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

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1. INTRODUCTION

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

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

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

2. PROBABILITY OF PRECIPITATION (PoP)

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

Two types of objective guidance were produced for the second and third periods: the so-called "early" and "final" guidance. The early guidance forecasts were based on forecast fields from the LFM-II model. The final guidance forecasts for the second period were based on fields from the LFM-II, 7LPE, and TJ model output. Third period final guidance equations used 7LPE predictors only.

We verified the forecasts by computing the Brier score (Brier, 1950). Please note that we use the standard NWS Brier score which is one-half the P-score defined by Brier. Brier scores will naturally vary from one section of the country to the next and from one year to the next because of changes in the relative frequency of precipitation. Therefore, we also verify in terms of percent improvement over climatology. This is the percent improvement of the Brier scores of the forecasts over the Brier scores produced by climatic forecasts. Climatic forecasts are defined as relative frequencies of precipitation by month and for each station determined from a 15-year sample (Jorgensen, 1967).

This verification differed from the one done by TPB because the source of the surface observations was different. TPB collects the verifying observations from hourly data files on a day-to-day basis. We obtained surface data from our Asheville data collection. This resulted in nearly five percent increase in data over the TPB verification. We verified PoP for the 87 stations shown in Table 2.1; these are the only stations where local PoP forecasts were available.

Table 2.2 shows the results for all 87 stations for 0000 GMT forecasts made during the period October 1977 through March 1978. Tables 2.3 through 2.6 show scores for the NWS Eastern, Central, Southern, and Western Regions, respectively. Note that both the second and third period verification is a three-way comparison between early guidance, final guidance, and subjective local forecasts. Since we did not begin transmitting early guidance forecasts for the third period until Dec. 7, 1977, our sample size for this period is somewhat reduced.

The results of this verification can be summarized in three general statements. First, NWS forecasters improve on the objective guidance by the greatest amount in the first period in most regions. The exception to this occurs in the Eastern Region where forecasters scored worse than the guidance in the first period and showed the greatest improvement in the third period. Second, the subjective improvement does not decrease uniformly for longer projections. In other words, Eastern, Central, and Southern Region forecasters were able to improve more over the third period forecasts than for second period forecasts. This result was seen in last summer's verification (Zurndorfer, et al., 1978), but was not seen in any previous verification. A possible explanation for this is that forecasters have recently started to receive more accurate LFM-II and 7LPE 36- and 48-h forecasts. Our objective forecasts did not utilize fully the benefits of the new models because the forecasts were based on PE-derived equations for this projection. It will be interesting to see if forecasters can continue to subjectively improve the third period forecasts since LFM-derived equations are now being used for early guidance. Thirdly, there is very little difference in accuracy between the early and final guidance for second period forecasts, but some differences do exist for third period forecasts. In the Western, Southern, and Central Regions, final guidance forecasts are considerably better than the early guidance forecasts. In the Eastern Region, the opposite is true. This supports the idea that LFM-II performs better over the Eastern U.S.

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

3. PRECIPITATION TYPE

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

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

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

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

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

for the 42-h projection. For the 18-h projection, the early guidance scored the same as the final guidance, except that the final guidance had a better bias.

For the regional scores, Table 3.2 shows that in the Eastern Region, the final guidance was slightly better than the local forecasts for percent correct and skill score[2] for all projections. In general, the local forecasts had a slightly better bias than the final guidance. Also, the final guidance was slightly better than the early guidance for all scores at the 18-h projection.

In the Southern Region, the final guidance scored better than the local forecasts for the percent correct and skill score for all projections. The locals had a better bias than the final guidance except for the 18-h projection for which the guidance was better. Also, the early guidance was slightly better than the final guidance for the percent correct and skill score at the 18-h projection, but the final guidance had a better bias.

In the Central Region, the local forecasts scored better than the final guidance for percent correct and skill score for the 18- and 42-h projection; the guidance was better at the 30-h projection. The guidance had a better bias than the local forecasts except that the opposite was true at the 42-h projection. At the 18-h projection, the early guidance was better than the final guidance but not as good as the local forecasts, except for the bias.

In the Western Region, the local forecasts scored about the same as the guidance for the percent correct and skill score at 18-h projection. However, the local forecasts were better at 30-h projection, and the guidance was better at the 42-h projection. The locals had a better bias than the final guidance except that the two systems were about the same for the 30-h projection. The early guidance was generally slightly better than the final at the 18-h projection.

The percent correct and skill scores were very high because the sample included many "obvious" forecasts. For instance, on some days in the southern states, precipitation, if it occurred, would obviously be rain. In order to isolate some of the more difficult forecasting situations, we looked at the cases in which the guidance and locals differed. Again we used only those cases for which local PoPs were $\geq$ 30%. Table 3.3 gives the results. The guidance and local forecasts were correct an equal number of times for the 18-h projection; however, for the 30- and 42-h projections, the guidance was correct in 60 to 62% of the cases.

The trends in the skill scores of the guidance and local forecasts for 5 seasons are shown in Fig. 3.1. Only the 18- and 42-h verification results are presented. It should be noted that some changes in the verification

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

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

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

4. SURFACE WIND

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

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

The results for all 93 stations combined are shown in Tables 4.2 and 4.3. The direction MAE scores reveal an advantage for the guidance that is approximately 4° for all three forecast projections. Overall, the MAE's, skill scores, and percent correct for speed were also better for the guidance. The speed MAE scores for the 18- and 30-h early guidance were substantially lower than the corresponding final guidance and local scores. Both the biases by category in Table 4.2 and the contingency tables in 4.3 indicate that the early guidance tended to underestimate winds stronger than 22 knots (i.e., categories 5, 6, and 7); the final guidance was better in this respect.

Tables 4.4-4.7 show scores for the NWS Eastern, Southern, Central, and Western Regions, respectively. The regional values had the same general characteristics as those overall; however, the magnitude of the advantage of the guidance over the local forecasts varied from region to region. Of particular note in Table 4.6 are the excellent comparative early guidance scores for the Central Region. In contrast, the results in Table 4.7 indicate that, for the 30-h projection, the final guidance is superior in Western Region. The bias by category values for the Eastern Region (Table 4.4) shows that winds between 18 and 32 knots (i.e., categories 4, 5, and 6) are consistently overforecast by the final guidance.

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 93 stations combined. Here we see that the early guidance had about 5% fewer errors of 40° or more than did the local forecasters for the 18-h projection. The final guidance was also superior to the locals in this respect with approximately 3% fewer errors for the same projection. The comparable improvements were 8% and 7% for the 30-h projection.

Distribution 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 that, once again, the magnitude of the advantage of the guidance over local forecasts differs from region to region. The 30-h early guidance forecasts for the Eastern and Central Regions had about 10% fewer errors of 40° or more than did the locals. In contrast, both sets of 30-h guidance forecasts for the Southern and Western Regions held only a 5% advantage over the locals.

A comparison of the overall MAE's and skill scores for the past 4 cool seasons for the 18- and 42-h guidance and local forecasts is presented in Figs. 4.1-4.4. In general, the verification data throughout this period were homogenous, with the exception that the cool season of 1973-74 did not include the month of October. The number of stations varied only slightly from season to season, and the same basic sets of verification stations were used. Early guidance scores were available for the cool seasons of 1976-77 and 1977-78 only.

The MAE's for direction are shown in Fig. 4.1. Except for a slight increase in some of the MAE's during the most recent (1977-78) cool season when new forecast models were introduced, the final guidance and local forecasts for both projections steadily improved over the span of these 5 cool seasons.

In contrast, the MAE's in Fig. 4.2 indicate a decrease in accuracy for the final guidance speed forecasts. This was caused by the intoduction of inflation in August of 1975. We realized that inflation would have this effect; however, the bias values shown in Table 4.2 are somewhat closer to 1 compared to the bias values in previous cool season surface wind verifications (Carter et al., 1976; Bocchieri et al., 1978).

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

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

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

5. OPAQUE SKY COVER

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

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. For both the early and final guidance packages, we convert the probability estimates to a single "best category" forecast in a manner which improves the bias characteristics of the product. For more details about our cloud amount forecast system, see National Weather Service (1978b).

For this verification, we compared the local forecasts at the 93 stations listed in Table 4.1 with a matched sample of early and final guidance forecasts. The comparison was conducted for 18-, 30-, and 42-h forecasts from the 0000 GMT cycle only. We converted the local forecasts and the surface observations used for verification from opaque sky cover amount to the categories in Table 5.1. Four-category, forecast-observed contingency tables were prepared from the transformed local and best-category guidance predictions. Using these tables, we computed the percent correct, Heidke skill score, and bias by category. The 18-h verifications covered the whole October-March cool season. However, the early guidance forecasts for the 30- and 42-h projections started on January 25, 1978; therefore, the matched samples used in the verification of those two projections covered only about 2 months rather than 6.

The results for all stations combined are shown in Table 5.2. For the 18-h projection, the percent correct and skill score for our final guidance were slightly better than that for our early guidance; the opposite is true at 30 hours. Comparing the guidance with the local forecasts, we find that for all projections both the early and final guidance were superior to the locals in terms of percent correct and skill score.

The fact that there is a difference between the scores for our 18-h early and final guidance is quite interesting since both sets of prediction equations were derived from LFM data. The lag in observed surface predictors is different, of course. Also, part of the explanation probably rests in the transformation of the probability forecasts to the best category. This can be deduced from the slightly different bias values of the early and final guidance. The biases for both the early and final guidance were better than the local biases for all three projections and four categories.

In Tables 5.3-5.6, we present the verification scores for stations in the NWS Eastern, Central, Southern, and Western Regions, respectively. Comparing the early and final guidance for the 18-h projection, we find that the percent correct and skill score were higher for the final guidance. For the 30-h projection, the early guidance scores were generally better than the final guidance scores, except for the Western Region, where final guidance was somewhat better. Early guidance had a slight advantage over final guidance at the 42-h projection in the Eastern and Central Regions; the reverse was true in the Southern and Western Regions. For all projections, the percent correct and skill scores for early and final guidance were superior to those of the locals except in the Western Region. In the Western Region the 18-h locals were superior to both the early and final guidance. At the 42-h projection, the locals perform as well as the early guidance. For the most part, the biases for early and final guidance are somewhat better (i.e., closer to 1) than the locals in all regions.

The percent correct and skill scores over the past 4 cool seasons are shown in Figs. 5.1 and 5.2, respectively. These figures show the 18-h early, 18-h final, 42-h final, and 18- and 42-h local forecast values. Examination of the figures shows a definite improvement for the 18-h final guidance throughout the period. However, there was a slight deterioration in percent correct and skill score for each of the other forecasts for the last season.

In Figs. 5.3 and 5.4, we show the biases, over the past 4 cool seasons, for category 1 and category 2, respectively. These figures are for the same projections as Figs. 5.1 and 5.2. During the past cool season, the category 1 bias (Fig. 5.3) deteriorated somewhat for both the guidance and the locals. For category 2 bias (Fig. 5.4), the locals improved significantly over previous years (i.e., closer to 1) while the early and final guidance deteriorated.

There are three possible reasons for the deterioration in the guidance verification scores from previous seasons. First, the equations derived from the LFM and PE model output are now being applied using LFM-II and 7LPE model output. Second, we employed the same threshold probabilities to determine the categorical forecasts that were used before the model changes. Third, the verification sample for the 30- and 42-h projections was considerably less than previous years due to the smaller matched sample of all three types of forecasts.

6. CEILING AND VISIBILITY

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

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

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

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

We constructed six-category forecast-observed contingency tables for all the forecasts involved in the comparative verification. Definitions of these categories are given in Table 6.1. These categories were then used for computing several different scores: bias-by-category, percent correct, and Heidke skill score. We then collapsed the tables to two categories (categories 1 and 2 combined versus categories 3 through 6 combined) and calculated the bias and threat score for categories 1 and 2 combined and the Heidke skill score and percent correct for the reduced tables. We have summarized the results in Tables 6.2-6.9. Trends for the last three cool seasons for Heidke skill score and bias for categories 1 and 2 combined are given in Tables 6.10-6.17.

Tables 6.2-6.5 present the results for the six-category ceiling and visibility forecasts. At the 12-h projection persistence is clearly the best performer for both ceiling and visibility. While local subjective forecasts scores were less than persistence, they did outperform the guidance. Final guidance which uses an observation 6 hours after cycle time consistently was better than the early guidance which uses an observation 3 hours after cycle time. Local subjective forecasts for ceiling outperformed persistence at both 15- and 21-h projections. Persistence forecasts of visibility were generally better than the locals at these projections. The guidance forecasts outperform persistence for projections of 24 through 48 hours. The early guidance is slightly better on the average than the final for the longer projections. The bias-by-category characteristics for the guidance forecasts are generally better than for persistence or the locals. The biases of 36-h persistence forecasts (actually a 26-h projection) should be as good as those of 12-h persistence forecasts (actually a 2-h projection). Tables 6.2 - 6.5 show this to be true.

Tables 6.6 through 6.9 present performance scores for categories 1 and 2 combined. While these tables lead to many of the same conclusions as do Tables 6.2 through 6.5, some differences can be noted. For 15-h ceiling, persistence beat the locals; for 21-h visibility, the locals were better than persistence. Also, there is no clear cut difference in accuracy between the early and final guidance for the longer projections.

Tables 6.10 through 6.13 present the trend for the Heidke skill scores computed from two-category contingency tables and Tables 6.14 through 6.17, the trend for the bias of categories 1 and 2 combined. We note that the change during the 1976-77 cool season to the threshold technique of choosing the best category greatly improved the bias scores for the 18- and 24-h projections and at the same time increased the skill. This satisfied one of our product improvement goals since the older technique of choosing the best category by maximizing the matrix score produced few, if any, forecasts in the lower two categories.

7. MAX/MIN TEMPERATURE

The objective forecasts during the October 1977 through March 1978 period were based on fall (September-November), winter (December-February), and spring (March-May) max/min temperature prediction equations used operationally during the appropriate months. These equations had been developed by stratifying numerical model output from the PE and TJ models, station observations, and the first two harmonics of the day of the year into seasons of 3-month duration (Hammons et al., 1976). Two basic types of objective forecasts were issued: the so-called early and final guidance. In operations, the early guidance max/min consisted of forecasts made from equations that did not use station observations as predictors. Additionally, model output from the LFM-II and from a TJ model that was dependent on the LFM-II was used in the PE-derived equations. In contrast, station observations available either 5 or 6 hours after the initial model time were used in the final guidance equations for the first two projections (approximately 24 and 36 hours). During the first part of the verification period, PE and TJ model data were input to the final guidance forecast equations for all projections. However, after the 1200 GMT cycle on January 19, the equations employed output from the 7LPE and a TJ model based on the 7LPE model as predictors.

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

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

Verification results are shown in Table 7.1 for all 87 stations combined. The mean algebraic errors were approximately the same for the locals and guidance except for the 36- and 60-h min. For these two projections the local forecasts had large positive errors, that is, the tendency to forecast too warm a min. This, perhaps, was due to the abnormally cold winter or to the fact that we did use calendar day observations in the verifications. In terms of mean absolute errors, the final guidance was better than the early guidance at all four projections by 0.3°F to 0.6°F. This is not surprising since, for the early guidance, LFM-II data were used as input to the PE-derived equations. From earlier work (Dallavalle and Hammons, 1976), we had some indication that this would be the case. In fact, we noticed several cases during the winter when very poor early guidance forecasts were issued because of spurious noise in the LFM-II 1000 mb forecast output. For the first projection, the locals improved on the final guidance by 0.3°F in mean absolute error. Part of this difference may be because the local forecaster used the latest station observations when he/she made the forecast. Also, during October through December a programming error allowed the final guidance to occasionally use synoptic reports of the maximum or minimum that were a day old. This likely contributed to some deterioration in the final guidance. For the last three projections, the final guidance and local forecasts were comparable in skill, although the local mean absolute errors were 0.1°F better in forecasting the 48-h max.

We also examined the verification scores for four NWS regions. For the Eastern and Southern Regions (Tables 7.2 and 7.4), the results were similar to those for the entire 87 station set. Generally, the early guidance was much less accurate in regard to mean absolute error than either the final guidance or local forecasts. In contrast, after the first period, the accuracy of the final and local guidance was comparable. In both regions, there was a definite tendency to forecast too warm a min for 36 and 60 hours. On the other hand, the local forecasts in the Central and Western Regions (Tables 7.3 and 7.5) had smaller absolute errors at all projections compared to the early and final objective guidance. The early guidance was quite poor, particularly in the Western Region. Again, we have previously seen this tendency for the early guidance to deteriorate in the western part of the United States (Dallavalle and Hammons, 1976). The local forecasts in the Central and Western Regions were usually better than the final guidance with mean absolute errors ranging from 0.1°F to 0.4°F lower. Note that in the Central Region, the mean algebraic errors in the local forecasts were generally greater than those for the final guidance. However, in the Western Region, where nearly all the mean algebraic errors were negative, the local forecasts usually had smaller errors than did the final objective forecasts.

7. CONCLUSIONS

This verification shows that TDL's aviation/public weather guidance forecasts continue to compare favorably with the local forecasts produced at WSFOs. Recent changes in the numerical models upon which MOS is based have not had a significantly harmful effect on the forecasts. In fact, both the guidance and local PoP forecasts were more skillful during the 1977-78 cool season than in previous winter seasons. Forecasters in general still improved upon the PoP forecasts for all projections with the largest difference for the 12-24 h forecasts. However, the forecaster's margin of improvement is shrinking for the 12-24 h period while growing for the 36-48 h period.

For forecasts of precipitation type, there was a slight decrease in accuracy from the previous season for both guidance and local forecasts. Forecasters performed about the same as the objective guidance for 18-h forecasts, but the objective guidance was still better for longer projections. The early and final guidance performed equally well.

For surface wind and opaque sky cover, the guidance forecasts were better than the local forecasts for all projections. The wind forecasts showed some deterioration in scores from the previous season while the cloud forecasts performed about the same.

Direct comparison between local, guidance, and persistence forecasts of ceiling and visibility was possible for only the 12-h projection; for that projection, local forecasts were superior to the guidance for both elements, while persistence was superior to both the locals and guidance. However, the bias of the guidance forecasts improved considerably as compared to previous verifications.

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

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

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

Table 2.2 Comparative verification of early and final guidance and local PoP forecasts for 87 stations, 0000 GMT cycle.

Projection	Type of Forecast	Brier Score	Improvement Over Guidance (%)	Improvement Over Climatology (%)	Number of Cases
12-24 h (1st period)	Early/Final	.1005		39.9	10461
	Local	.0967	3.8	43.4	
24-36 h (2nd period)	Early	.1286		30.0	10375
	Final	.1271		30.7	
	Local	.1236	3.9[1] (2.8)	32.7	
36-48 h (3rd period)	Early	.1304		26.8	6592
	Final	.1324		26.4	
	Local	.1244	4.6 (6.0)	29.2	

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

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

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

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

Table 2.4 Same as Table 2.2 except for 22 stations in the Central Region.

Projection	Type of Forecast	Brier Score	Improvement Over Guidance (%)	Improvement Over Climatology (%)	Number of Cases
12-24 h (1st period)	Early/Final	.0961		36.7	2659
	Local	.0899	6.4	42.0	
24-36 h (2nd period)	Early	.1324		24.9	2661
	Final	.1315		25.4	
	Local	.1273	3.9[1] (3.2)	27.8	
36-48 h (3rd period)	Early	.1312		18.7	1684
	Final	.1303		19.2	
	Local	.1253	4.5 (3.8)	22.3	

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

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

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

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

Table 2.6 Same as Table 2.2 except for 16 stations in the Western Region.

Projection	Type of Forecast	Brier Score	Improvement Over Guidance (%)	Improvement Over Climatology (%)	Number of Cases
12-24 h (1st period)	Early/Final	.1163		31.5	1949
	Local	.1048	9.9	38.2	
24-36 h (2nd period)	Early	.1221		29.5	1951
	Final	.1226		29.2	
	Local	.1149	5.9[1] (6.3)	33.6	
36-48 h (3rd period)	Early	.1651		26.2	1215
	Final	.1565		24.4	
	Local	.1565	5.2[1] (0.0)	24.4	

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

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

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

Table 3.2 Comparative verification of early and final PoF guidance and local forecasts by NWS Region, 0000 GMT cycle. Only cases when local PoP was ≥ 30% were included. Early PoF guidance was verified only for the 18-h projection.

Projection (h)	Region	Type of Fcst.	Bias Snow	Bias Rain	Percent Correct	Skill Score	Number of Cases
18	Eastern	Early	.95	1.04	94	.88	
		Final	.98	1.02	95	.90	434
		Local	.98	1.02	93	.87	
	Southern	Early	.74	1.05	95	.77	
		Final	.78	1.04	94	.75	149
		Local	.70	1.06	93	.68	
	Central	Early	.99	1.01	91	.78	
		Final	1.01	.99	90	.76	258
		Local	.98	1.05	93	.83	
	Western	Early	1.08	.97	92	.80	
		Final	1.17	.93	91	.80	205
		Local	.90	1.04	92	.80	
	All Stations	Early	.97	1.02	93	.86	
		Final	1.00	1.00	93	.86	1046
		Local	.95	1.04	93	.86	
30	Eastern	Final	.95	1.04	93	.86	445
		Local	1.00	1.00	92	.84	
	Southern	Final	.72	1.05	94	.74	128
		Local	1.06	.99	90	.59	
	Central	Final	1.04	.91	90	.75	288
		Local	1.07	.85	87	.69	
	Western	Final	1.10	.95	88	.74	208
		Local	1.11	.94	89	.77	
	All Stations	Final	1.00	1.00	91	.83	1069
		Local	1.04	.96	90	.80	
42	Eastern	Final	1.03	.97	93	.86	415
		Local	.98	1.01	91	.82	
	Southern	Final	.76	1.04	96	.85	108
		Local	1.06	.99	90	.62	
	Central	Final	1.03	.92	88	.71	255
		Local	1.01	.97	89	.74	
	Western	Final	1.17	.94	90	.75	175
		Local	.91	1.03	87	.67	
	All Stations	Final	1.04	.97	92	.83	953
		Local	.99	1.01	90	.79	

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

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

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

PWM	Portland, Maine	TCC	Tucumcari, New Mexico
BTV	Burlington, Vermont	SSM	Sault Ste Marie, Michigan
CON	Concord, New Hampshire	DTW	Detroit, Michigan
BOS	Boston, Massachusetts	SBN	South Bend, Indiana
PVD	Providence, Rhode Island	IND	Indianapolis, Indiana
BUF	Buffalo, New York	LEX	Lexington, Kentucky
SYR	Syracuse, New York	SDF	Louisville, Kentucky
ALB	Albany, New York	MSN	Madison, Wisconsin
JFK	New York (Kennedy), New York	MKE	Milwaukee, Wisconsin
EWR	Newark, New Jersey	ORD	Chicago (O'Hare), Illinois
ERI	Erie, Pennsylvania	SPI	Springfield, Illinois
AVP	Scranton, Pennsylvania	STL	St. Louis, Missouri
PIT	Pittsburgh, Pennsylvania	MCI	Kansas City, Missouri
PHL	Philadelphia, Pennsylvania	TOP	Topeka, Kansas
CLE	Cleveland, Ohio	DDC	Dodge City, Kansas
CMH	Columbus, Ohio	DEN	Denver, Colorado
HTS	Huntington, West Virginia	GJT	Grand Junction, Colorado
CRW	Charleston, West Virginia	SHR	Sheridan, Wyoming
DCA	Washington, D.C.	CYS	Cheyenne, Wyoming
ORF	Norfolk, Virginia	BIS	Bismarck, North Dakota
RDU	Raleigh-Durham, North Carolina	FAR	Fargo, North Dakota
CLT	Charlotte, North 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	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 (Tacoma), 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
GTF	Great Falls, Montana		

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

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

Tabl .3. Contingency bles for early and final gu ce and local surface wind eed forecasts for 93 stations, 0000 GMT cycle.

18-h Forecasts

EARLY

OBS	1	2	3	4	5	6	7	T
1	4251	1193	131	12	1	0	0	5588
2	1991	2414	561	71	6	1	0	5044
3	279	1038	890	216	26	3	1	2453
4	30	160	329	193	51	9	1	773
5	8	15	46	78	32	6	2	187
6	0	2	10	10	11	6	3	42
7	0	0	1	0	2	4	2	9
T	6559	4822	1968	580	129	29	9	14096

FINAL

OBS	1	2	3	4	5	6	7	T
1	3899	1446	205	33	3	2	0	5588
2	1791	2340	765	131	16	1	0	5044
3	256	922	939	283	48	5	0	2453
4	37	135	307	209	67	16	2	773
5	5	13	51	58	45	10	5	187
6	0	3	8	14	9	3	5	42
7	0	0	0	1	5	1	2	9
T	5988	4859	2275	729	193	38	14	14096

LOCAL

OBS	1	2	3	4	5	6	7	T
1	3052	2146	330	54	5	0	1	5588
2	1125	2774	967	160	14	0	4	5044
3	195	916	1001	290	44	4	3	2453
4	16	138	318	239	53	6	3	773
5	3	13	46	76	31	17	1	187
6	0	3	12	12	4	9	2	42
7	0	0	0	1	3	2	3	9
T	4391	5990	2674	832	154	38	17	14096

30-h Forecasts

EARLY

OBS	1	2	3	4	5	6	7	T
1	6564	1494	167	9	2	0	0	8236
2	1902	1706	423	54	9	0	0	4094
3	225	565	368	87	14	4	1	1264
4	17	122	144	62	15	1	0	361
5	6	12	23	31	7	1	0	80
6	0	2	4	3	5	2	1	17
7	0	1	0	0	3	1	0	5
T	8714	3902	1129	246	55	9	2	14057

FINAL

OBS	1	2	3	4	5	6	7	T
1	6375	1590	244	24	3	0	0	8236
2	1830	1663	517	68	12	4	0	4094
3	223	485	393	136	22	4	1	1264
4	29	111	138	58	18	7	0	361
5	2	21	20	26	9	1	1	80
6	0	0	5	6	4	1	1	17
7	0	0	0	4	0	1	0	5
T	8459	3870	1317	322	68	18	3	14057

LOCAL

OBS	1	2	3	4	5	6	7	T
1	5519	2361	289	61	2	0	4	8236
2	1533	1976	471	99	12	3	0	4094
3	190	565	393	97	14	4	1	1264
4	23	134	129	55	13	5	2	361
5	1	27	27	21	2	2	0	80
6	0	1	6	7	1	1	1	17
7	0	1	0	3	0	0	1	5
T	7266	5065	1315	343	44	15	9	14057

42-h Forecasts

FINAL

OBS	1	2	3	4	5	6	7	T
1	3447	1629	356	58	7	1	0	5498
2	1746	2276	813	160	23	2	0	5020
3	385	955	785	238	69	15	8	2455
4	58	222	281	148	48	19	2	778
5	12	35	56	55	28	4	2	192
6	1	6	12	6	14	3	1	43
7	0	0	1	5	5	0	1	12
T	5649	5123	2304	670	194	44	14	13998

LOCAL

OBS	1	2	3	4	5	6	7	T
1	2626	2346	455	60	7	0	4	5498
2	1302	2772	792	136	15	2	1	5020
3	333	1192	702	185	33	9	1	2455
4	51	303	301	98	21	3	1	778
5	9	57	70	42	12	1	1	192
6	3	13	10	12	3	2	0	43
7	0	0	1	6	4	0	1	12
T	4324	6683	2331	539	95	17	9	13998

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

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

Note: CAT1–CAT7 columns are under CONTINGENCY TABLE — BIAS-NO. FCST/NO. OBS; SKILL SCORE and PERCENT FCST CORRECT are under CONTINGENCY TABLE.

Table 4.5. Same as Table 4.2 except for 28 stations in the Central Region.

FCST PROJ (HOURS)	TYPE OF FCST	DIRECTION: MEAN ABS ERROR (DEG)	DIRECTION: NO. OF CASES	SPEED: MEAN ABS ERROR (KTS)	SPEED: MEAN FCST (KTS)	SPEED: MEAN OBS (KTS)	SPEED: NO. OF CASES	CONTINGENCY TABLE: SKILL SCORE	CONTINGENCY TABLE: PERCENT FCST CORRECT	BIAS-NO. FCST/NO. OBS: CAT1 (NO. OBS)	CAT2 (NO. OBS)	CAT3 (NO. OBS)	CAT4 (NO. OBS)	CAT5 (NO. OBS)	CAT6 (NO. OBS)	CAT7 (NO. OBS)	NO. OF CASES
18	EARLY	21		3.2	13.3			0.33	54	1.19	0.95	0.84	0.94	0.61	0.71	1.60	
	FINAL	24	2054	3.6	13.8	13.2	2065	0.29	50	1.06	0.97	0.93	1.07	1.03	0.81	2.00	4119
	LOCAL	27		3.5	14.2			0.27	48	0.64 (1409)	1.22 (1524)	1.14 (808)	1.27 (258)	0.81 (94)	0.71 (21)	1.60 (5)	
30	EARLY	25		3.8	12.8			0.29	58	1.08	0.91	0.97	0.73	0.72	1.00	0.50	
	FINAL	28	1179	4.1	13.2	12.0	1197	0.26	55	1.02	0.95	1.00	1.04	1.00	1.00	0.50	4118
	LOCAL	33		4.1	12.9			0.22	51	0.81 (2189)	1.33 (1285)	1.07 (459)	0.83 (135)	0.42 (40)	1.00 (6)	0.25 (4)	
42	FINAL	38	2348	4.3	13.0	11.9	2392	0.18	43	1.03	1.01	0.96	0.97	0.87	0.57	0.57	4110
	LOCAL	43		4.2	12.6			0.16	42	0.66 (1383)	1.43 (1517)	0.99 (819)	0.63 (270)	0.44 (93)	0.10 (21)	0.14 (7)	

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

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

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

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

FCST PROJ (HOURS)	TYPE OF FCST	DIRECTION MEAN ABS ERROR (DEG)	DIRECTION NO. OF CASES	SPEED MEAN ABS ERROR (KTS)	SPEED MEAN FCST (KTS)	SPEED MEAN OBS (KTS)	SPEED NO. OF CASES	CONTINGENCY TABLE SKILL SCORE	PERCENT FCST CORRECT	BIAS-NO. FCST/NO. OBS CAT1 (NO. OBS)	CAT2 (NO. OBS)	CAT3 (NO. OBS)	CAT4 (NO. OBS)	CAT5 (NO. OBS)	CAT6 (NO. OBS)	CAT7 (NO. OBS)	NO. OF CASES
	EARLY	32		4.1	12.9			0.28	63	1.15	0.83	0.67	0.58	0.75	0.57	**	
18	FINAL	32	534	4.5	13.4	12.9	541	0.27	61	1.08	0.97	0.73	0.72	0.75	0.57	***	2833
	LOCAL	33		4.3	14.0			0.28	60	1.00	1.06	0.95	0.92	0.58	0.43	***	
										(1732)	(691)	(270)	(109)	(24)	(7)	(0)	
	EARLY	36		4.5	12.1			0.25	64	1.01	1.01	1.05	0.53	0.50	0.0	*	
30	FINAL	35	413	4.4	12.1	11.2	426	0.28	67	1.06	0.88	1.10	0.51	0.25	0.0	*	2819
	LOCAL	39		4.4	12.0			0.22	63	1.02	1.02	1.04	0.36	0.08	0.0	*	
										(1898)	(664)	(169)	(72)	(12)	(4)	(0)	
42	FINAL	50	725	4.9	12.3	10.5	755	0.23	58	1.02	1.08	0.84	0.69	0.80	0.43	*	2817
	LOCAL	54		4.9	12.2			0.16	53	0.96	1.26	0.85	0.54	0.52	0.14	*	
										(1720)	(693)	(267)	(105)	(25)	(7)	(0)	

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

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

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

Table 4.9. Same as Table 4.8 except for 23 stations in the Eastern Region.

FORECAST PROJECTION (HOURS)	TYPE OF FORECAST	PERCENTAGE FREQUENCY OF ABSOLUTE ERRORS BY CATEGORY					
		0-30°	40-60°	70-90°	100-120°	130-150°	160-180°
18	EARLY	76.9	16.1	4.1	1.6	0.7	0.7
	FINAL	74.4	17.7	4.9	1.7	0.8	0.4
	LOCAL	72.3	17.1	6.5	2.7	1.1	0.4
30	EARLY	71.2	19.6	4.6	2.3	1.5	0.9
	FINAL	67.6	22.1	5.6	2.9	1.4	0.5
	LOCAL	63.2	22.4	7.5	3.3	2.4	1.3
42	FINAL	62.5	20.9	8.9	3.4	2.6	1.7
	LOCAL	57.1	21.9	9.5	5.9	3.1	2.5

Table 4.10. Same as Table 4.8 except for 28 stations in the Central Region.

FORECAST PROJECTION (HOURS)	TYPE OF FORECAST	PERCENTAGE FREQUENCY OF ABSOLUTE ERRORS BY CATEGORY					
		$0-30^{o}$	$40-60^{o}$	$70-90^{o}$	$100-120^{o}$	$130-150^{o}$	$160-180^{o}$
18	EARLY	82.4	12.8	2.4	1.2	0.6	0.6
	FINAL	80.6	13.4	2.7	1.7	0.6	1.0
	LOCAL	75.3	16.3	4.7	1.9	0.8	1.1
30	EARLY	78.2	14.2	3.4	1.7	1.3	1.3
	FINAL	75.2	14.8	5.5	2.0	1.5	1.0
	LOCAL	66.9	21.0	5.9	2.5	2.6	1.2
42	FINAL	62.6	19.8	6.9	4.9	3.3	2.5
	LOCAL	56.9	21.1	10.2	5.3	4.0	2.5

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

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

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

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

Table 5.1 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 5.2. Comparative verification of early and final guidance and local forecasts of four categories of cloud amount (clear, scattered, broken, and overcast) for 93 stations, 0000 GMT cycle.

PROJECTION (HRS)	TYPE OF FORECAST	BIAS - NO. FCST/NO. OBS				PERCENT CORRECT	SKILL SCORE	NO. OF CASES
		CAT 1 (No. Obs.)	CAT 2 (No. Obs.)	CAT3 (No. Obs)	CAT4 (No. Obs.)			
18	EARLY	1.17	0.73	0.98	1.05	53.0	.354	
	FINAL	1.17	0.72	0.99	1.04	53.8	.365	14024
	LOCAL	0.70 (3671)	1.37 (2835)	1.33 (2568)	0.84 (4950)	51.6	.352	
30	EARLY	1.09	0.80	0.82	1.04	56.7	.359	
	FINAL	0.89	0.79	0.97	1.20	55.3	.343	4808
	LOCAL	0.60 (1824)	1.95 (693)	2.07 (516)	0.73 (1775)	45.5	.274	
42	EARLY	1.08	0.72	1.32	0.94	45.4	.262	
	FINAL	0.87	0.69	1.46	1.07	45.4	.263	4833
	LOCAL	0.49 (1348)	1.58 (1058)	1.48 (859)	0.78 (1568)	39.5	.201	

Table 5.3. Same as Table 5.2 except for 23 stations in the Eastern Region.

PROJECTION (HRS)	TYPE OF FORECAST	BIAS - NO. FCST/NO. OBS				PERCENT CORRECT	SKILL SCORE	NO. OF CASES
		CAT 1 (No. Obs.)	CAT 2 (No. Obs.)	CAT3 (No. Obs)	CAT4 (No. Obs.)			
18	EARLY	1.07	0.66	1.04	1.11	53.7	.344	3486
	FINAL	1.08	0.67	0.99	1.13	54.6	.355	
	LOCAL	0.61 (694)	1.30 (688)	1.43 (670)	0.84 (1434)	52.0	.341	
30	EARLY	1.05	0.61	1.44	0.99	56.8	.354	1225
	FINAL	0.81	0.72	1.64	1.12	56.6	.356	
	LOCAL	0.59 (450)	1.91 (164)	2.61 (106)	0.73 (505)	46.8	.283	
42	EARLY	0.81	0.74	1.71	0.92	44.9	.267	1212
	FINAL	0.53	0.76	1.90	1.03	43.0	.244	
	LOCAL	0.37 (321)	1.46 (287)	1.48 (234)	0.89 (370)	41.7	.228	

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

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

Table 5. 5. Same as Table 5.2 except for.24 stations in the Southern Region.

PROJECTION (HRS)	TYPE OF FORECAST	BIAS - NO. FCST/NO. OBS				PERCENT CORRECT	SKILL SCORE	NO. OF CASES
		CAT 1 (No. Obs.)	CAT 2 (No. Obs.)	CAT3 (No. Obs)	CAT4 (No. Obs.)			
18	EARLY	1.23	0.79	0.87	0.96	55.6	.385	3623
	FINAL	1.21	0.84	0.91	0.92	56.9	.405	
	LOCAL	0.79 (1174)	1.65 (687)	1.23 (625)	0.70 (1137)	52.2	.365	
30	EARLY	1.08	1.10	0.36	1.02	63.5	.430	1267
	FINAL	1.00	1.03	0.44	1.13	60.5	.387	
	LOCAL	0.69 (587)	2.15 (156)	2.13 (107)	0.72 (417)	49.6	.307	
42	EARLY	1.27	0.85	0.83	0.89	50.2	.300	1258
	FINAL	1.17	0.71	1.00	0.57	51.0	.312	
	LOCAL	0.64 (422)	1.95 (238)	1.60 (179)	0.57 (419)	40.6	.221	

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

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

Table 6.1. 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 and final guidance, persistence, and local ceiling forecasts for 93 stations, 0000 GMT cycle.

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

Table 6.3. Same as 6.2 except for visibility.

Projection (h)	Type of Forecast	Bias by Category						Percent Correct	Heidke Skill Score
		1	2	3	4	5	6		
12	Early	.83	.83	.87	1.28	.83	1.02	71.6	.298
	Final	.79	.84	.89	1.32	.80	1.01	73.2	.339
	Local	.63	1.03	.75	1.65	1.24	.96	75.4	.433
	Persistence	.74	.91	.81	.99	1.00	1.03	80.5	.508
	No. Obs.	315	243	770	707	833	8942		
15	Local	.40	.56	.46	1.39	1.12	1.05	70.1	.312
	Persistence	.88	.65	.60	.92	.93	1.08	71.6	.326
	No. Obs.	278	356	1123	822	936	9118		
18	Early	.80	.76	.76	1.29	.91	1.02	72.2	.273
	Final	.58	.72	.78	1.22	.84	1.03	73.0	.279
	Persistence	2.02	.88	.74	1.07	.97	1.01	71.8	.271
	No. Obs.	118	255	846	668	859	9213		
21	Local	3.09	1.12	.86	1.29	1.19	.96	72.5	.226
	Persistence	.19	.37	.42	1.28	1.21	1.03	77.3	.273
	No. Obs.	79	209	776	583	733	10229		
24	Early	.53	.99	.77	1.02	.88	1.03	77.2	.272
	Final	.45	.82	.84	1.01	.89	1.03	77.9	.281
	Persistence	2.77	1.44	.99	1.16	1.21	.95	72.3	.214
	No. Obs.	86	156	633	618	692	9774		
36	Early	.34	.65	.62	.80	.58	1.12	70.2	.165
	Final	.60	.89	.59	.97	.72	1.08	68.8	.174
	Persistence	.80	1.01	.85	.98	.89	1.03	65.7	.151
	No. Obs.	89	83	285	260	324	3141		
48	Early	.56	.95	.76	.76	.57	1.07	76.1	.179
	Final	.68	.53	.64	.73	.59	1.09	77.2	.196
	Persistence	2.84	1.45	1.05	1.33	.99	.96	67.7	.106
	No. Obs.	25	58	232	192	291	3384		

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

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

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

Projection (h)	Type of Forecast	Bias by Category 1	2	3	4	5	6	Percent Correct	Heidke Skill Score
12	Early	.50	.81	.83	.97	.85	1.03	79.7	.320
	Final	.35	.80	.94	.90	1.00	1.02	80.8	.375
	Local	.64	.95	.81	1.39	1.30	.97	82.6	.484
	Persistence	.75	1.38	1.16	.89	1.11	.99	84.2	.518
	No. Obs.	84	153	630	603	692	9864		
15	Local	.45	1.05	1.07	1.69	1.24	.94	78.9	.374
	Persistence	.59	1.39	1.43	.93	1.11	.97	80.4	.383
	No. Obs.	108	150	515	594	719	10307		
18	Early	.58	.72	.90	.97	.85	1.03	77.3	.266
	Final	.72	.72	.95	.99	1.01	1.01	77.1	.287
	Persistence	.42	1.17	1.24	.87	[illegible]	.99	76.7	.302
	No. Obs.	158	183	592	628	713	9983		
21	Local	.28	1.21	1.09	1.68	1.18	.95	71.9	.288
	Persistence	.25	1.11	1.09	1.68	1.18	.95	73.9	.254
	No. Obs.	259	190	693	719	726	9806		
24	Early	.70	.99	1.13	.89	.88	1.02	70.4	.258
	Final	.86	.85	1.12	.95	1.00	1.00	70.2	.269
	Persistence	.21	.85	.94	.75	.93	1.06	70.3	.208
	No. Obs.	321	253	783	732	848	9275		
36	Early	.47	.75	1.02	.79	.55	1.06	75.3	.197
	Final	.28	.58	.99	.85	.71	1.05	74.7	.192
	Persistence	.75	1.22	1.09	1.04	1.03	.99	70.8	.167
	No. Obs.	32	69	244	208	298	3494		
48	Early	.62	.68	.65	.73	.56	1.12	68.6	.123
	Final	.45	.66	.62	.66	.64	1.12	68.9	.124
	Persistence	.26	.92	.90	.82	.92	1.05	65.5	.115
	No. Obs.	91	91	297	264	333	3269		

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

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

Table 6.7. Same as 6.6 except for visibility.

Projection (h)	Type of Forecast	Rel Freq Cats. 1&2 combined	Bias Cats. 1&2 combined	Percent correct	Heidke Skill Score	Threat Score
12	Early	.047	.826	93.8	.255	.167
	Final		.810	94.6	.345	.229
	Local		.806	96.1	.524	.373
	Persistence		.815	96.5	.570	.417
15	Local	.050	.487	95.0	.302	.194
	Persistence		.756	94.4	.334	.222
18	Early	.031	.769	95.8	.218	.136
	Final		.676	96.0	.207	.128
	Persistence		1.239	94.7	.215	.138
21	Local	.023	.318	97.5	.166	.096
	Persistence		1.664	94.8	.114	.075
24	Early	.020	.831	96.9	.147	.088
	Final		.690	97.2	.157	.094
	Persistence		1.909	95.0	.130	.083
36	Early	.041	.488	94.7	.109	.071
	Final		.738	94.2	.158	.103
	Persistence		.901	93.2	.099	.072
48	Early	.020	.831	96.9	.142	.086
	Final		.578	97.2	.094	.056
	Persistence		1.867	94.7	.051	.039

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

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

Table 6.9. 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	Heidke Skill Score	Threat Score
12	Early Final Local Persistence	.020	.700 .641 .844 1.156	97.4 97.7 98.1 97.7	.205 .266 .457 .442	.123 .161 .304 .294
15	Local Persistence	.021	.802 1.058	97.5 97.1	.323 .309	.202 .193
18	Early Final Persistence	.028	.654 .716 .821	96.1 96.0 96.1	.137 .148 .221	.085 .091 .137
21	Local Persistence	.036	.672 .617	95.4 95.1	.220 .133	.138 .085
24	Early Final Persistence	.047	.828 .855 .488	93.4 93.3 93.8	.193 .200 .087	.128 .133 .061
36	Early Final Persistence	.023	.663 .485 1.069	96.7 96.9 95.6	.139 .093 .054	.084 .056 .040
48	Early Final Persistence	.042	.648 .555 .593	94.3 94.5 93.7	.152 .129 .032	.099 .084 .032

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

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

Table 6.11. Same as 6.10 except visibility.

Projection (h)	Type of Forecast	Year 1975/76	Year 1976/77	Year 1977/78
12	Early		.221	.255
	Final	.260	.217	.345
	Local	.493	.462	.524
	Persistence	.541	.494	.570
	No. Cases	14142	4200	11810
15	Local	.295	.194	.302
	Persistence	.331	.193	.334
	No. Cases	15322	4282	12633
18	Early		.136	.218
	Final	.120	.148	.207
	Persistence	.194	.113	.215
	No. Cases	14217	4226	11959
21	Local	.117	.051	.166
	Persistence	.107	.090	.114
	No. Cases	15312	4274	12607
24	Early		.138	.147
	Final	.000	.127	.157
	Persistence	.108	.056	.130
	No. Cases	14230	4225	11959
36	Early			.109
	Final		.074	.158
	Persistence		.045	.099
	No. Cases		4226	4182
48	Early			.142
	Final		.048	.094
	Persistence		.018	.051
	No. Cases		4225	4182

Table 6.12. Same as 6.10 except 1200 GMT cycle.

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

Table 6.13. Same as 6.11 except 1200 GMT cycle.

Projection (h)	Type of Forecast	Year 1975/76	Year 1976/77	Year 1977/78
12	Early		.116	.205
	Final	.087	.109	.266
	Local	.452	.367	.457
	Persistence	.441	.494	.442
	No. Cases	13783	4237	12026
15	Local	.340	.257	.323
	Persistence	.263	.317	.309
	No. Cases	15151	3234	12393
18	Early		.094	.137
	Final	.070	.131	.148
	Persistence	.152	.121	.221
	No. Cases	13895	4278	12212
21	Local	.206	.169	.220
	Persistence	.121	.089	.133
	No. Cases	15127	4223	12393
24	Early			.193
	Final	.087		.200
	Persistence	.071		.087
	No. Cases	13897		12212
36	Early			.139
	Final		.074	.093
	Persistence		.022	.054
	No. Cases		4277	4345
48	Early			.152
	Final		.024	.129
	Persistence		.011	.032
	No. Cases		4278	4345

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

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

Table 6.15. Same as 6.14 except for visibility.

Projection (h)	Type of Forecast	Year		
		1975/76	1976/77	1977/78
12	Early		.88	.83
	Final	.47	.75	.81
	Local	.79	.76	.82
	Persistence	.79	.69	.81
	No. Cases			
15	Local	.51	.38	.49
	Persistence	.90	.66	.76
	No. Cases			
18	Early		1.20	.77
	Final	.14	.85	.68
	Persistence	1.60	1.08	1.24
	No. Cases			
21	Local	.28	.37	.32
	Persistence	2.00	1.29	1.66
	No. Cases			
24	Early		1.35	.83
	Final	.00	1.26	.69
	Persistence	2.18	1.29	1.91
	No. Cases			
36	Early			.49
	Final		.45	.74
	Persistence		.70	.90
	No. Cases			
48	Early			.83
	Final		1.21	.58
	Persistence		1.14	1.87
	No. Cases			

Table 6.16. Same as 6.14 except for 1200 GMT.

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

Table 6.17. Same as 6.15 except 1200 GMT cycle.

Projection (h)	Type of Forecast	Year 1975/76	1976/77	1977/78
12	Early		.53	.70
	Final	.24	.60	.64
	Local	.70	.72	1.16
	Persistence	1.09	1.04	.84
	No. Cases			
15	Local	.77	.74	.80
	Persistence	1.08	1.21	1.06
	No. Cases			
18	Early		1.22	.65
	Final	.15	.94	.72
	Persistence	.72	1.08	.82
	No. Cases			
21	Local	.56	.55	.67
	Persistence	.51	.82	.62
	No. Cases			
24	Early			.83
	Final	.10		.86
	Persistence	.38		.49
	No. Cases			
36	Early			.66
	Final		1.00	.49
	Persistence		.95	1.07
	No. Cases			
48	Early			.65
	Final		.93	.56
	Persistence		.59	.59
	No. Cases			

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

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

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

FORECAST PROJECTION (HOURS)	TYPE OF FORECAST	MEAN ALGEBRAIC ERROR (°F)	MEAN ABSOLUTE ERROR (°F)	NUMBER (%) OF ABSOLUTE ERRORS ≥ 10°	NUMBER OF CASES
24 (MAX)	EARLY	0.5	4.0	275 (6.9)	3967
	FINAL	-0.4	3.6	178 (4.5)	
	LOCAL	-0.5	3.4	160 (4.0)	
36 (MIN)	EARLY	0.2	4.4	272 (8.5)	3198
	FINAL	0.0	4.0	212 (6.6)	
	LOCAL	1.1	4.2	231 (7.2)	
48 (MAX)	EARLY	0.3	4.4	401 (10.2)	3941
	FINAL	-0.3	4.2	329 (8.4)	
	LOCAL	-0.8	4.2	329 (8.4)	
60 (MIN)	EARLY	-0.5	5.8	586 (18.3)	3210
	FINAL	0.2	5.0	413 (12.9)	
	LOCAL	0.9	5.0	402 (12.5)	

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

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

Table 7.4. Same as Table 7.1 except for 23 stations in the Southern Region.

FORECAST PROJECTION (HOURS)	TYPE OF FORECAST	MEAN ALGEBRAIC ERROR (^{o}F)	MEAN ABSOLUTE ERROR (^{o}F)	NUMBER (%) OF ABSOLUTE ERRORS ≥ 10^{o}	NUMBER OF CASES
24 (MAX)	EARLY	0.6	4.3	318 (9.1)	3488
	FINAL	0.0	3.9	236 (6.8)	
	LOCAL	0.3	3.6	180 (5.2)	
36 (MIN)	EARLY	0.6	4.3	285 (8.6)	3312
	FINAL	0.2	4.1	231 (7.0)	
	LOCAL	1.0	4.2	260 (7.9)	
48 (MAX)	EARLY	0.6	5.1	472 (13.6)	3466
	FINAL	0.3	4.7	416 (12.0)	
	LOCAL	0.3	4.6	386 (11.1)	
60 (MIN)	EARLY	0.8	5.6	584 (17.8)	3291
	FINAL	0.5	5.1	455 (13.8)	
	LOCAL	0.9	5.2	472 (14.3)	

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

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

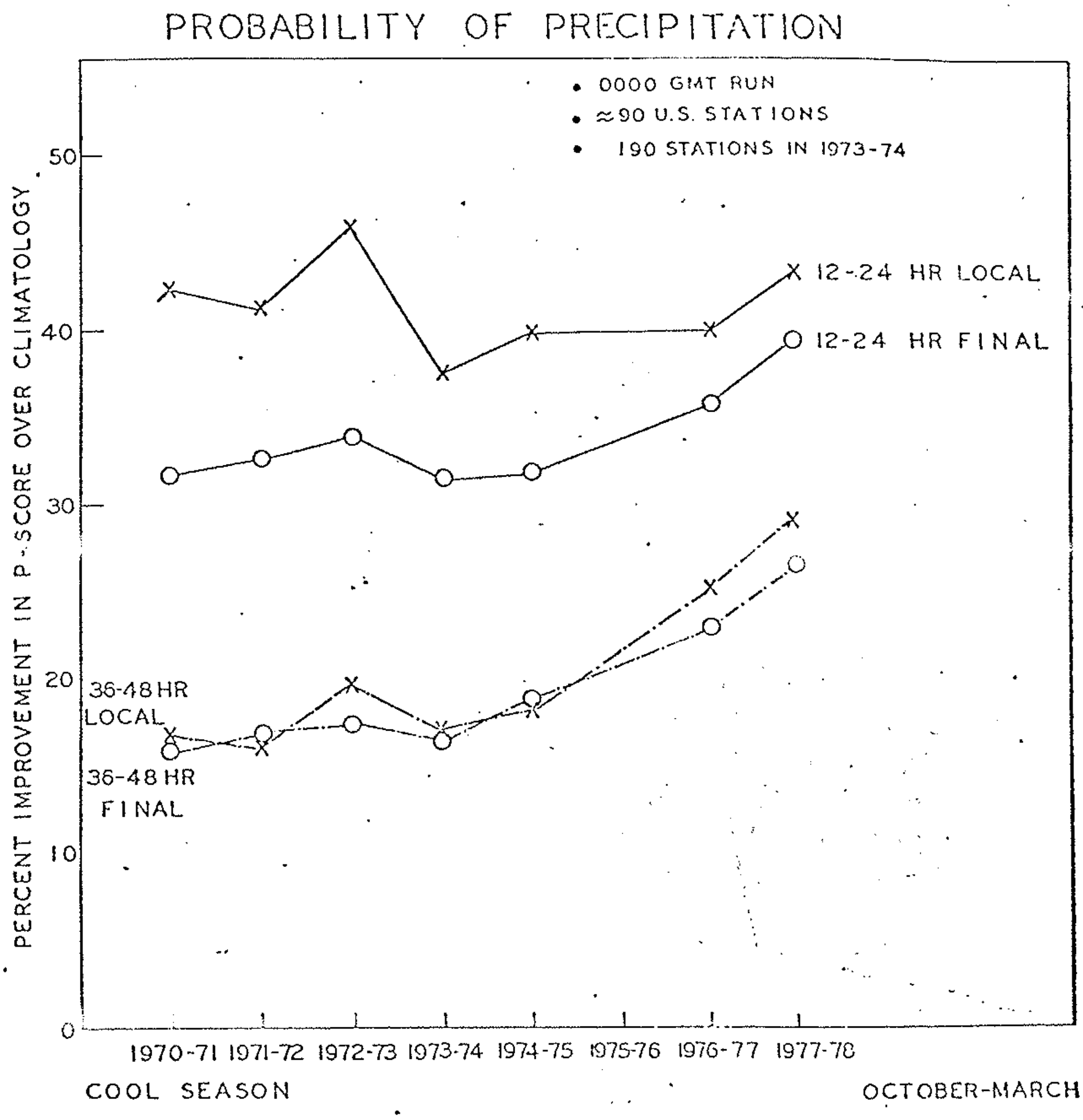

Figure 2.1. Percent improvement in Brier score over climatology of local and final guidance PoP forecasts for the cool season.

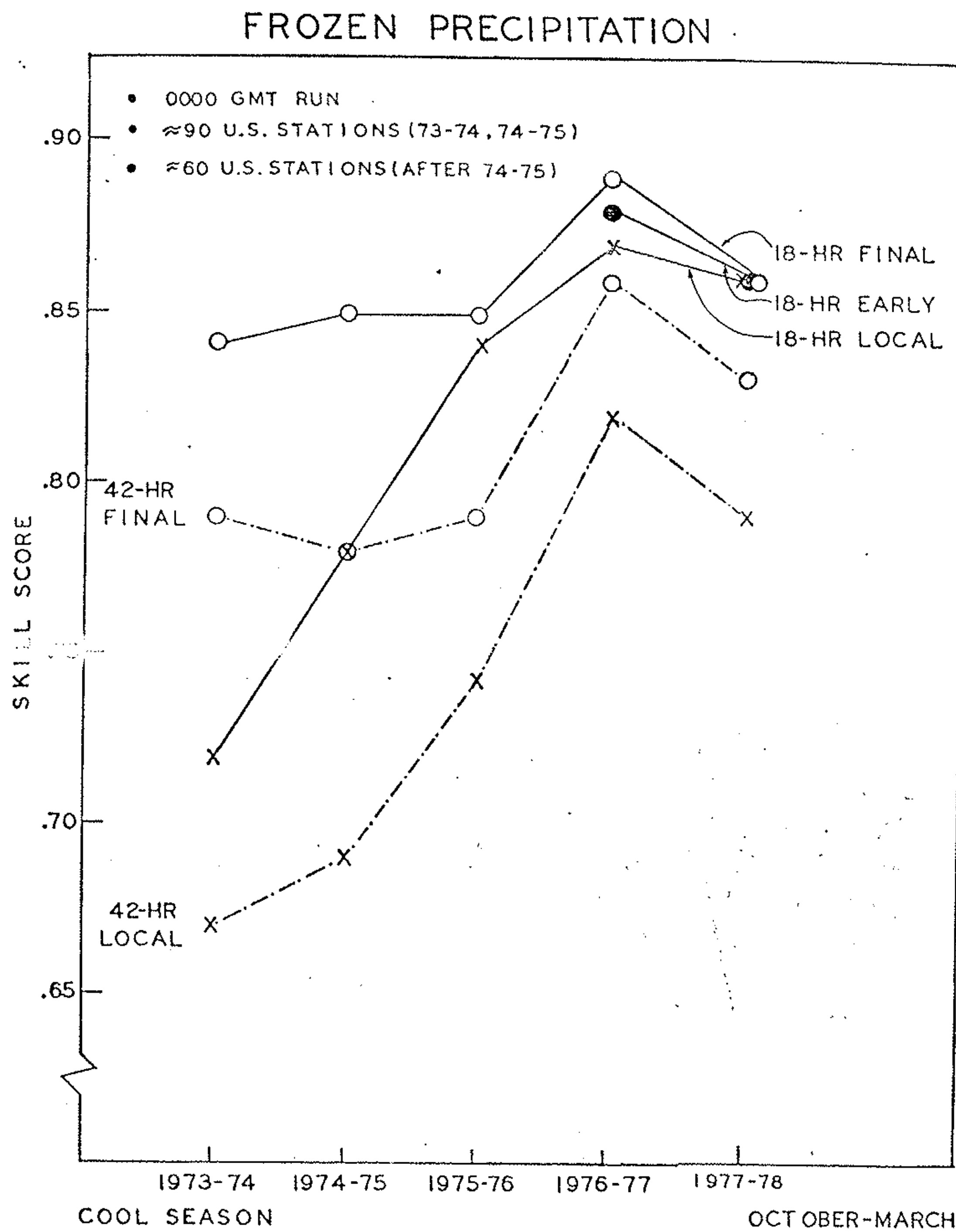

Figure 3.1. The trend in skill scores for guidance and local forecasts of frozen precipitation.

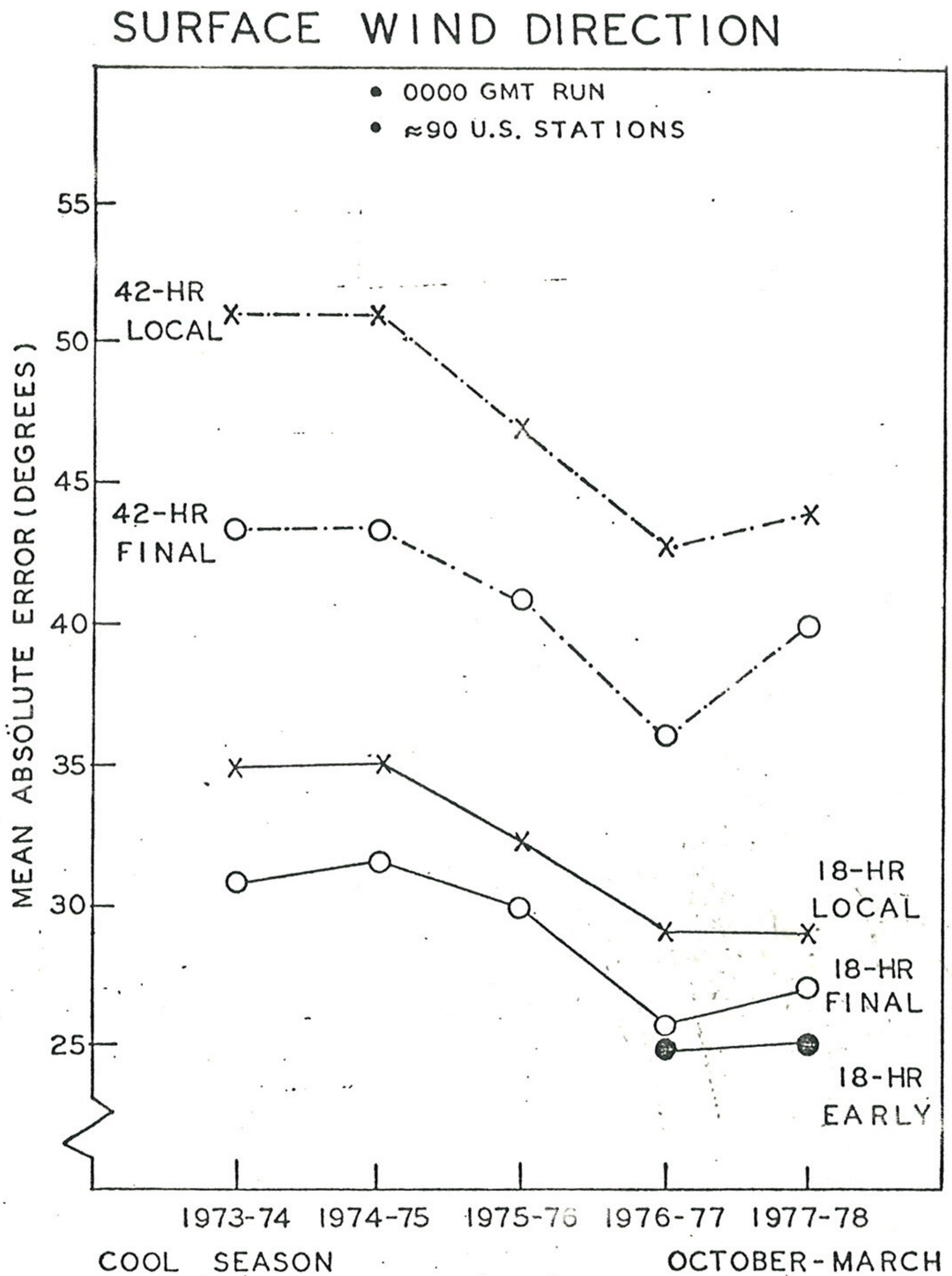

Figure 4.1. Mean absolute errors for subjective local and objective guidance (early and final) surface wind direction forecasts for approximately 90 U.S. stations.

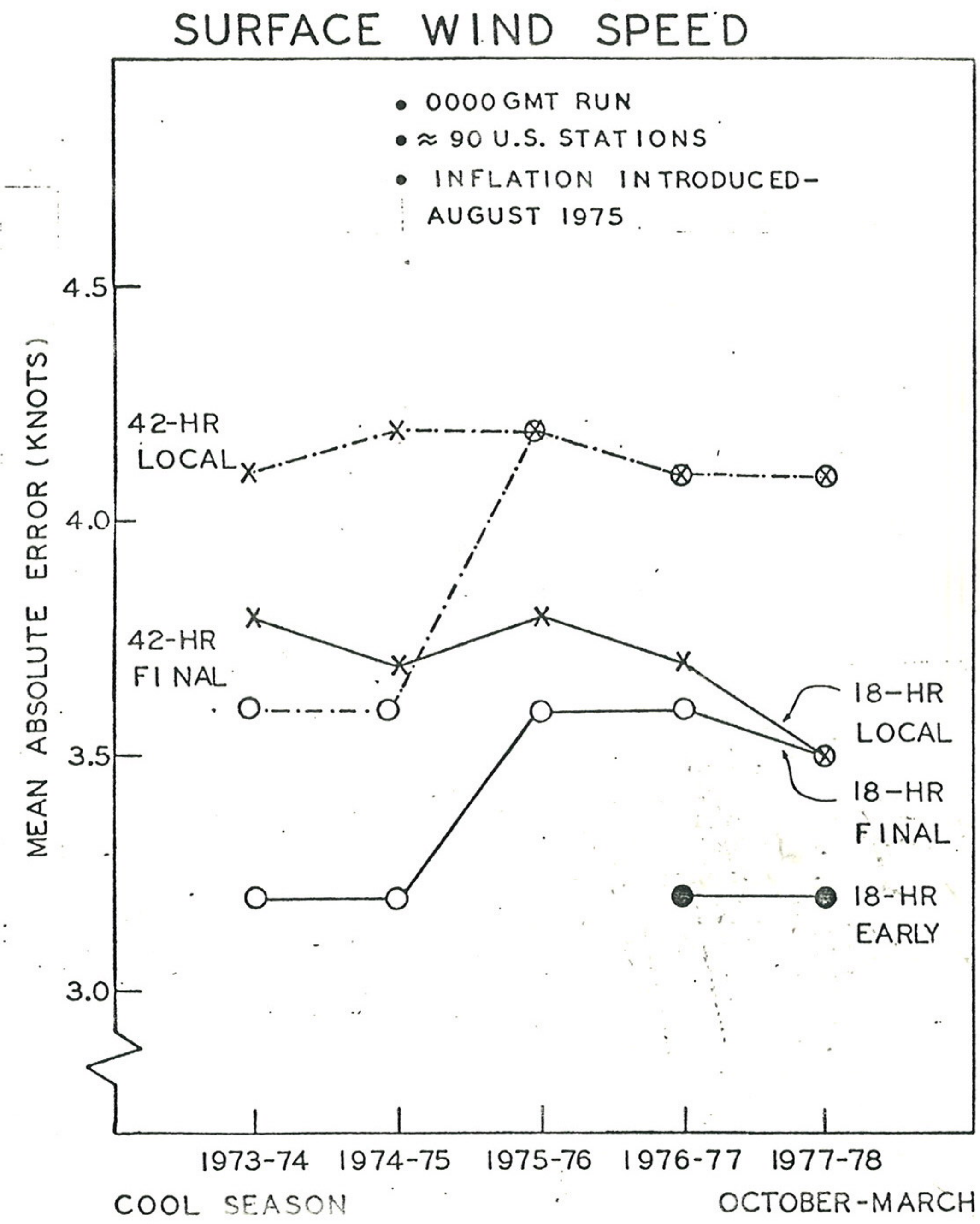

Figure 4.2. Same as Fig. 4.1 except for wind speed forecasts.

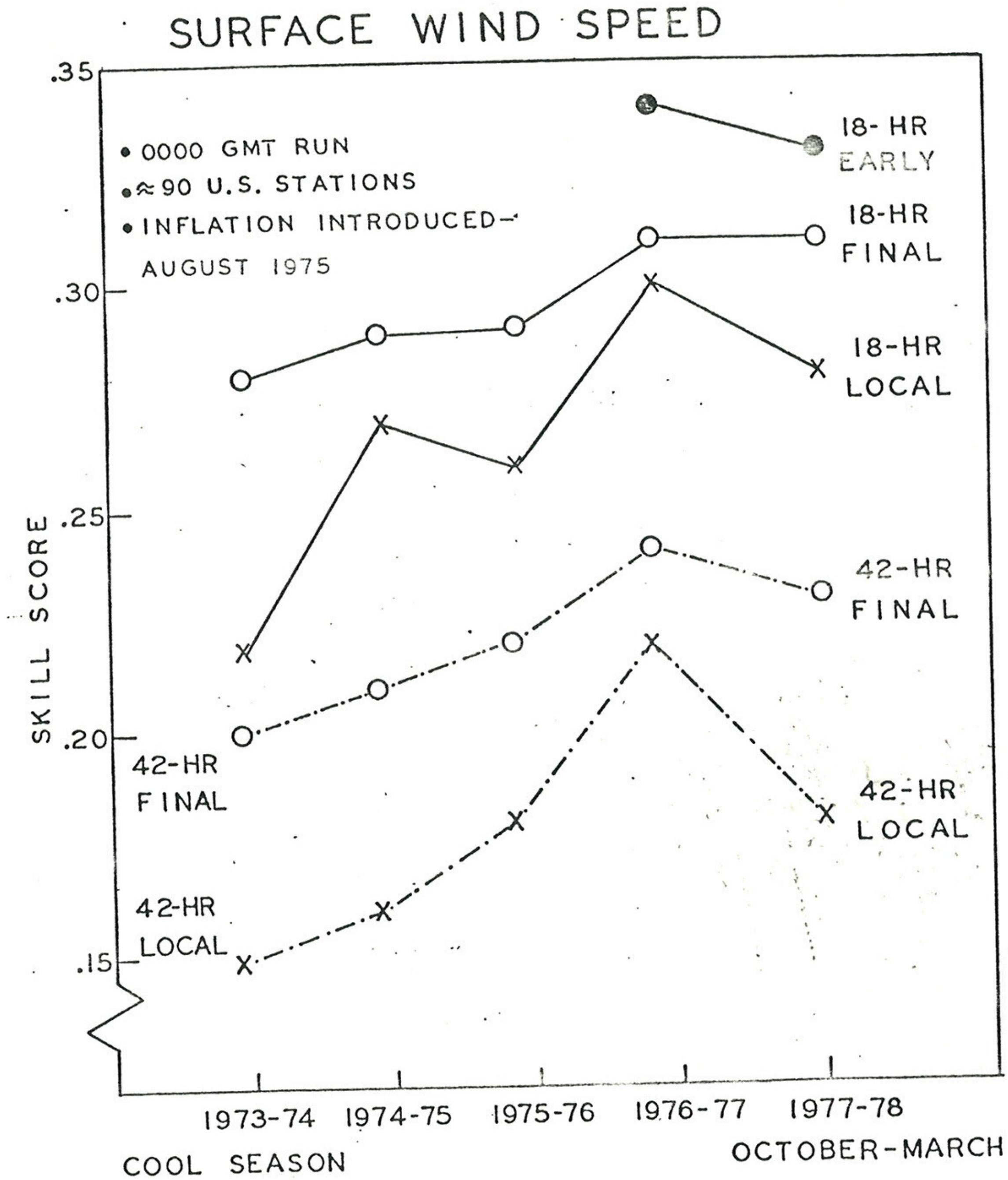

Figure 4.3. Skill scores computed from five category contingency tables for subjective local and objective guidance (early and final) surface wind speed forecasts for approximately 90 U.S. stations.

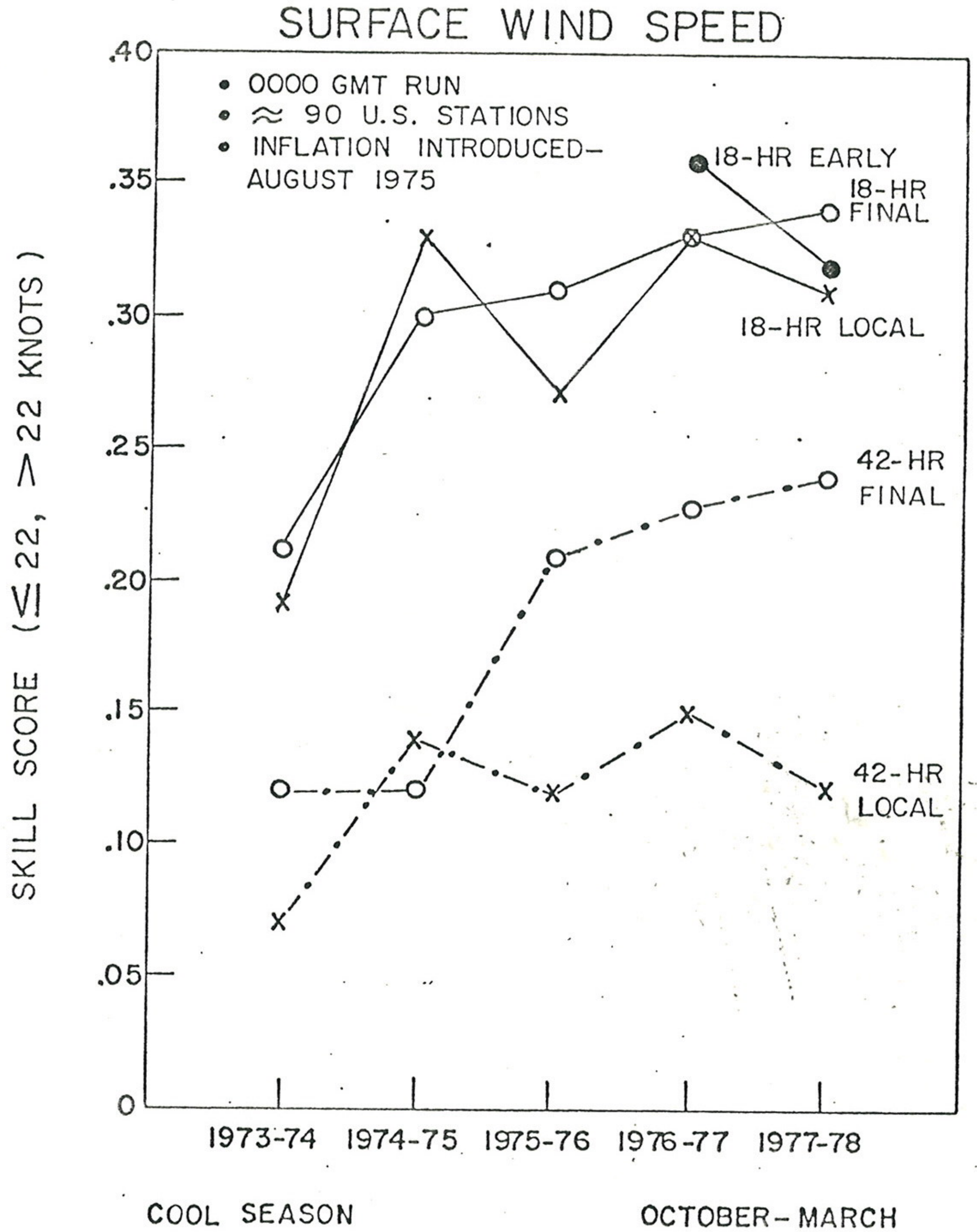

Figure 4.4. Same as Fig. 4.3 except for two-category contingency tables.

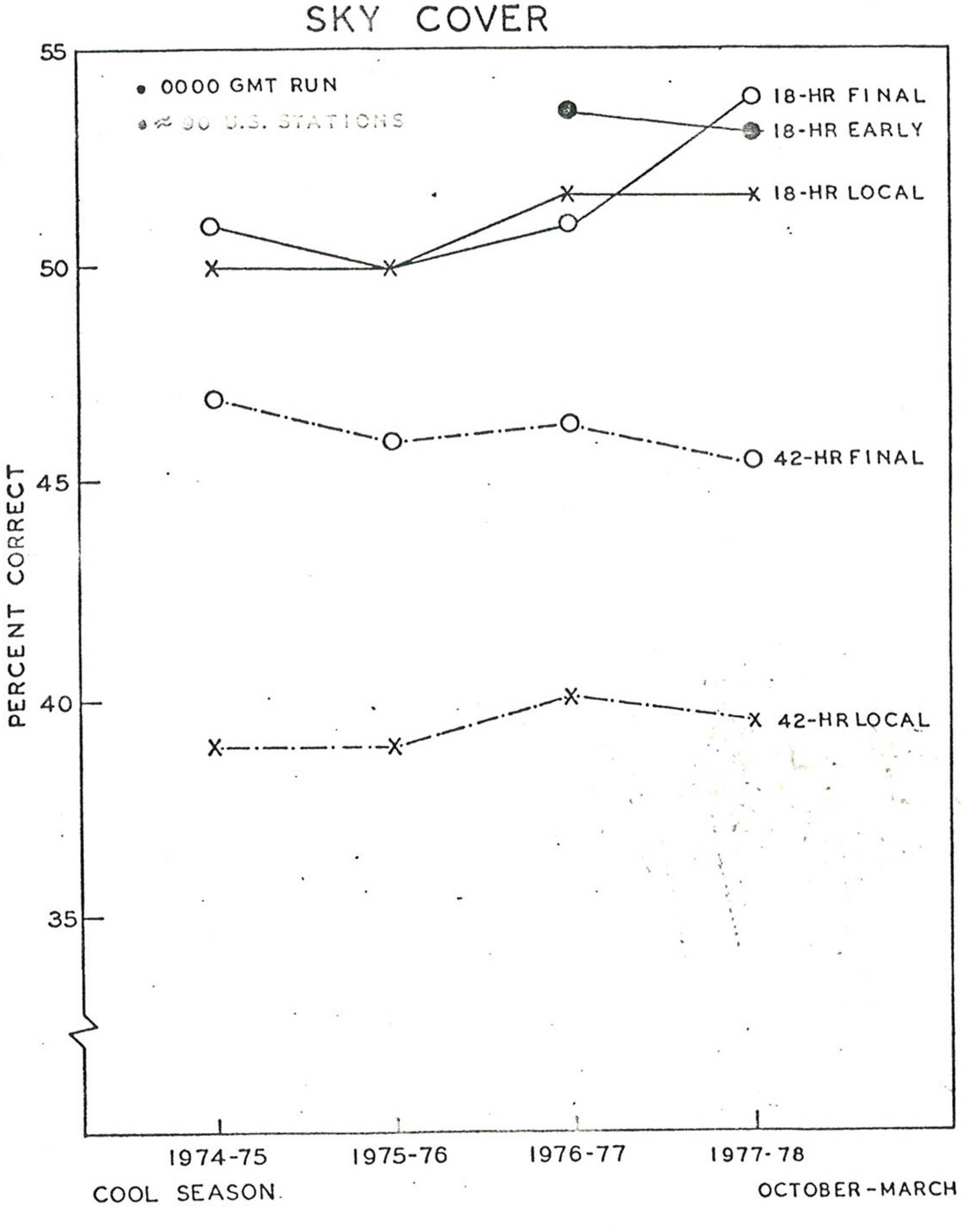

Figure 5.1. Percent correct for local and guidance cloud amount forecasts for the cool season.

SKY COVER

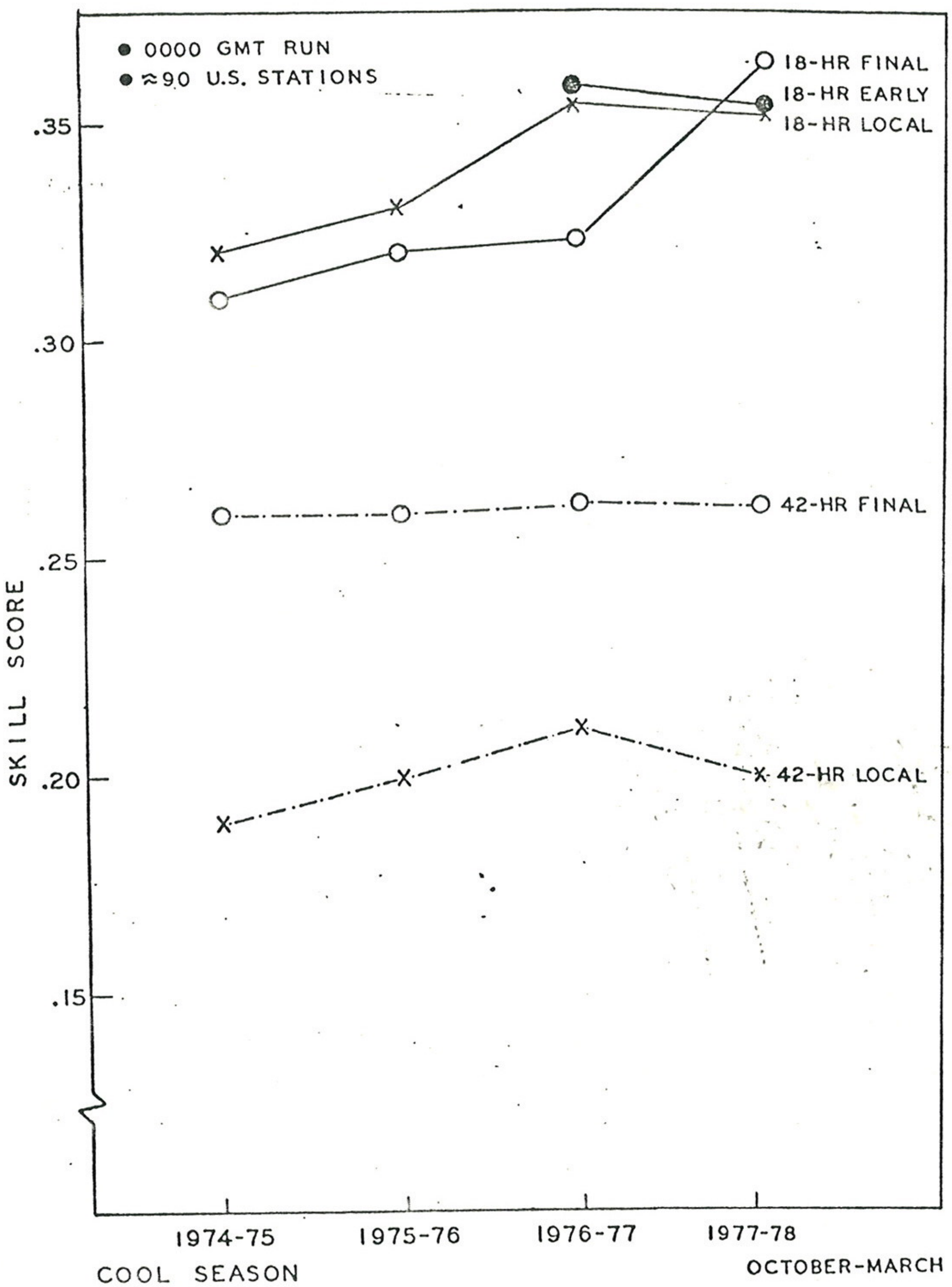

Figure 5.2. Skill score for local and guidance cloud amount forecasts for the cool season.

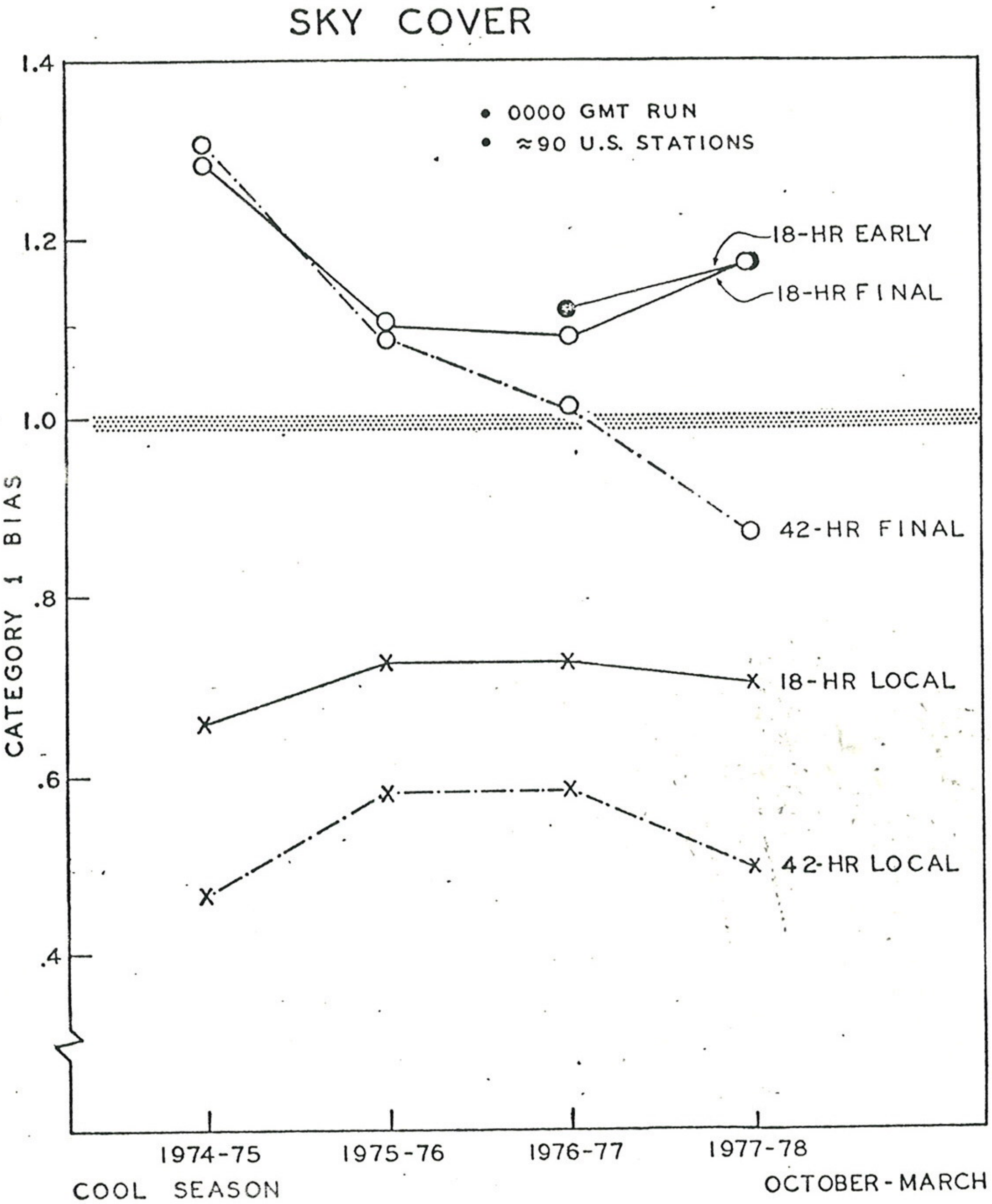

Figure 5.3. Bias of the local and guidance cloud amount forecasts of category 1 for the cool season.

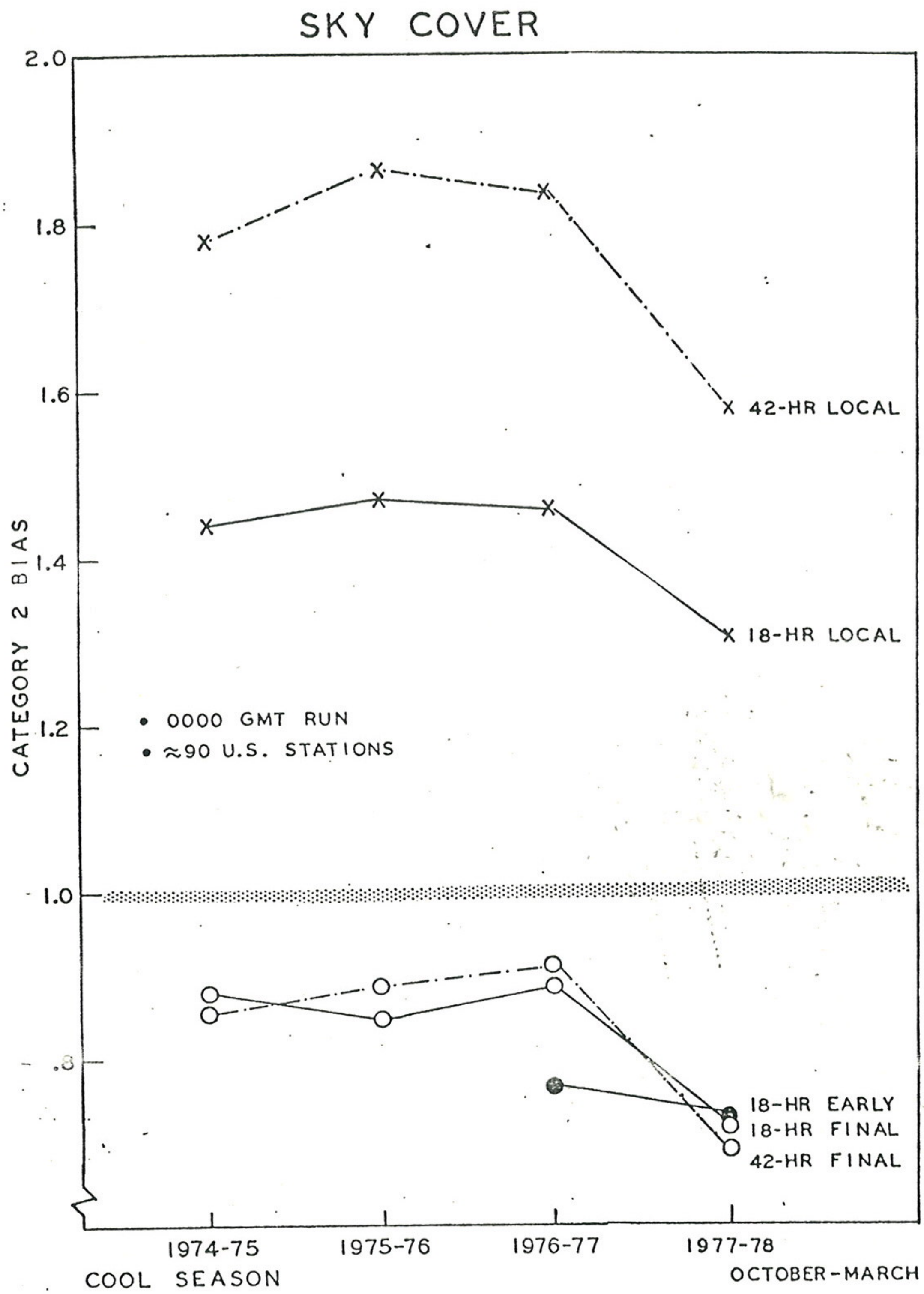

Figure 5.4. Same as Fig. 5.3 except for category 2 bias.