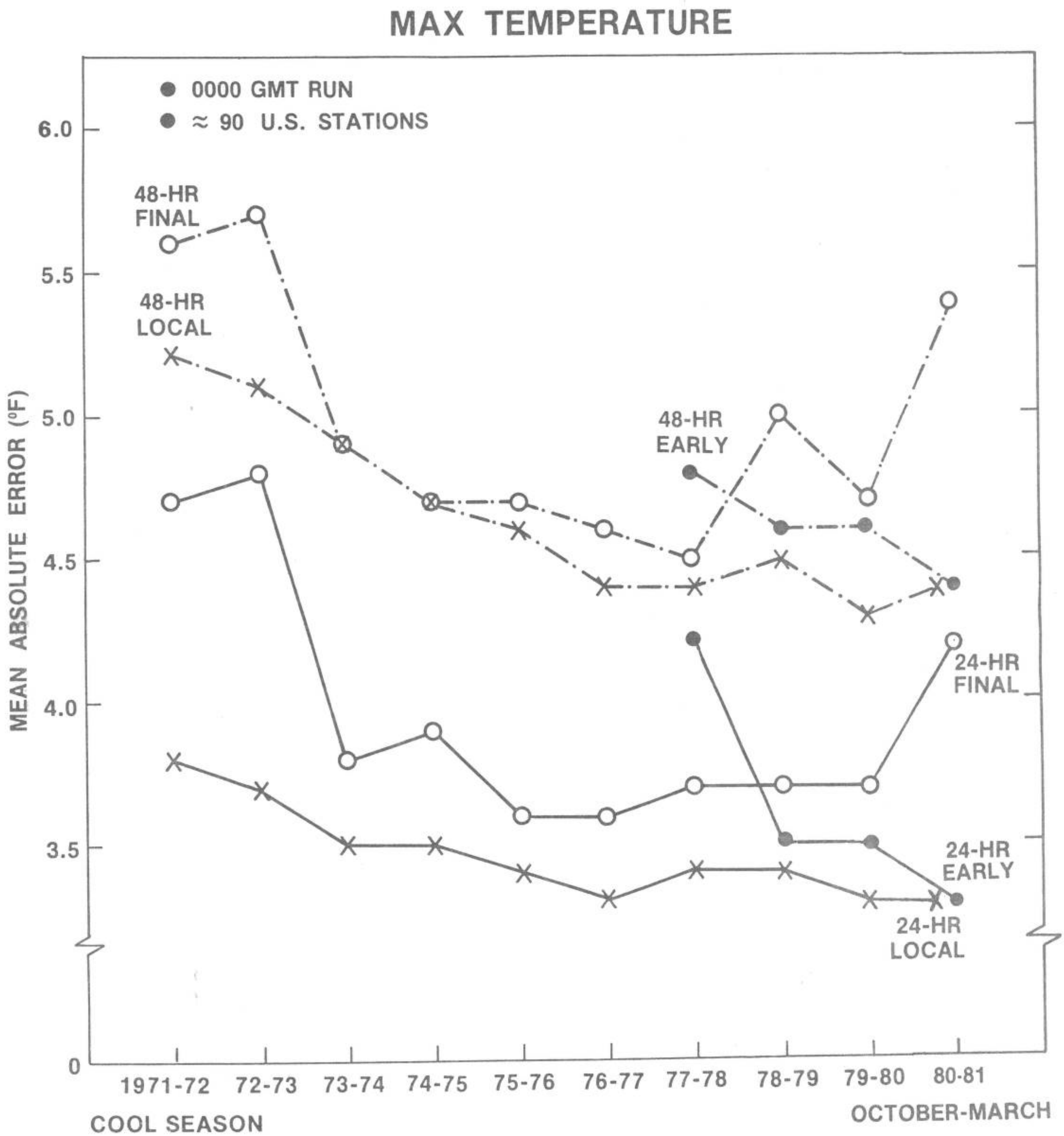

Figure 7.1. Mean absolute error for the local and the early and final guidance max temperature forecasts.

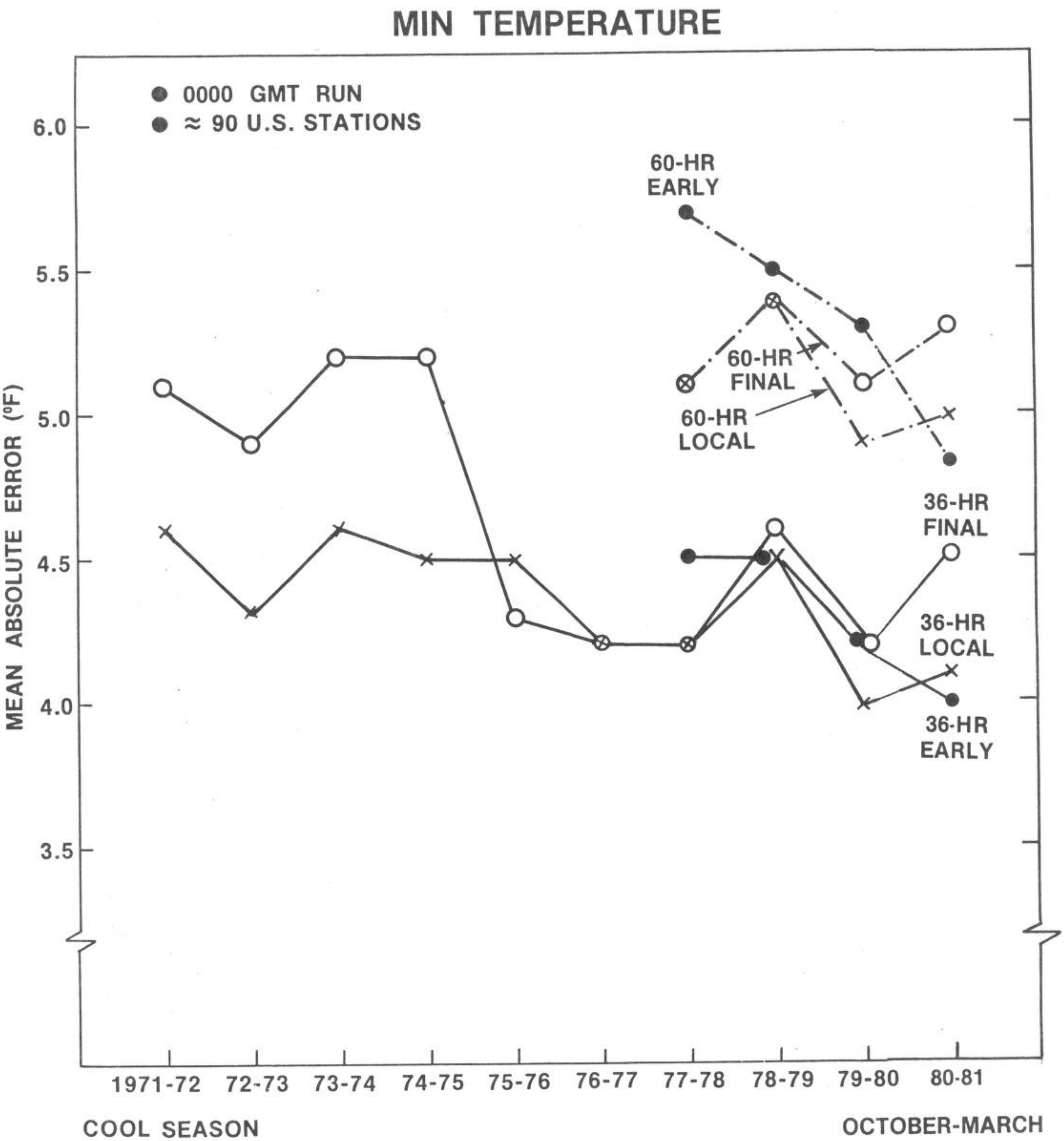

Figure 7.2. Same as Fig. 7.1 except for the min temperature forecasts.