U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
OFFICE OF SYSTEMS DEVELOPMENT
TECHNIQUES DEVELOPMENT LABORATORY

TDL OFFICE NOTE 90-3

# AN EVALUATION OF SURFACE WIND FORECAST EQUATIONS BASED ON A NEW WIND SPEED PREDICTAND

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July 1990

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## 1. INTRODUCTION

National Weather Service (NWS) aviation and public weather forecasters have been provided with surface wind guidance (Carter, 1975) based on the Model Output Statistics (MOS) technique (Glahn and Lowry, 1972) since May 1973. Forecasts for 1-min average surface wind speed and direction valid at specific times (i.e., 0000, 0600, 1200, and 1800 UTC) are produced twice daily. Since July 1975, a procedure known as inflation (National Weather Service, 1985a) has been used operationally to increase wind speed forecasts that are greater than the mean wind speed of the developmental sample and to decrease forecasts that are less than the mean. As of this writing, the most recent wind guidance based on Limited-area Fine-mesh Model (LFM) data was implemented in 1983 (National Weather Service, 1985a).

One of the aviation weather forecasts produced by NWS forecasters is the terminal forecast (FT). The FT's (National Weather Service, 1988) are valid for a 24-h period; forecasts of prevailing conditions of wind, ceiling, visibility, and weather are available for periods within the first 18 hours while categorical forecasts of flight conditions are given for the last 6 hours. Note, too, that the forecast wind conditions are mentioned explicitly only when the winds are expected to be greater than 6 kt or when a significant change is expected.

In order to evaluate in a simplified manner the FT's as part of the NWS AFOS-era verification (AEV) program (Ruth and Alex, 1987), software is used at the local NWS forecast offices to collect local wind forecasts that are valid at specific times, namely, 3, 9, and 15 hours after the start of the FT period. Thus, the AEV software extracts wind forecasts for these projections from the winds in the FT periods associated with each specific time. Henceforth, we will refer to the AEV-extracted wind forecasts as local winds.

Since the last implementation of LFM-based MOS wind guidance, two notable events have impacted the usefulness of the guidance. In January 1985, the surface stress formulation was modified in the operational version of the LFM (National Weather Service, 1985b); this change caused some degradation in skill of the MOS wind speed guidance. In particular, the MOS guidance developed a tendency to underforecast wind speeds $\geq$ 18 knots (Carter et al., 1985). In December 1986, the issuance times for the FT's were changed to correspond to local time (Ruth and Alex, 1987). As a consequence, the valid time for FT's now varies across the nation relative to UTC. At some stations, the local wind forecasts are no longer valid at the same time as the MOS guidance. Some details regarding these changes are explained later.

In an attempt to provide forecasts that more closely fit the AEV projections and have a better (i.e., closer to 1.0) bias for stronger winds without artificially altering the speed forecasts by inflation, a series of variations on a new approach for predicting surface wind was evaluated. This report presents the development and testing of LFM-based MOS equations that were derived from new predictands, namely, the highest hourly wind speed and the associated direction reported within ±1 hour of the specific valid time.

## 2. EXPERIMENTAL DESIGN

The current operational LFM-based MOS wind equations were developed by using as predictands observations of the 1-min average surface wind speed and direction valid at 6-h intervals from 6 to 48 hours after initial cycle time. The data sample was from 1977 to 1982, prior to the implementation of the surface stress modification in the LFM. Surface observations were included as predictors at the 6- and 12-h projections. The importance of boundary layer predictors in wind equations was tested in anticipation of the model change (Janowiak, 1981). No boundary layer predictors were used in development of the operational MOS equations because the results of those tests showed no substantial loss of accuracy when boundary layer variables were omitted. In a post-processing procedure, the operational wind speed forecasts are inflated.

In our tests, an experimental equation set (hereafter, called NEW±1) was developed by using as predictands hourly reports of the surface wind within ±1 hour of the specific valid time. The wind observation with the highest wind speed was chosen for the U, V, and speed predictands for that valid time. The test equations were developed by using data from the 1985-86 and 1986-87 cool seasons (October-March). Note that this period was after the modification was made to the LFM surface stress. This data sample had the disadvantage of being shorter than the developmental sample used for the operational MOS. On the other hand, using these dates allowed us to develop equations from the most recent version of the LFM. Although the predictor list was similar to that used in development of the operational MOS equations, there were two notable exceptions. No surface observations were used as predictors, and boundary layer model variables were included in the predictor list. In fact, the most often chosen predictors for the new equation sets were the boundary layer wind variables. Other important predictors included the 1000-mb geostrophic wind and the 850-mb model wind. In tests on independent data, forecasts of wind speed from the NEW±1 equation sets were not inflated.

Another set of equations (hereafter, called NEW1) analogous to operational MOS was developed by using as predictands the wind speed and direction observed at the specific valid times. However, NEW1 was developed on the same data sample and from the same predictor list as NEW±1 to approximate what operational MOS would do if redeveloped on more recent model data. Wind speed forecasts from NEW1 equation sets were inflated. By comparing forecasts from the experimental equations to those from NEW1, we were able to estimate how much of the increased skill and accuracy was due to a more recent developmental sample.

The two new sets of equations were developed for projections of 12, 18, 24, and 42 hours from the 0000 UTC cycle for 94 stations (Table 1). These projections were the same as those used in evaluating the FT's in the AEV system until December 1986. In that AEV system, the MOS wind forecasts and the local wind forecasts from the 0000 UTC cycle were valid at all stations at the same corresponding times, namely, 1200, 1800, and 0000 UTC. Note that the local 42-h wind forecast is not extracted from the FT's, but is produced directly by the forecasters. The stations were chosen to match those used in the AEV system (Dagostaro et al., 1989).

Since the FT's are now based on local time, the valid times during standard time for the local winds in the Pacific Time Zone (PTZ) are two hours later than the valid time for the guidance (see Appendix I); thus, the local wind valid times for the PTZ lie outside of the ±1 hour experimental predictand window. For example, the 12-h MOS forecasts from the 0000 UTC cycle are valid at 1200 UTC, whereas the corresponding local winds from sites in the PTZ are valid at 1400 UTC. Therefore, equations based on a predictand window of ±1 hour centered on 1500 UTC rather than 1200 UTC are more appropriate for these sites. For this reason, a second set of NEW±1 equations was developed for the 10 AEV stations in the PTZ (see Table 1) by using predictand projections of 15, 21, and 27 hours rather than 12, 18, and 24 hours. Since the valid time of the 42-h significant wind forecasts does not vary by time zone, the MOS and local 42-h wind forecasts are valid at the same UTC hour. Therefore, the same 42-h predictand was used at all stations.

Operational MOS and test forecasts from the two new equation sets were compared on two independent samples--10 January 1985 to 31 March 1985 and 26 October 1987 to 1 March 1988. The first test sample included the period following the LFM change but before the change in FT valid times. The goal of this preliminary test was to determine whether the NEW±1 equations were accurate enough to merit further study. Operational MOS, NEW1, and NEW±1 were verified for 12-, 18-, 24-, and 42-h projections for all stations. The forecasts were verified against both the wind observation at the specific hour and the highest wind speed (and coincident direction) observed ±1 hour of the specific time. Two types of verification were also used (Table 2). The AEV criteria followed exactly the AEV system which is tailored to aviation needs. The developmental criteria were used for a more general verification that did not have the restrictions that the AEV system had on evaluating the slower wind speeds.

The second test sample was for the period following the change in FT issuance times. Only the AEV criteria were used in this test to see how forecasts made from test equations might do in the current environment of varying FT issuance times. The verifying observation was at the valid hour unless otherwise specified. Operational MOS, NEW1, and NEW±1 were verified for the 12-, 18-, and 24-h projections. The local winds were verified for the corresponding 3-, 9-, and 15-h projections. The equations developed for the PTZ stations for 15-, 21-, and 27-h projections were substituted for those of 12, 18, and 24 hours in the NEW±1 equation sets.

The 42-h significant wind forecast was verified by using the Heidke skill score (HSS) (National Weather Service, 1982) as is done in the AEV system. This forecast is a yes/no prediction for a wind speed greater than 22 knots valid 42 hours after 0000 UTC. Two verifying observations were used: the wind speed valid at 42 hours and the highest wind speed reported within ±3 hours of that valid time.

## 3. TEST RESULTS

On the first test sample, wind speeds were initially verified according to the developmental verification criteria and the traditional 1-min average observation. NEW1 exhibited higher HSS than operational MOS, but the mean absolute error (MAE) scores were about even (not shown). NEW±1 was overall slightly less skillful and accurate than either the operational MOS or NEW1 (not shown).

When the wind speeds were verified against the 1-min average observation by using the AEV criteria (Fig. 1), NEW1 had higher HSS than operational MOS at all four projections, and NEW±1 was slightly more skillful overall than NEW1. Operational MOS and NEW±1 had the lowest MAE's (not shown). However, the results for both of these verification measures were usually close. Note that NEW1 had slightly higher MAE's than the other two systems in part due to forecasting more of the higher wind speeds. NEW1 equations forecast higher wind speeds more often than NEW±1 because the NEW1 forecasts were inflated while NEW±1 forecasts were not. NEW1 forecast more strong winds than operational MOS, even though both were inflated, because of the change in the treatment of surface stress in the LFM. That change resulted in slower low-level wind speed forecasts in the LFM than were in the dependent sample used to develop the currently operational MOS. The effects of this are more noticeable in the verification scores using the AEV criteria because only stronger (≥10 kt) wind speed cases are included.

Quite a different picture emerged when wind speeds were verified against the ±1-h observation. For verification using the AEV criteria, forecasts produced by the NEW±1 equations were superior in HSS (Fig. 2) and MAE (not shown) at all projections. The same was true for verification using the developmental criteria (not shown).

We hoped that basing the experimental predictand on wind speed would not degrade the wind direction forecasts. Perhaps, taking the wind direction from observations with the highest wind speed might result in wind directions that were more synoptically realistic. In fact, all the wind forecast schemes had very similar wind direction scores. Overall, a slight edge went to NEW±1 direction forecasts in the first test period (not shown).

This initial test indicated that the forecasts from the NEW±1 equations exhibited a substantial degree of skill and accuracy. The test also showed that NEW1 was more accurate than operational MOS and supported further testing NEW±1 against NEW1 as the standard. A summary of results from the first test is shown in Table 3.

The forecast equations were next tested on the second independent sample with variable FT issuance times by using the AEV system alone. Note that the forecasts from the local NWS offices were included in this test. As can be seen from the wind speed HSS in Fig. 3, NEW±1 had greater skill than NEW1 at two of the three projections, with one tie. The MAE's were lower for NEW±1 than for NEW1 (Fig. 4) at all projections. For wind direction, the HSS (not shown) and the MAE's (Fig. 5) were about even. The most pronounced difference in scores was found in the significant wind verification (Fig. 6). NEW1 was far superior in skill to NEW±1 for both the specific hour and the ±3-h observation.

Even though the valid times for the local wind forecasts matched the observation times used in verification, the local winds did not exhibit any notable advantage in any of the scores. In fact, the local scores were generally inferior to the guidance scores for the projections verified.

Although forecasts from the NEW±1 wind speed equations were generally more accurate than NEW1, the results did not show that the reason for the better scores was the match of the developmental predictand to the verifying observation. A breakdown of scores by time zone (not shown) indicated that

NEW±1 fared worse instead of better against NEW1 and local winds in time zones where local wind valid times differed from the standard MOS guidance valid times (Mountain Time Zone (MTZ) and the PTZ). NEW±1 did better in time zones where the valid times matched (Eastern Time Zone (ETZ) and Central Time Zone (CTZ)). It's more likely that the use of the experimental predictand in development and not inflating the forecasts led to better scores for NEW±1.

The bias by category scores (not shown) revealed that NEW±1 had trouble forecasting the higher wind speeds and, at some projections, significantly overforecast wind speeds in the 12- to 22-kt range. Since the wind guidance has a history of being deficient in forecasting higher wind speeds, we next attempted to improve the bias in the higher wind speed categories while maintaining a high degree of accuracy and skill.

## 4. WIND SPEED BIAS IMPROVEMENT

Four variations of the NEW±1 equations were tested in order to raise the bias to near 1.0 for higher wind speed forecasts while retaining accuracy when verified against wind speed observations at the specific verifying hour. The first variation was simply to inflate the forecasts. With an overall wind speed bias of 1 knot to 1.5 knots without inflation, this first variation of NEW±1 was expected to overforecast speeds somewhat. The second variation was designed to moderate the inflation by using a variable inflation technique. The formulas for inflation and the variable inflation are shown in Appendix II. In essence, variable inflation reduced the amount of inflation by as much as one half, depending on the value of the multiple correlation coefficient. In the third and fourth variations, the ±1-h wind speed predictand was mathematically transformed before performing the regression procedure in order to force the developmental sample predictand to assume a more normal distribution. All wind speed predictors were similarly transformed. The functions that were applied to the experimental predictand to normalize the distribution were: $\ln(\text{wind speed} + 1)$ and $(\text{wind speed} + 1)^{1/2}$.

A distribution curve of ±1-h observations of wind speeds valid at 1800 UTC (Fig. 7a) shows that the distribution was positively skewed. Note that the distribution of observations at the hour is given for comparison. Figs. 7b and 7c show the resultant transformed wind speed distributions for the same sample. The predictand distribution obtained by applying the ln transformation actually exhibited a negative skew, while that obtained by using the square root transformation exhibited very little skew. By visual inspection, the transformed distributions appeared to be more normal than the original distribution. However, no statistical test for normality was applied.

Note in Fig. 7a that for the 94 stations over 5 1/2 months, no 1-kt wind speeds were reported; moreover, the number of even-value wind speed reports exceeded the number of odd-value reports. This is especially noticeable at the peak of the curve where the number of observations of 9 knots is about 300 less (approximately 30%) than the total at 10 knots.

The four variations described above were evaluated on the second test period dates by using the AEV criteria. The results were compared with those of NEW±1 and NEW1. The ten PTZ stations were not verified at the 12-, 18-, and 24-h projections to avoid the confusion with the valid times of the local winds.

The one clear result from these tests was that fully inflating the forecasts from the NEW±1 equations resulted in wind speeds that were much too high. For example, the MAE and the mean algebraic error at 42-h increased from 3.7 kt and 1.6 kt without inflation to 4.6 kt and 3.2 kt with inflation, respectively. The HSS had a pronounced drop from .341 to .305. Because of these poor results, this system was not tested further.

Forecasts from NEW±1 without inflation had lower MAE's than NEW1 while MAE's from the variable inflation (VI) forecasts were consistently higher (Fig. 8a) than NEW±1. Forecasts from the natural logarithm transform system (LN) and the square root transform (SQRT) had the lowest MAE's compared to NEW1 (Fig. 8b). Comparing these two figures, we ordered the different forecast systems from lowest to highest MAE's averaged over all four projections in the following way: LN, NEW±1, SQRT, NEW1, and VI. The HSS were highest for NEW±1, but the SQRT and LN were close (Fig. 9); VI was a little less skillful than LN and NEW1 was the least skillful.

Verification of the threat score for wind speeds greater than 22 knots at the specific valid time was also performed. This score was used to get a clearer picture of skill in forecasting higher wind speeds than is possible from considering the bias by category alone. As can be seen from Fig. 10, NEW1 had the best threat scores, followed by VI, NEW±1, SQRT, and LN. As is evident in Figs. 8, 9, and 10, no one system was better at all projections and by all verification measures.

## 5. DISCUSSION

A new MOS technique for predicting surface wind was tested on LFM output. The technique involved using new developmental predictands which were the highest hourly wind speed and the associated direction reported within ±1 hour of the specific valid time. Wind speed forecasts were not inflated. Several variations using this new predictand were also tested. These included ln and square root transformations of the wind speed predictand in the development and variable inflation of the wind speed forecasts produced by equations that were developed from the ±1-h predictand.

To summarize the results of the first and second tests, wind speed forecasts from the experimental NEW±1 were found to be more skillful and accurate than operational MOS and slightly more so than the rederived version of operational MOS (NEW1). However, without inflating the wind speed forecasts, NEW±1 equations did not predict enough strong winds of >22 knots, especially at the longer projections. The wind direction scores for all systems were very close and did not significantly favor any one system.

There were two important conclusions from these tests. First, the skill exhibited by NEW1 indicated that much of the increased skill and accuracy exhibited by NEW±1 over operational MOS was likely attributable to the more recent developmental sample used. The comparison between operational MOS and NEW1 showed that rederiving the LFM-based wind equations in the traditional manner on more recent data would improve forecast performance. Furthermore, new equations would forecast higher wind speeds--something the current operational equations have trouble doing. To support this idea, we compared our wind speed test scores of MAE, HSS, and bias by category with their AEV counterparts generated prior to (1983-84) and after (1985-86) the change in the LFM stress formulation. The operational MOS verification scores in our tests were similar to the actual operational MOS AEV scores after the LFM change. However, the NEW1 scores more closely resembled operational MOS AEV scores before the LFM change in that the NEW1 scores exhibited greater skill, especially in forecasting higher wind speeds. Despite this deficiency in the current operational MOS system, we've not redeveloped the LFM-based MOS guidance due to constraints on resources and the development of MOS guidance based on the Nested Grid Model (NGM). The second important conclusion from these tests was that the equations derived with a ±1-h predictand did not do a better job of predicting winds at the new variable local valid times than equations derived with a predictand at the specific valid time.

The tests of variations on NEW±1 showed that both the transformation and variable inflation techniques exhibited some improvement in strong wind forecasts with varying success in retaining accuracy. All approaches had strengths and weaknesses in regard to the accurate and skillful prediction of operationally significant surface winds. Since no single approach was clearly superior for a majority of evaluation measures, we decided to continue to use the traditional approach in developing wind guidance. NGM-based MOS surface wind guidance was developed and implemented in 1989 in the traditional way (Jacks et al., 1990).

Although the tests reported in this office note did not clearly indicate one best technique, and no form of the new approach was implemented, I believe that both the techniques of predictand transformation and some form of variable inflation hold promise for improving surface wind forecasts in the future.

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Table 1. The 94 stations used in verifying the wind forecasts.

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

Table 2. Comparison of criteria used to verify wind speed and wind direction forecasts. Categories are for contingency tables used to compute skill scores. Cases where station forecasts or observations do not satisfy verification criteria on any date or projection are not included in the verification. Note that SPD denotes wind speed in knots; DIR denotes wind direction according to the standard meteorological convention.

| Weather Element | Categories | Verification Measure | Criteria | |
|---|---|---|---|---|
| | | | Developmental | Operational (AEV) |
| Wind Speed | $\text{SPD} \le 7$<br>$7 < \text{SPD} \le 12$*<br>$12 < \text{SPD} \le 17$<br>$17 < \text{SPD} \le 22$<br>$22 < \text{SPD} \le 27$<br>$27 < \text{SPD} \le 32$<br>$32 < \text{SPD}$ | Heidke Skill Score<br>Bias by Category<br>Mean Absolute Error | All cases<br>All cases<br>All cases | All cases<br>All cases<br>Forecasts $\ge$ 10 kts |
| Significant Wind | $\text{SPD} \le 22$<br>$22 < \text{SPD}$ | Heidke Skill Score | All cases | All cases |
| Wind Direction | $337.5 < \text{DIR} \le 22.5$<br>$22.5 < \text{DIR} \le 67.5$<br>$67.5 < \text{DIR} \le 112.5$<br>$112.5 < \text{DIR} \le 157.5$<br>$157.5 < \text{DIR} \le 202.5$<br>$202.5 < \text{DIR} \le 247.5$<br>$247.5 < \text{DIR} \le 292.5$<br>$292.5 < \text{DIR} \le 337.5$ | Heidke Skill Score<br>Mean Absolute Error | SPD Forecasts and Observations > 8 kts | SPD Forecasts > 10 kts and Observations > 1 kt |

* For the operational (AEV) verification, the lowest wind speed category is for all winds $\le$ 12 knots.

Table 3. Summary of first test period scores, 10 January 1985 to 31 March 1985. For each score and verification scheme, the first number is the number of projections NEW±1 scores were better than NEW1 scores. The number following the slash is how many projections NEW1 scores were better. The third number, if any, is the number of projections that the two systems had virtually equal scores. Verification observation type 1 is for observations at the specific hour; type ±1 is for highest wind speed (and associated direction) ±1 hour of the specific valid time.

| Weather Element | Verification Measure | Verification Type | | | |
|---|---|---|---|---|---|
| | | Developmental 1 | AEV 1 | Developmental ±1 | AEV ±1 |
| Speed | HSS | 0/4 | 2/1/1 | 4/0 | 4/0 |
| | MAE | 1/3 | 2/1/1 | 4/0 | 4/0 |
| Direction | HSS | 2/2 | 3/1 | 3/1 | 2/2 |
| | MAE | 3/1 | 4/0 | 3/0/1 | 4/0 |
| | TOTAL | 6/10 | 11/3/2 | 14/1/1 | 14/4 |

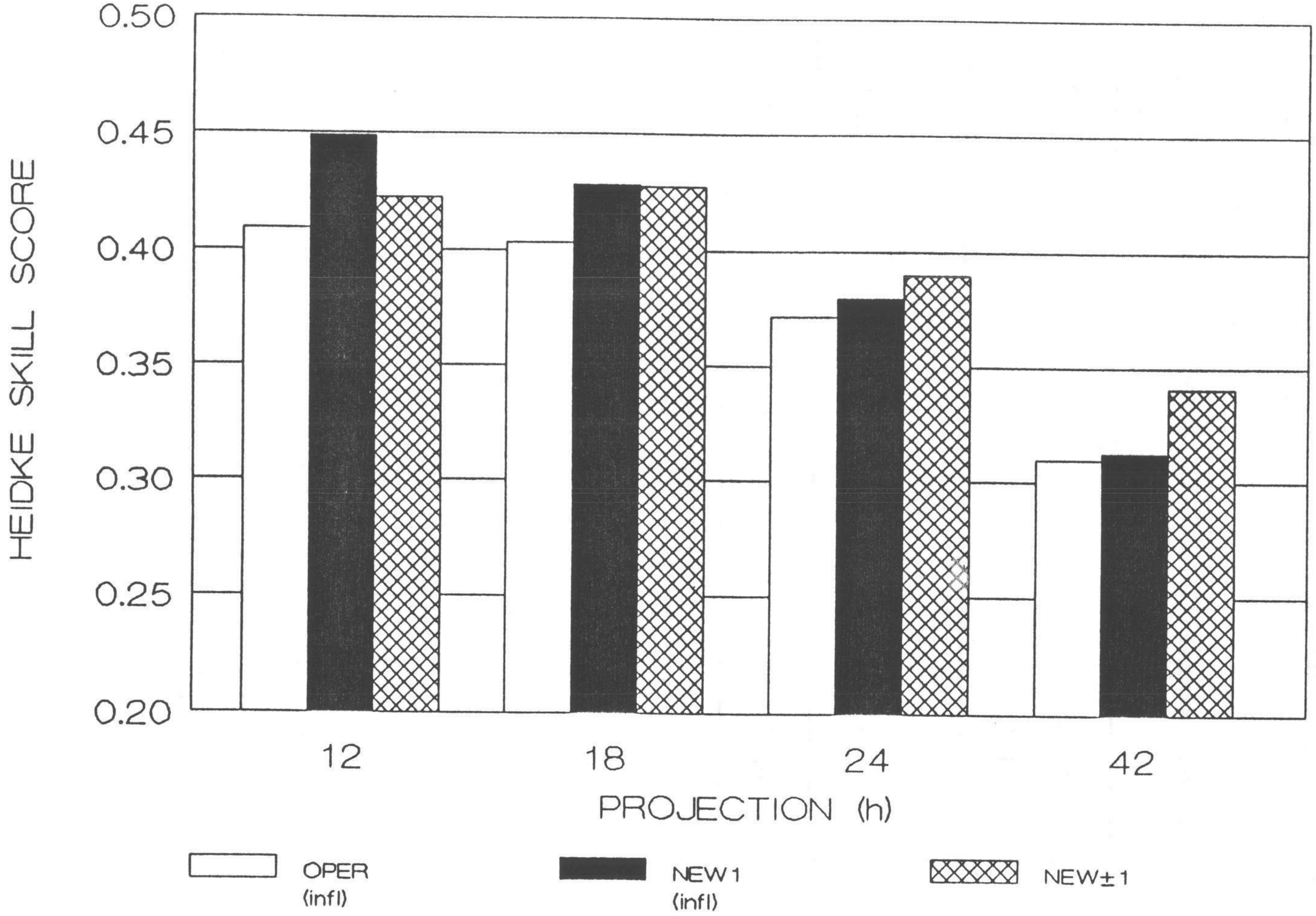

Figure 1. Skill scores of operational and experimental MOS wind speed forecasts. AEV criteria were used with the verifying observations at the specific verifying hour. The results are from 10 January 1985 to 31 March 1985 and are valid for approximately 94 stations. All forecasts were based on 0000 UTC LFM data. The term "infl" indicates that the forecasts were inflated.

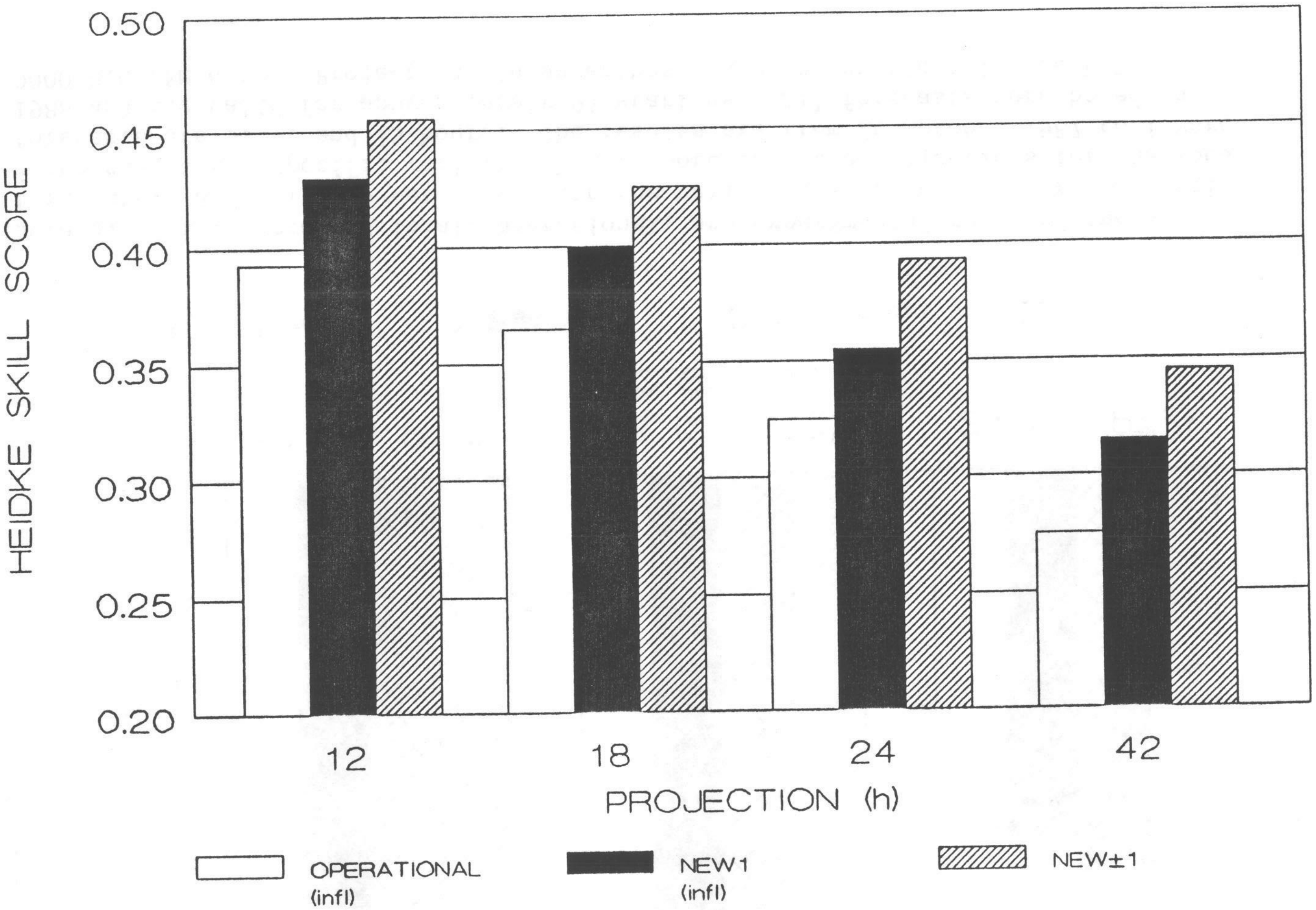

Figure 2. Same as Fig. 1, except that the verifying observations were highest wind speed ±1 hour about the valid time.

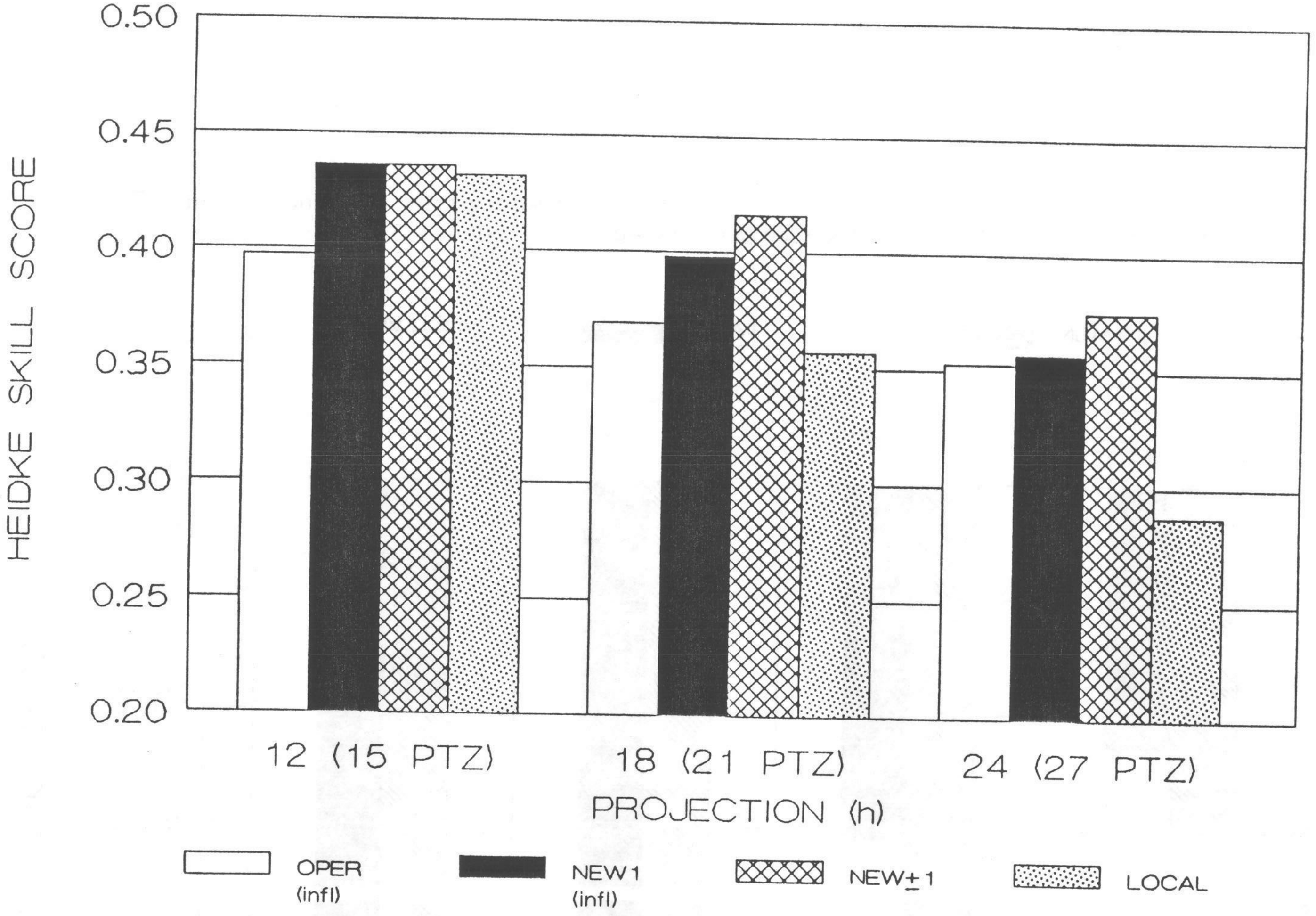

Figure 3. Skill scores of local, operational, and experimental MOS wind speed forecasts. AEV criteria were used with the verifying observations for the local forecasts at the specific verifying hour. Note that the projections for the local forecasts are 3, 9, and 15 hours. The results are from 26 October 1987 to 1 March 1988 and are valid for approximately 94 stations. All forecasts were based on 0000 UTC LFM data. Projections in parentheses are for stations in the PTZ.

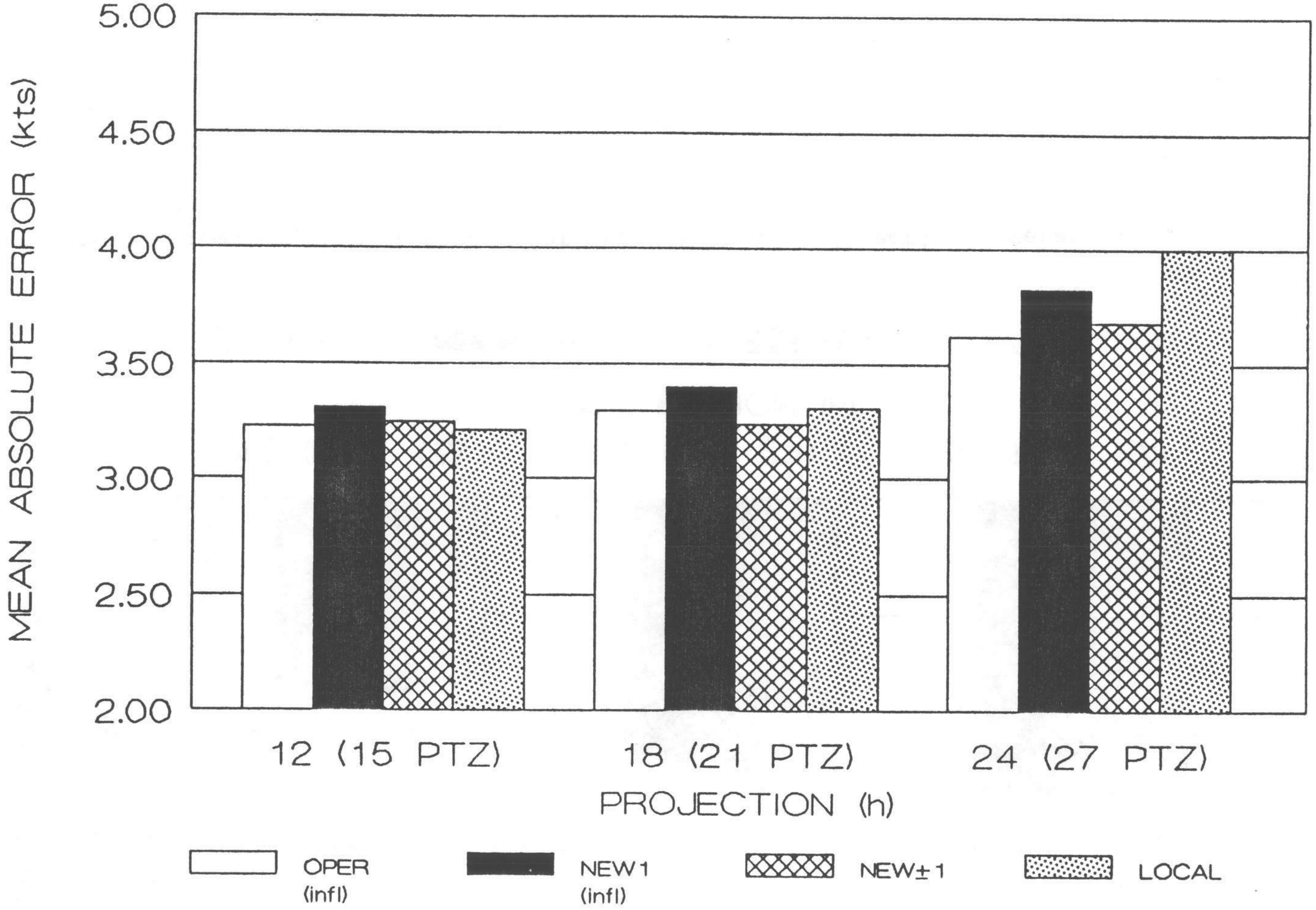

Figure 4. Same as Fig. 3, except for MAE.

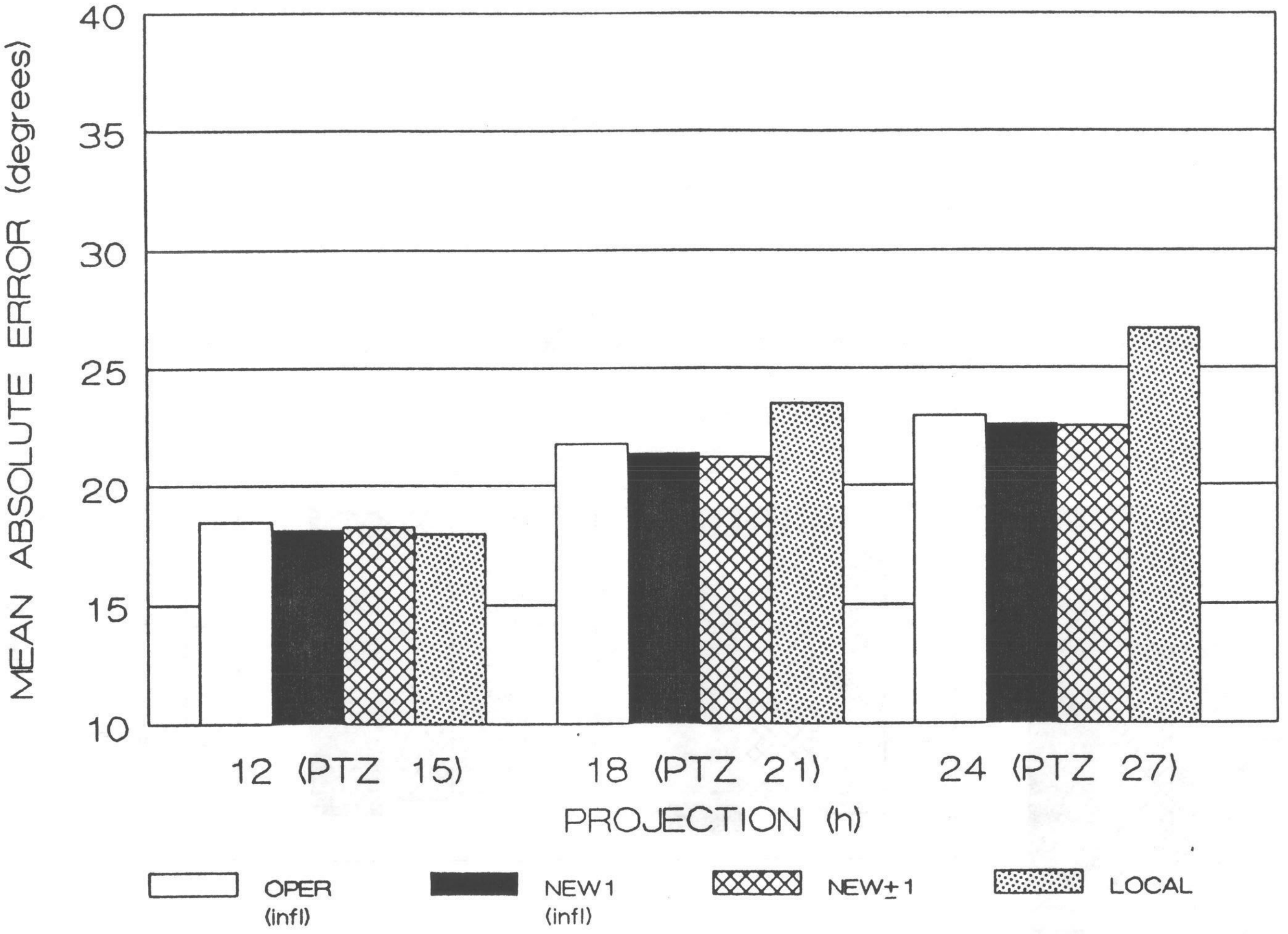

Figure 5. Same as Fig. 3, except for the MAE of wind direction forecasts.

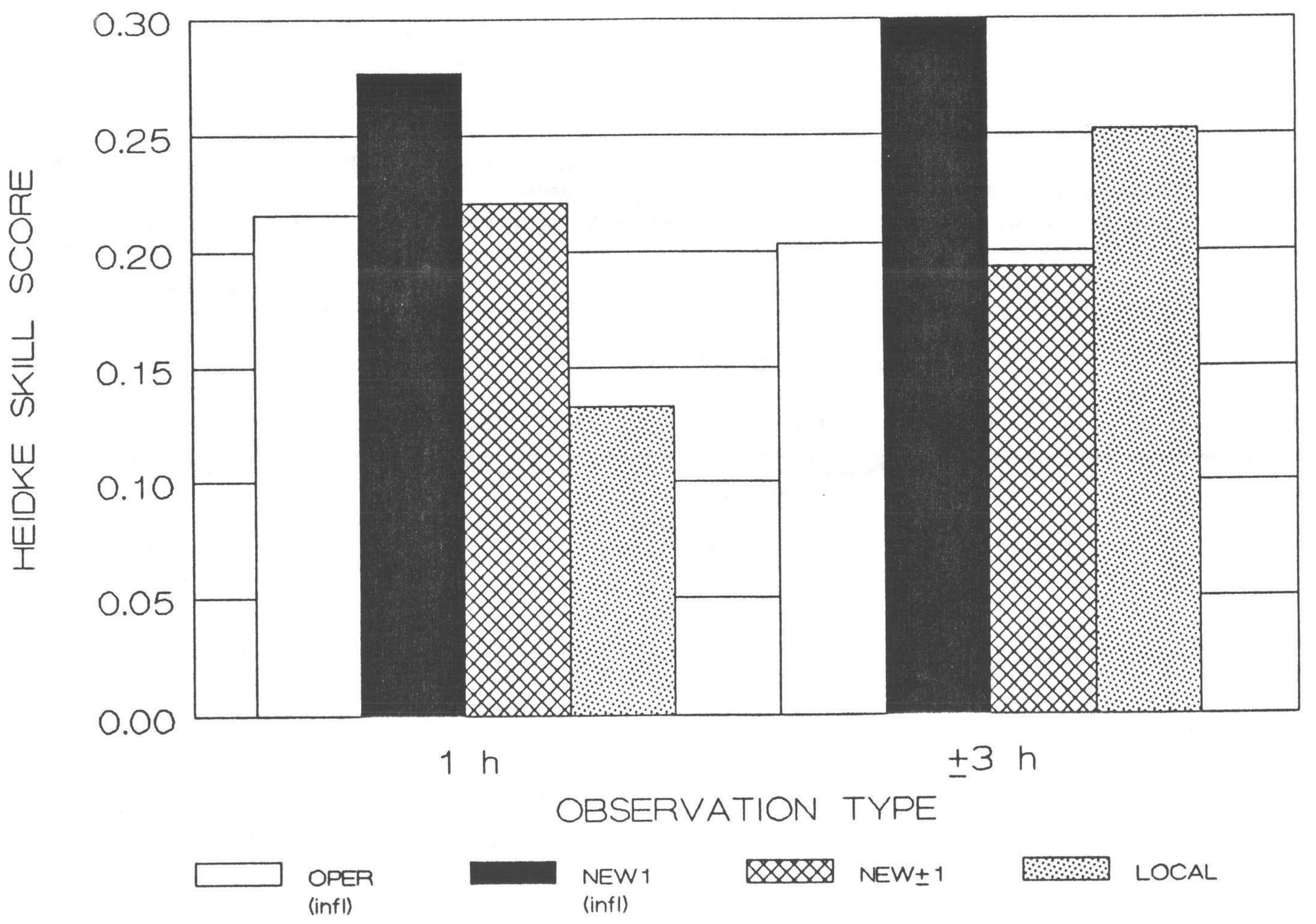

Figure 6. Skill scores of local, operational, and experimental MOS 42-hour significant wind speed forecasts. AEV criteria were used with the verifying observations at 1800 UTC and the highest wind speed ±3 hours of 1800 UTC. The results are from 26 October 1987 to 1 March 1988 and are valid for approximately 94 stations. All forecasts were based on 0000 UTC LFM data.

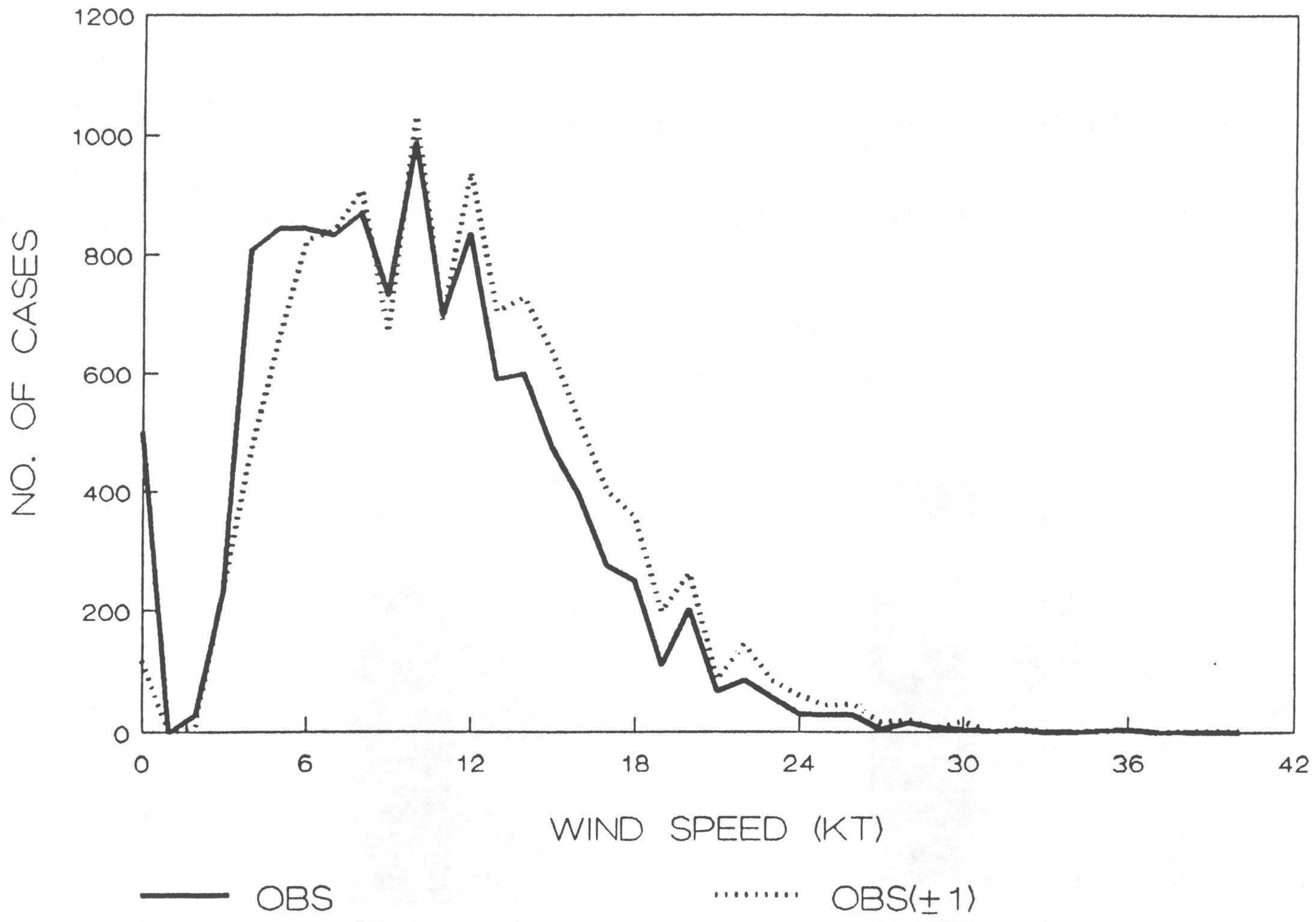

Figure 7a. Frequency distribution of the wind speed observed at 1800 UTC and the highest wind speed observed ±1 hour of 1800 UTC. Data are from approximately 94 stations for 26 October 1987 to 1 March 1988 (11752 cases).

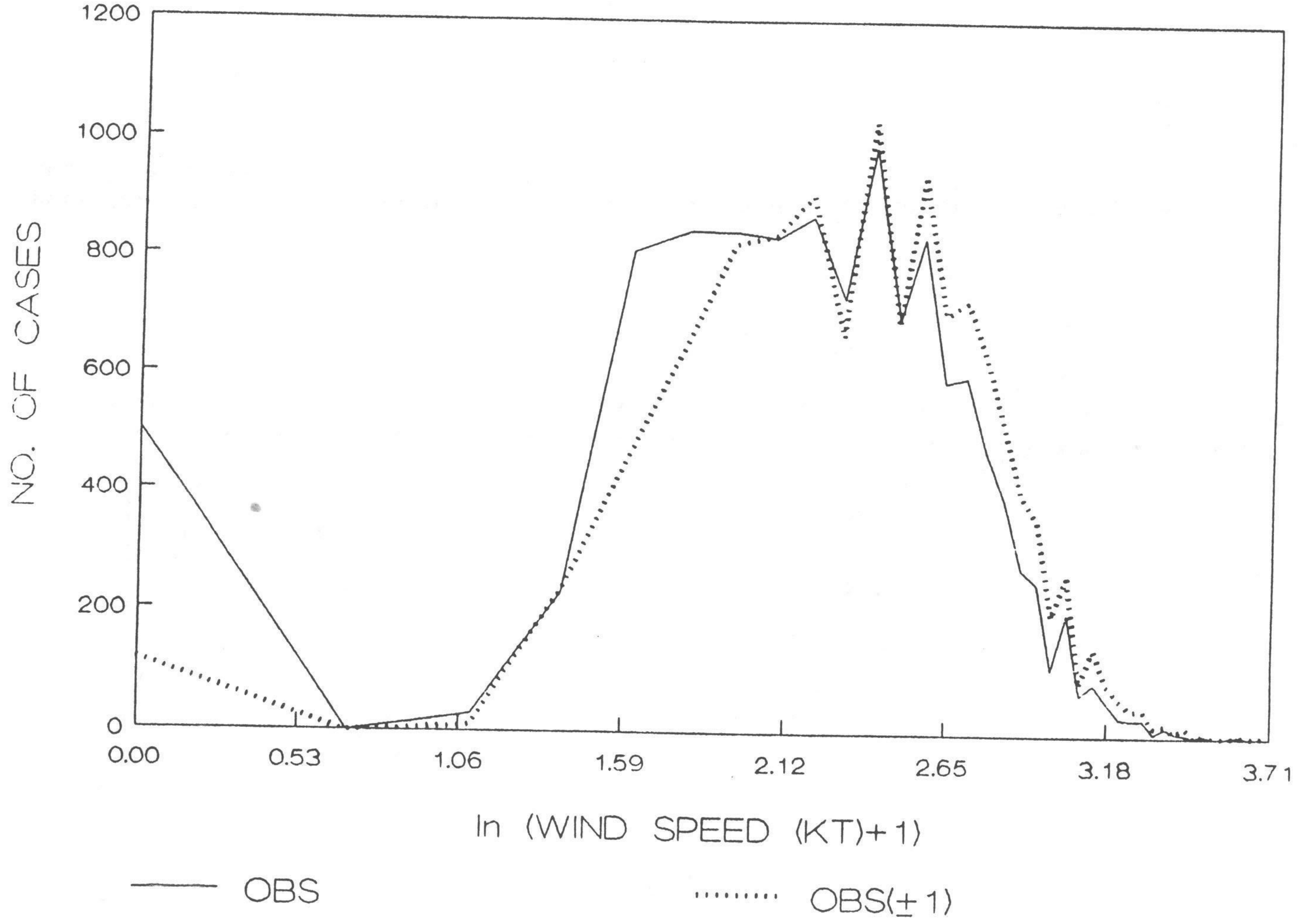

Figure 7b. Same as Fig. 7a, except that a ln transformation was applied to the observed data.

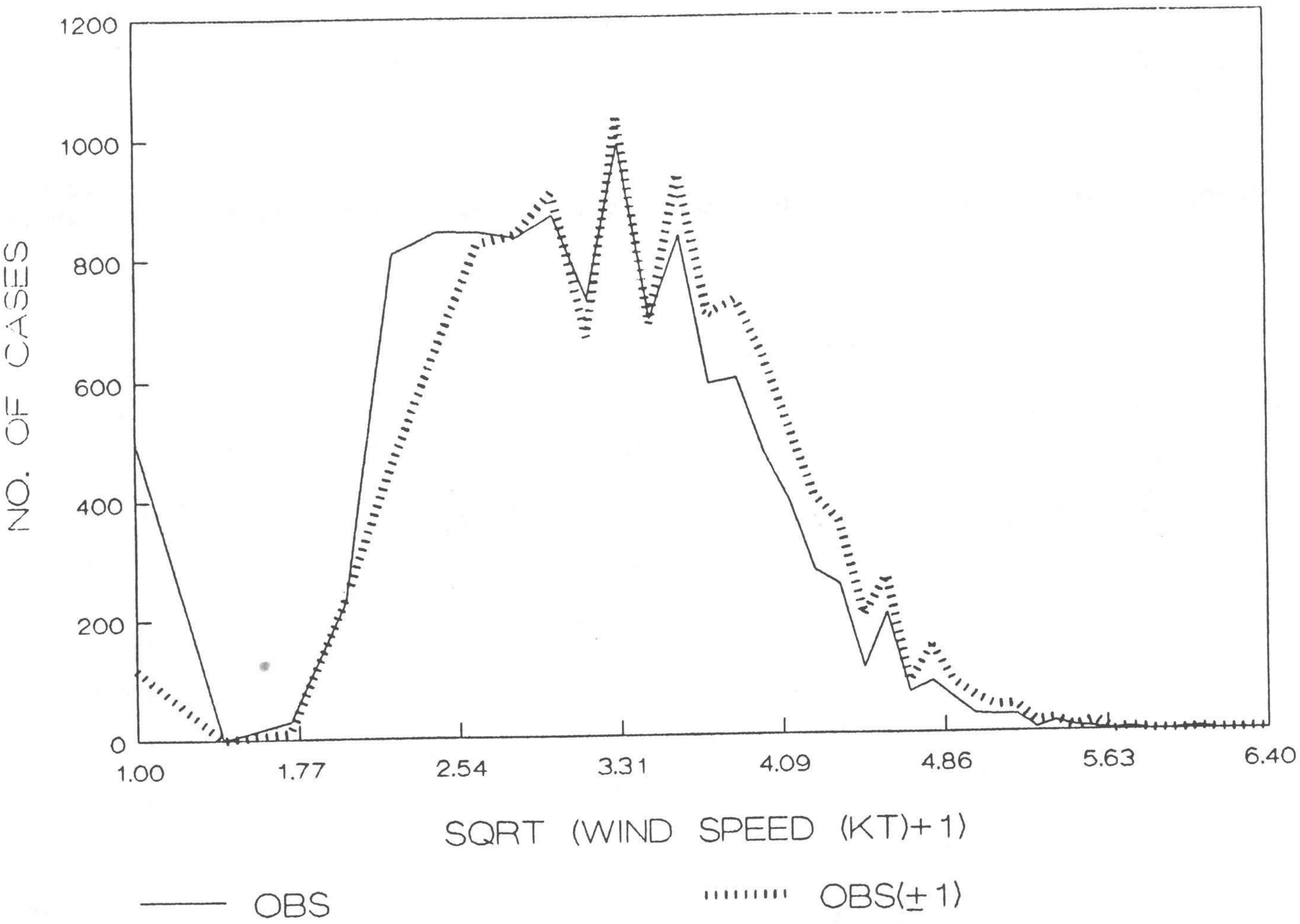

Figure 7c. Same as Fig. 7a, except that a square root transformation was applied to the observed data.

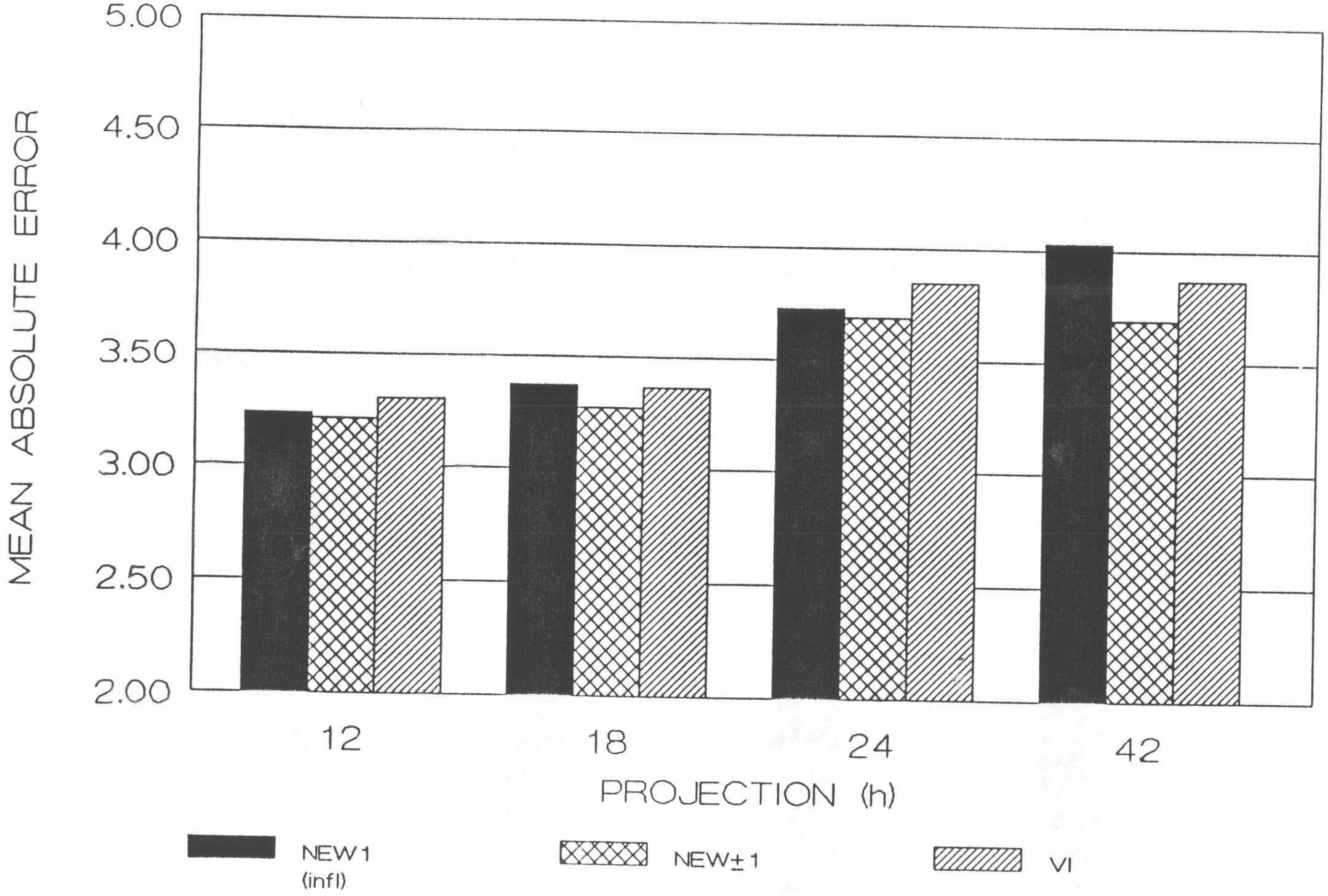

Figure 8a. MAE's of experimental MOS wind speed forecasts for NEW1, NEW±1, and VI. AEV criteria were used with the verifying observation at the specific hour. Results are from 26 October 1987 to 1 March 1988 and are valid for 84 stations. All forecasts were based on 0000 UTC LFM data.

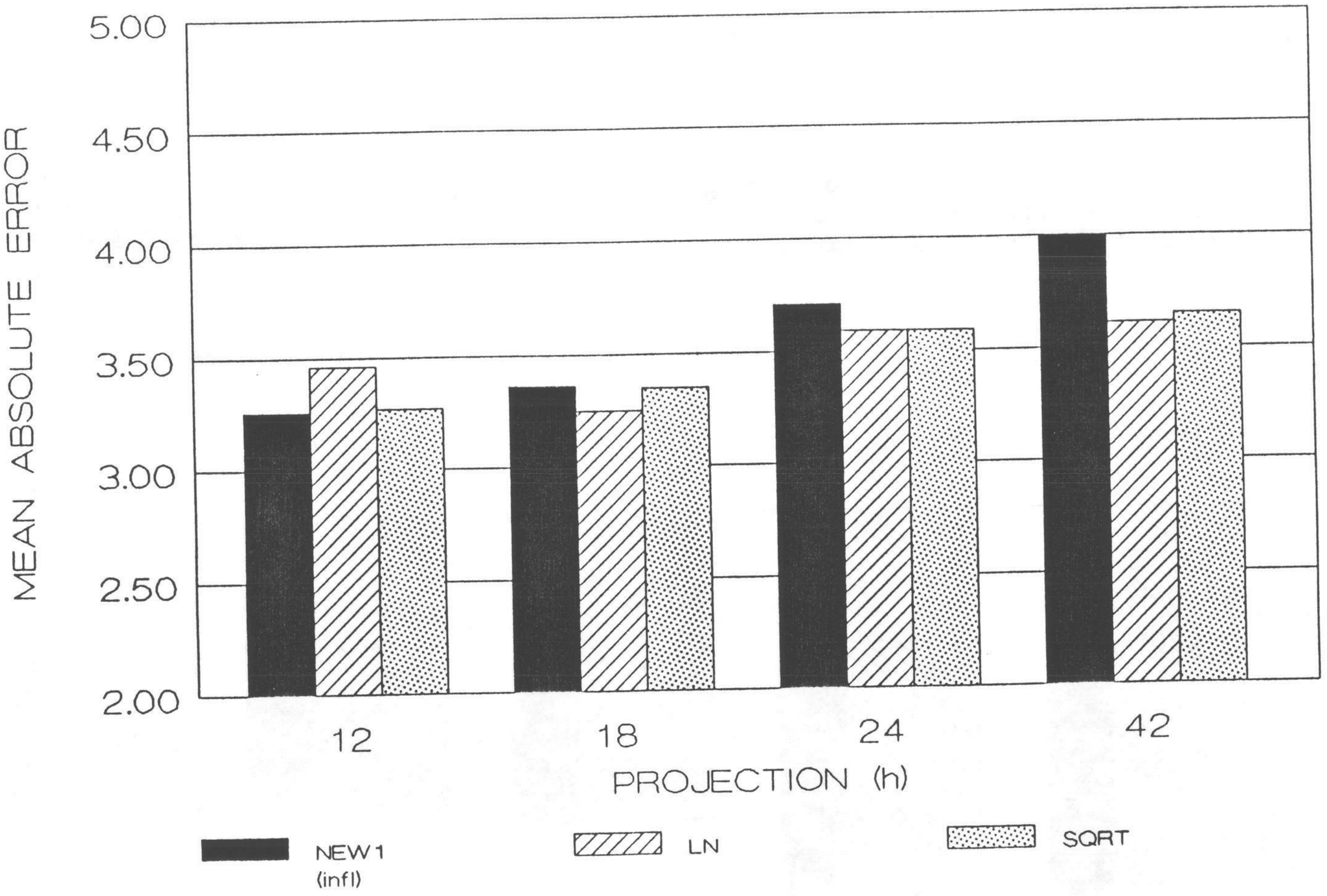

Figure 8b. Same as Fig. 8a, except for NEW1, LN, and SQRT. Note that because of the AEV criteria, there is a slightly different number of cases for the results shown in Figs. 8a and 8b.

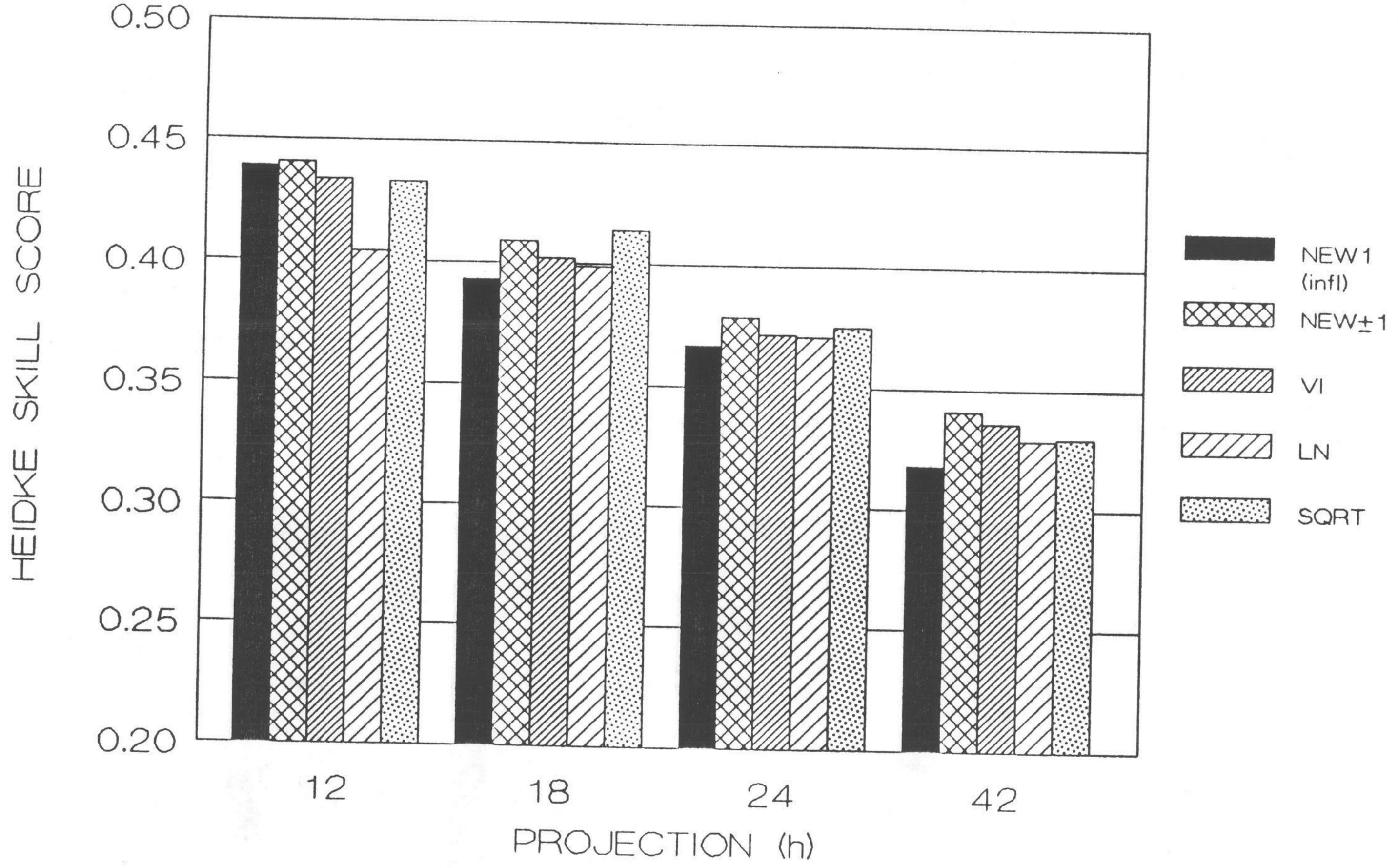

Figure 9. Skill scores of experimental MOS wind speed forecasts for NEW1, NEW±1, VI, LN, and SQRT. AEV criteria were used with the verifying observation at the specific hour. Results are from 26 October 1987 to 1 March 1988 and are valid for 84 stations. All forecasts were based on 0000 UTC LFM data.

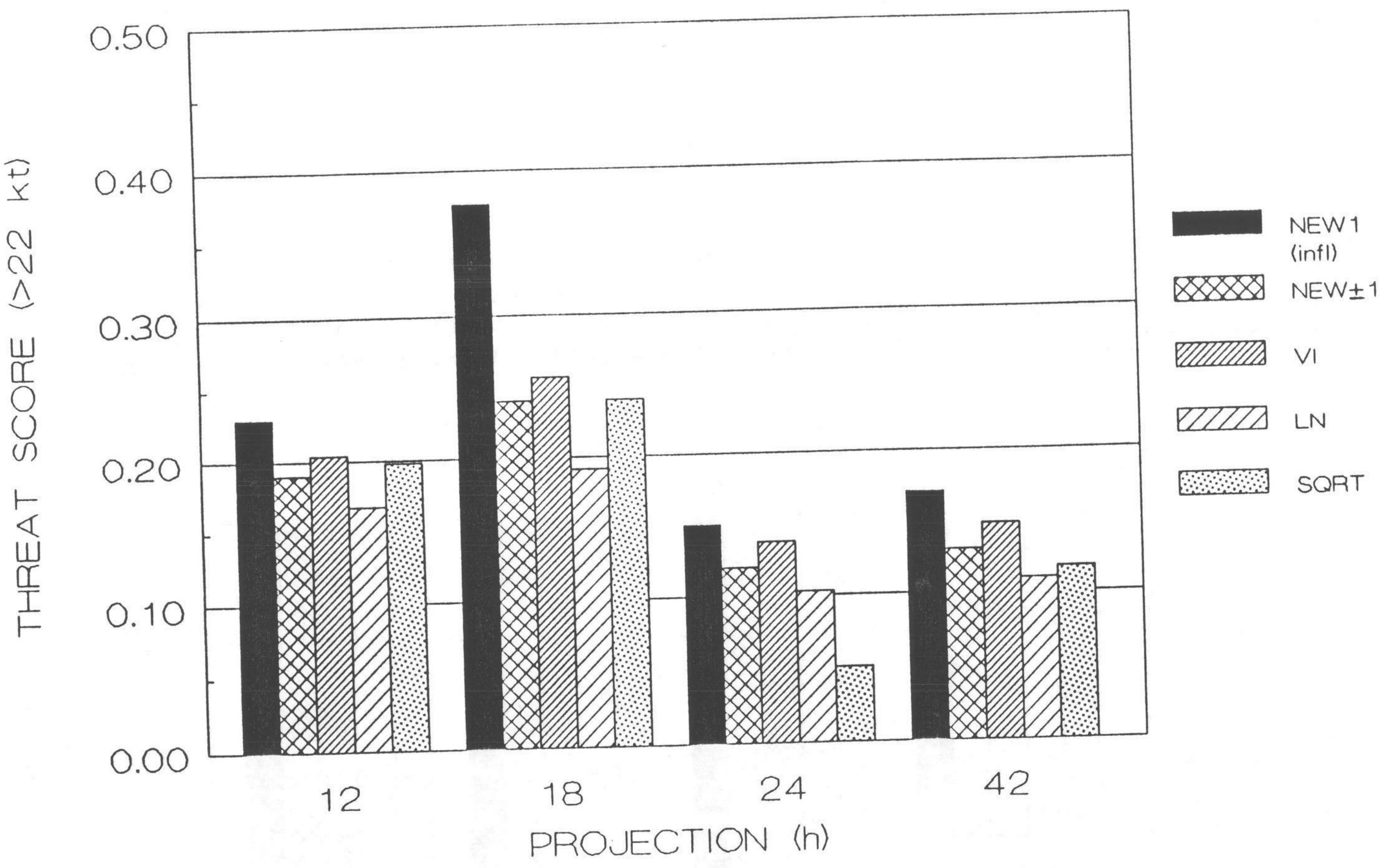

Figure 10. Same as Fig. 9, except for threat score.

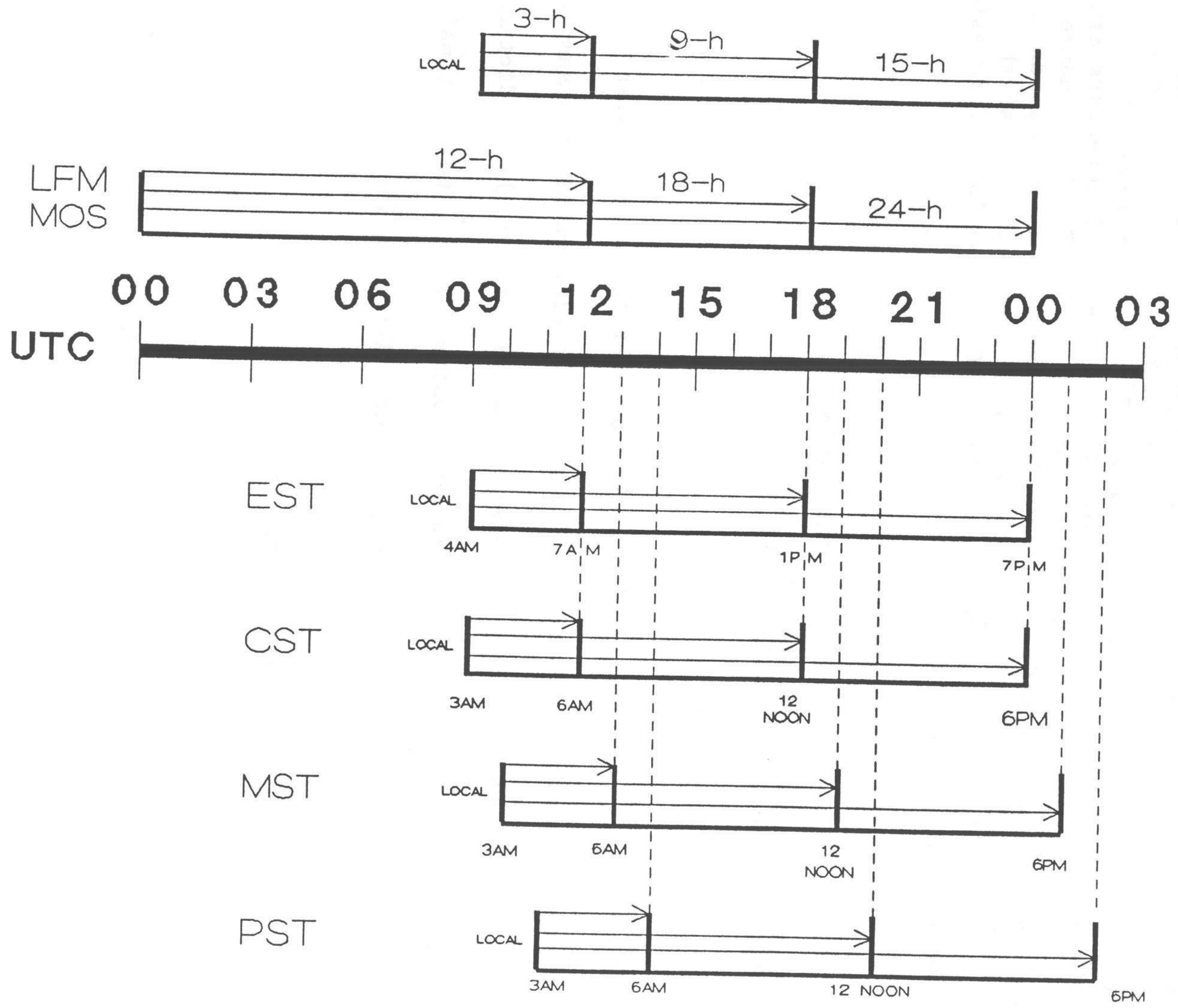

Figure 11. Schematic of local and MOS forecast issuance and valid times.

# APPENDIX I

## Local Wind Forecast Times

The schematic shown in Fig. 11 should help in understanding how the valid times of the local wind forecasts extracted from the FT's compare to UTC. The top half and bottom half of the figure are separated by a UTC time line. The top half shows the issuance and valid times for local and MOS forecasts based on 0000 UTC before the change in local issuance in December 1986. Note that the local forecasts have projections of only 3, 9, and 15 hours and that the valid times of both types of forecasts are the same.

The bottom half of the figure shows how the change in December 1986 affected the valid times of the local forecasts in standard time. In the ETZ, local forecasts are issued at 4 a.m. local time. For EST, that corresponds to 0900 UTC which means there is no change from before. The local forecasts are issued at 3 a.m. local time in the CTZ, MTZ, and PTZ. For CST, the issuance time also corresponds to 0900 UTC. For MST, the issuance time corresponds to 1000 UTC. Therefore, those local forecasts are valid 1 hour later than the MOS forecasts. For PST, the issuance time is 1100 UTC, so the local forecasts are valid 2 hours later than MOS.

# APPENDIX II

## Inflation Formulation

The traditional inflation formulation is:

$$\hat{S}_I = \frac{\hat{S} - \bar{S}}{R} + \bar{S},$$

where $\hat{S}$ is the original, unmodified wind speed forecast for a particular station, $\bar{S}$ is the mean value of wind speed from the developmental data sample for that station, R is the multiple correlation coefficient of the predictand with the predictors in that station's forecast equation, and $\hat{S}_I$ is the final inflated forecast of wind speed. The variable inflation equation is:

$$\hat{S}_I = \frac{\hat{S} - \bar{S}}{R + R(1 - R)} + \bar{S}.$$