National Weather Service
Office of Meteorology

Technical Procedures Bulletin

Subject: NGM-BASED MOS WIND GUIDANCE FOR ALASKA

Series No. 439

Program and Plans Division, **Silver Spring, MD 20910**

Abstract:

This Technical Procedures Bulletin (TPB), written by Joseph M. Foose of the Techniques Development Laboratory (TDL), describes the development and implementation of the Nested Grid Model (NGM)-based Model Output Statistics (MOS) wind speed and direction guidance for 60 stations in Alaska. This guidance was implemented in December 1994 and is available in the FOAK13 and FOAK14 (AFOS product FWCAK) messages containing NGM-based MOS guidance for Alaska. Similarly, the FOAK10, FOAK11, and FOAK12 messages transmitted to the U.S. Air Force communications system contain the NGM-based MOS guidance for military sites in Alaska. The present TPB describes the wind guidance in more complete detail than was done originally in TPB No. 425 which explains how to read the FOAK13 and FOAK14 products.

Paul Hirschberg
Chief, Science Plans Branch

U.S. DEPARTMENT OF COMMERCE **National Oceanic and Atmospheric Administration**

NGM-BASED MOS WIND GUIDANCE FOR ALASKA
by Joseph M. Foose

1. INTRODUCTION

The Techniques Development Laboratory (TDL) has developed linear regression equations to forecast surface wind speed and direction for Alaskan stations by using the Model Output Statistics (MOS) method (Glahn and Lowry 1972) on output from the Nested Grid Model (NGM) (Hoke et al. 1989). In the new NGM-based MOS system, forecasts are available for projections valid every 3 hours from 6 through 60 hours after the initial model time (0000 and 1200 UTC). This temporal resolution represents a substantial increase over the LFM-based MOS system in which forecasts were only available at 6-h intervals from 6 through 54 hours after initial model time (Maglaras 1983). The new wind guidance was implemented in December 1994 and is disseminated in the FOAK13 and FOAK14 messages (Dallavalle et al. 1995).

2. METHOD

In the development, the predictands, namely the surface wind speed and u- and v-components, were related statistically to predictors such as variables interpolated from the NGM gridpoint fields, climatic variables, and observations. The relationship between the predictands and predictors was determined by multiple linear regression. The MOS approach selects predictors on the basis of their contribution to the reduction of variance. The variable chosen first is the one that produces the greatest reduction in variance in the predictand. Subsequent predictors are selected in an order determined by the amount of variance explained when combined in the equation with variables already chosen. Selection is terminated when no remaining predictor contributes greater than 0.75% to the reduction of variance or when a maximum of 12 predictors has been selected.

3. DEVELOPMENT

a. Developmental Sample

The developmental sample was divided into two seasons, cool (October through March) and warm (April through September). The sample for the cool season contained data from October 1986 through March 1994, while the warm season consisted of data from April 1987 through September 1994. Two weeks of data were added to the developmental sample at the beginning and end of each season to enhance continuity between the two seasonal sets of equations. Prior to the final development, test equations were created by reserving the 1994 warm and 1993-94 cool seasons as independent data and using the remainder of the sample as dependent data. Forecasts from the test equations were made on the independent seasons. We then did comparative verifications between the NGM and LFM MOS wind guidance (see Section 3.f).

b. Predictands

For predictands, we used the surface u- and v-wind components and the wind speed obtained from the hourly surface aviation observations. The wind observations represent a 1-minute average value. The u- and v-components are not reported directly, of course, but are computed from the speed and direction observations. The u- and v- predictands are used to develop equations for the wind components from which the wind direction can be computed. The components are used because the wind direction is not easily dealt with by linear regression. Wind speed forecasts are not computed from the forecast u- and v-components because forecasts generated from the components are less accurate than forecasts produced from an equation predicting the speed directly (Glahn 1970). Hence, three predictands are used to develop the equations required to forecast wind speed and direction.

c. Predictors

Predictors which could have been selected by the regression analysis included NGM gridpoint fields interpolated to stations and the sinusoidal functions of the day and twice the day of the year. For the 6-, 9-, and 12-h forecast equations, the wind speed and direction observations at 2 hours after the initial model times were also offered as possible predictors. Since observations were offered at the 6-, 9-, and 12-h projections as predictors, "backup" equations were also developed for these projections. The backup equations which do not have observations as predictors are used in case the wind reports are not available for the primary equations. The NGM variables were available every 6 hours from initial model time up to and including 48 hours. Wind forecast equations for the 6-, 12-, 18- ,..., and 48-h projections were developed by offering variables valid at their respective projection and before and after the projection to compensate for any possible time bias in the model. For example, the regression analysis for the 12-h projection was offered model variables at the 6-, 12-, and 18-h projections. For wind guidance forecast projections which did not have coincident model projections, we offered predictors from the projections immediately preceding and following the desired forecast time.

We also averaged the NGM variables which preceded and followed the desired forecast time and offered the result as a predictor to the regression analysis. For example, the regression analysis for the 9-h projection was offered 6- and 12-h model fields along with the average of the model fields at the 6- and 12-h projections. For projections after 48 hours where no model data existed, model variables valid at 48 hours after initial model time were used as predictors.
Most model gridpoint data were smoothed before interpolation as potential predictors. The smoothing compensates for small-scale noise in the model fields. Smoothing increases with projection as the model's skill decreases; therefore, predictors for earlier projections are smoothed over 5 or 9 gridpoints while model predictors for projections after 42 hours are smoothed over 9 or 25 points.

NGM predictors which were commonly selected by the regression routine included the 10-meter u- and v-components and speed, 950- and 850-mb geostrophic u- and v-components and speed, 850-mb vertical velocity, and 850- and 700-mb relative vorticities. The 0200 and 1400 UTC wind observations were often selected in the 6-, 9-, and 12-h equations, and for many projections, the sinusoidal functions of the day of the year were used.

d. Equation Development
With one exception, all forecast equations were developed by using the single-station approach in

which equations are derived for the individual sites. Due to a shortage of predictand data, a regional equation was developed for Cape Lisburne by using data from Kotzebue and Barrow. For all sites, equations were developed simultaneously for wind speed and the u- and the v-components. The simultaneous derivation produced three equations which use the same predictors, but with different coefficients. We developed a set of equations for each projection (6-, 9-, 12-,..., and 60-h), for both cycles, both seasons, and all stations. Backup equations were also developed for the 6-, 9-, and 12-h projections for both cycles, both seasons, and all stations. The linear regression equation used to forecast wind speed 12 hours after 0000 UTC during the cool season for Nome is shown in Table 1. The first column gives a description of each predictor. The predictors are listed in the order they were chosen by the regression analysis. The projection of each predictor, or time after initial model time of an observation used as a predictor, is listed in the PROJ column in hours. The COEFF column lists the coefficient for each predictor.

e. Inflation of Wind Speed Forecasts

All wind speed forecasts in the operational messages go through an inflation routine which increases the standard deviation of the distribution of wind speed forecasts (Carter and Schwartz 1985). This is done to increase the frequency of higher-speed forecasts. The inflation procedure essentially increases the difference between the forecast wind speed and the mean wind speed observed during the developmental sample. As a consequence, wind speeds greater than the mean are increased, while wind speeds less than the mean are decreased.

f. Verification

As previously mentioned, test equations were generated for both seasons before final development. From the test equations, forecasts were made on independent data and compared to the then-operational LFM MOS forecasts. Again, the independent data used for the cool season ranged from October 1993 through March 1994 while the warm season extended from April 1994 through September 1994. Also, to compare the new NGM MOS forecasts with LFM MOS forecasts, only stations with available LFM MOS wind guidance were used. This limited the verifications to approximately 35 stations. Use of the LFM MOS also restricted the projections which could be verified to 6-, 12-, 18-,..., and 54-h after initial model times rather than the whole suite of NGM MOS projections.

The wind speed forecasts were verified in terms of the Heidke skill score (HSS), critical success index (CSI) or threat score, and mean absolute error (MAE). All wind speed forecasts were inflated (see Section 3.e) before verification. Typically, approximately 6000 cases were verified for each projection. Wind direction forecasts were verified in terms of the HSS and MAE. Wind direction forecasts were verified only when the wind speed observation valid at the time of the forecast was greater than or equal to 6 knots. This prevents direction forecasts associated with light and variable winds from degrading verification scores and reduces the number of cases to approximately 3500. Both the HSS and CSI were obtained from contingency tables of the wind speed and wind direction. The HSS measures the skill of the forecasts where a value of one indicates that all forecasts are correct. The CSI gauges the skill of the wind speed forecasts during a significant wind event, in this case, a wind in excess 22 kt. The CSI varies from 0 to 1, with a higher score being desirable. The MAE measures the average absolute difference between the forecasts and observations.

Figures 1 through 6 show wind speed verifications for 0000 UTC. Figures 1 and 2 compare the Heidke skill scores for the LFM and NGM MOS wind speed forecasts for the cool and warm seasons, respectively. For both seasons, the skill of the NGM MOS is higher at every projection. The CSI for the LFM and NGM MOS wind speed forecasts is shown for the cool season in Fig. 3 and for the warm season in Fig. 4. The NGM MOS showed improvement over the LFM MOS at nearly every projection and both seasons. Figures 5 and 6 are comparisons between the MAE for the LFM and NGM MOS wind speed forecasts for the cool and warm seasons, respectively. At every projection and both seasons, the NGM MOS had lower errors than the LFM MOS. Results for the 1200 UTC cycle were similar.

Figures 7 through 10 show verifications for the wind direction forecasts for 0000 UTC. The HSS for LFM and NGM MOS is shown for the cool season in Fig. 7 and the warm season in Fig. 8. As with the wind speed forecasts, the NGM MOS skill scores were higher for all projections and both seasons; however, wind direction scores generally show smaller improvements over the LFM MOS than the wind speed skill scores. Lastly, MAE values for LFM and NGM MOS wind direction forecasts are shown for the cool season in Fig. 9 and the warm season in Fig. 10. The cool season errors are less consistent than previous verifications. Although the NGM MOS shows improvement at the majority of projections, for the 30-, 36-, and 54-h projections, the LFM MOS had slightly lower errors. The warm season NGM MOS mean absolute errors (Fig. 10) are less than LFM MOS errors at every projection excluding 54 hours.
Warm season Heidke skill scores reveal a pattern where the score is a local minimum at the 24- and 48-h projections. These projections coincide with valid times in which, on average, maximum convective activity is occurring.

4. OPERATIONAL CONCERNS

Forecasters should be aware that when predictor observations are not available for the 6-, 9-, and 12-h forecast equations forecasts will be made by using the backup equations. This may produce forecasts which are less skillful than forecasts based on the primary equations.
Since some Alaskan stations had no observational data for certain projections, equations could not be developed; therefore, these stations do not have complete sets of equations. Table 2 lists all the stations in the Alaskan wind guidance development and the projections for which forecasts are unavailable.

The inflation routine (see Section 3.e) increases the frequency of higher-speed forecasts and as a result increases the critical success index (see Section 3.f). However, when the Alaska wind speed guidance was examined operationally, some forecasts were noted as being "over-inflated" and probably represented wind gusts rather than sustained speeds. Miller (1993) also noted this overforecast tendency in the contiguous United States.
The cool season equations for Alaska generally had higher reductions of variance than the warm season equations. This difference is probably due to the large scale forcing mechanisms present during the cool season as opposed to the more local convective influences during the warm

season (Miller 1993).

The wind guidance for Alaska is disseminated in the FOAK13 and FOAK14 message along with other weather elements. The surface wind speed is given in knots and the direction in degrees divided by ten. A sample message for Nome, Alaska, is shown in Fig. 11 with the wind speed and direction lines highlighted.

5. ACKNOWLEDGMENTS

I would like to thank both Chad Southall and Brent Bower for their work with the Alaskan wind guidance development and Paul Dallavalle for his assistance throughout the project.

6. REFERENCES

Carter, G. M., and B. E. Schwartz, 1985: The use of Model Output Statistics (MOS) for predicting surface wind. NWS Technical Procedures Bulletin No. 347, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 11 pp.

Dallavalle, J. P., S. A. Gilbert, and F. G. Meyer, 1995: NGM-based MOS guidance for Alaska - the FOAK13/FOAK14 messages. NWS Technical Procedures Bulletin No. 425, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 13 pp.

Glahn, H. R., 1970: A method for predicting surface winds. ESSA Technical Memorandum WBTM TDL 29, Environmental Science Services Administration, U.S. Department of Commerce, 18 pp.

_____, and D. A. Lowry, 1972: The use of Model Output Statistics (MOS) in objective weather forecasting. J. Appl. Meteor., 11, 1203-1211.

Hoke, J. E., N. A. Phillips, G. J. DiMego, J. J. Tuccillo, and J. G. Sela, 1989: The regional analysis and forecast system of the National Meteorological Center. Wea. Forecasting, 4, 323-334.

Maglaras, G., 1983: Alaskan temperature, surface wind, probability of precipitation, conditional probability of frozen precipitation, and cloud amount guidance (FMAK1 bulletin). NWS Technical Procedures Bulletin No. 329, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 16 pp.

Miller, D. T., 1993: NGM-based MOS wind guidance for the contiguous United States. NWS Technical Procedures Bulletin No. 399, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 19 pp.

Table 1. Linear regression equation to forecast wind speed for Nome during the cool season. The equation produces forecasts which are valid 12 hours after 0000 UTC.

PREDICTOR	PROJ	COEFF
950-mb geostrophic wind speed	12	0.6870
10-m earth oriented V-component	12	-0.4279
10-m earth oriented U-component	12	-0.2227
950-mb earth oriented V-component	12	0.4074
Observed wind speed	2	0.2142
Observed U-component	2	-0.0383
Observed V-component	2	-0.0195
950-mb geostrophic U-component	18	0.0403
10-m earth oriented wind speed	12	0.0992
950-mb geostrophic wind speed	6	-0.1951

Equation constant = 0.5066

Table 2. List of Alaska Stations for which NGM MOS guidance is available. The hours listed in the columns indicate those forecast projections for which guidance is unavailable

.	.	Cool Season		Warm Season	
Call Letters	**Station Name**	**0000 UTC**	**1200 UTC**	**0000 UTC**	**1200 UTC**
ADQ	Kodiak	-	-	-	-
AKN	King Salmon	-	-	-	-
ANC	Anchorage	-	-	-	-
ANI	Aniak	-	-	-	-
ANN	Annette Island	06,09,27,30,33,51,54,57	15,18,21,39,42,45	06,27,30,51,54	15,18,39,42
BET	Bethel	-	-	-	-
BIG	Big Delta	-	-	-	-
BRW	Barrow	-	-	-	-
BTI	Barter Island	-	-	-	-
BTT	Bettles	-	-	-	-
CDB	Cold Bay	-	-	-	-
CDV	Cordova	-	-	-	-
DLG	Dillingham	-	-	-	-
DUT	Dutch Harbor	-	-	-	-
ENA	Kenai	-	-	-	-

ENN	Nenana	-	-	-	-
FAI	Fairbanks	-	-	-	-
FYU	Fort Yukon	-	-	-	-
GAM	Gambell	-	-	-	-
GKN	Gulkana	-	-	-	-
HOM	Homer	-	-	-	-
ILI	Iliamna	-	-	-	-
JNU	Juneau	-	-	-	-
KTN	Ketchikan	-	-	-	-
MCG	McGrath	-	-	-	-
MDO	Middleton	-	-	-	-
MRI	Merrill Field	-	-	-	-
OME	Nome	-	-	-	-
ORT	Northway	-	-	-	-
OTZ	Kotzebue	-	-	-	-
PACZ	Cape Romanzoff	-	-	-	-
PAED	Elmendorf AFB	-	-	-	-
PAEH	Cape Newenham	-	-	-	-
PAEI	Eielson AFB	-	-	-	-
PAGA	Galena	-	-	-	-

PAIM	Indian Mountain	-	-	-	-
PALU	Cape Lisburne	-	-	-	-
PAQ	Palmer	09,12,33,36,57,60	21,24,45,46	16,19,12,30,33,36,54,57,60	18,21,24,42,45,48
PASV	Sparrevohn	-	-	-	-
PATC	Tin City AFS	-	-	-	-
PATL	Tatalina AFS	-	-	-	-
PSG	Petersburg	-	-	-	-
PTH	Port Heiden	-	-	-	-
PUO	Prudhoe Bay	-	-	-	-
SCC	Deadhorse	-	-	-	-
SGY	Skagway	06,09,12,27,30,33,36,51,54,57,60	15,18,21,24,39,42,45,48,54,57,60	06,09,12,27,15,18,21,24	15,18,21,24,39,42,45,48
SIT	Sitka	-	-	-	-
SNP	Saint Paul	-	-	-	-
TAL	Tanana	09,12,33,36,57,60	21,24,45,48,57,60	09,12,33,36,	21,24,45,48
TKA	Talkeetna	-	-	-	-
UNK	Unalakleet	-	-	-	-

VDZ	Vaidez	06,09,12,30,33,36,54,57,60	18,21,24,42,45,48,57,60	09,12,33,36,	21,24,45,48 -
VWS	Valdez WSO	-	-	-	-
WRG	Wrangell	-	-	-	-
YAK	Yakutat	-	-	-	-
Z26	Haines	09,12,33,36,57,60	21,24,45,48,57,60	09,12,33,36,	21,24,45,48
5WD	Seward	27,51	15,39	27,51	15,39
5WT	Whittier	-	-	-	-

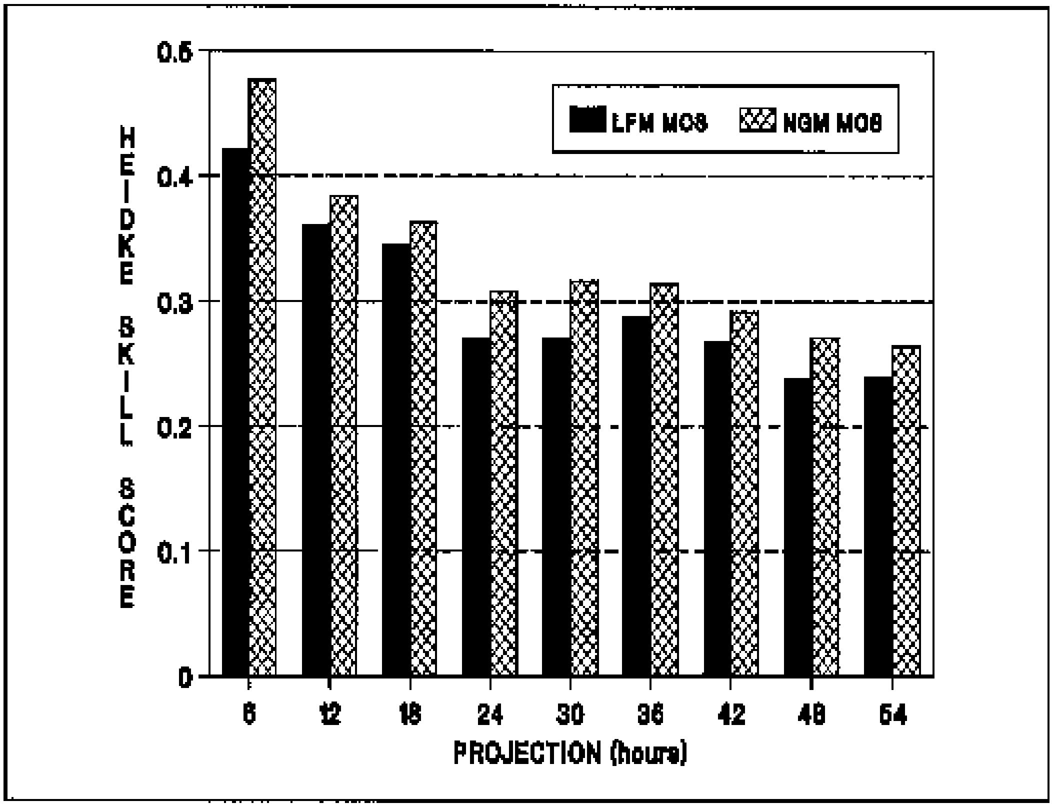

Figure 1. Heidke skill scores for wind speed forecasts for approximately 35 Alaskan stations during the 1993-94 cool season, 0000 UTC cycle.

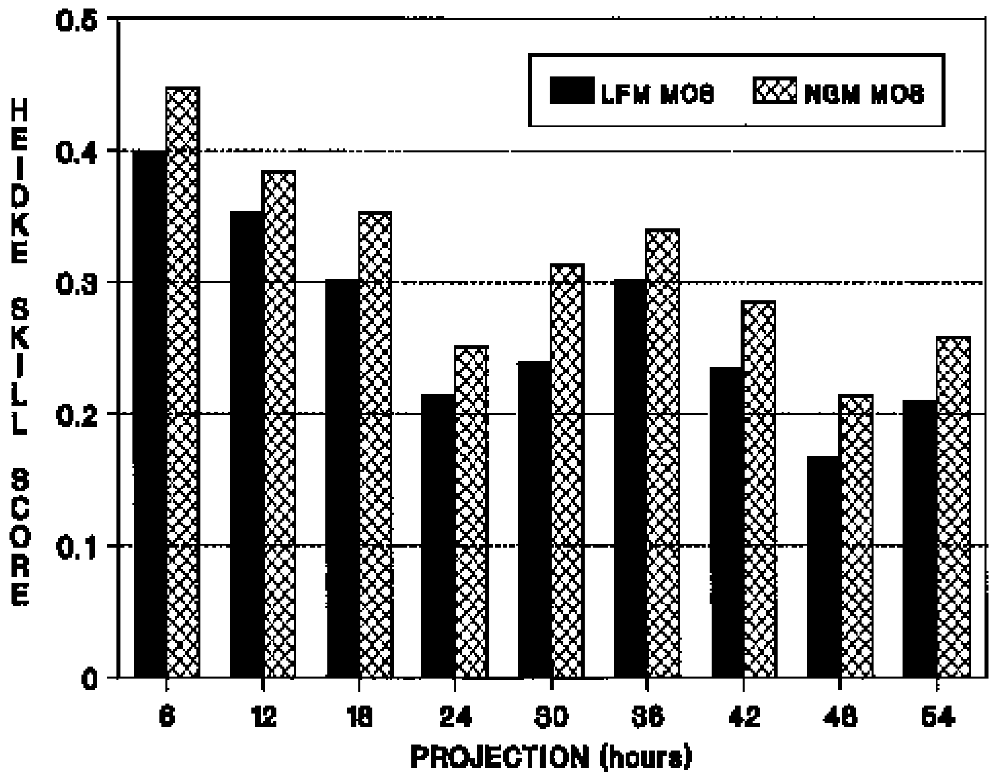

Figure 2. Same as Fig. 1 except for the 1994 warm season.

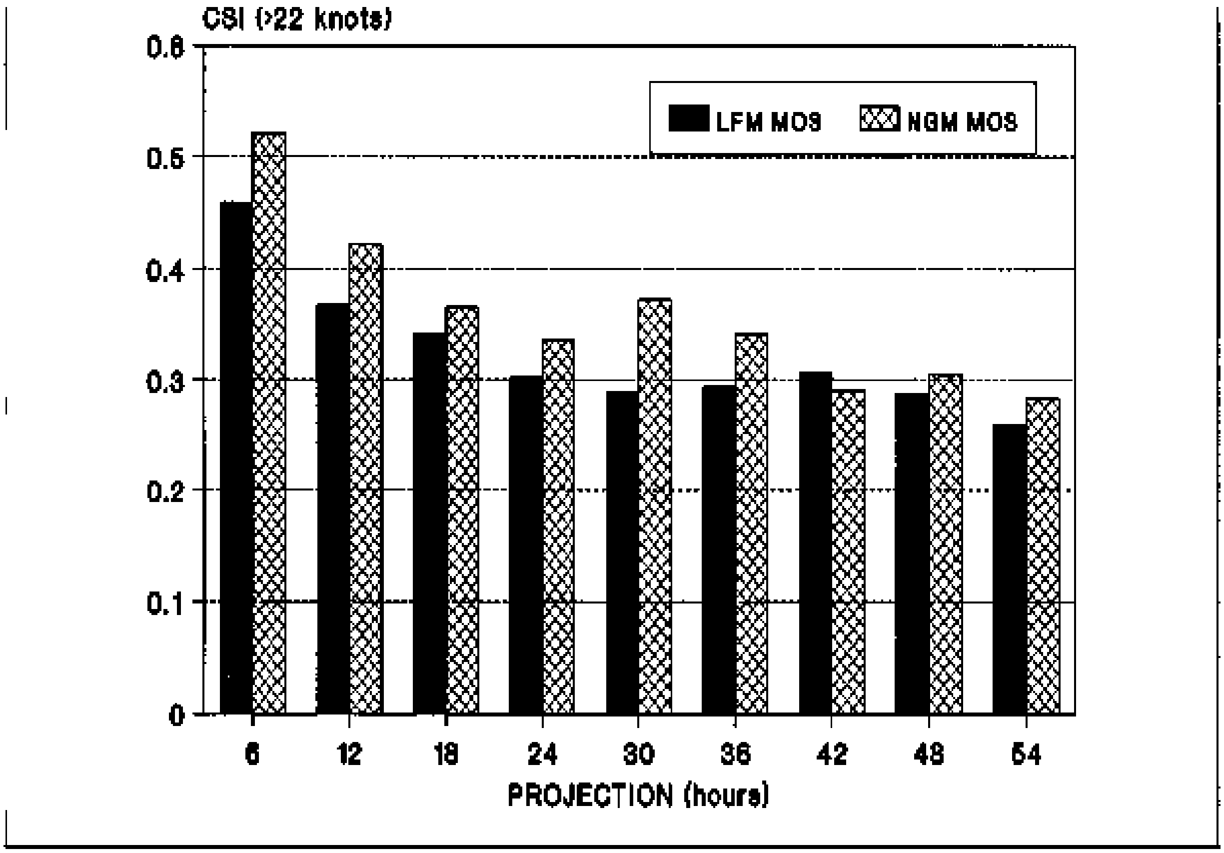

Figure 3. Critical success indices (CSI) for wind speed in excess of 22 kt for approximately 35 Alaskan stations during the 1993-94 cool season, 0000 UTC cycle.

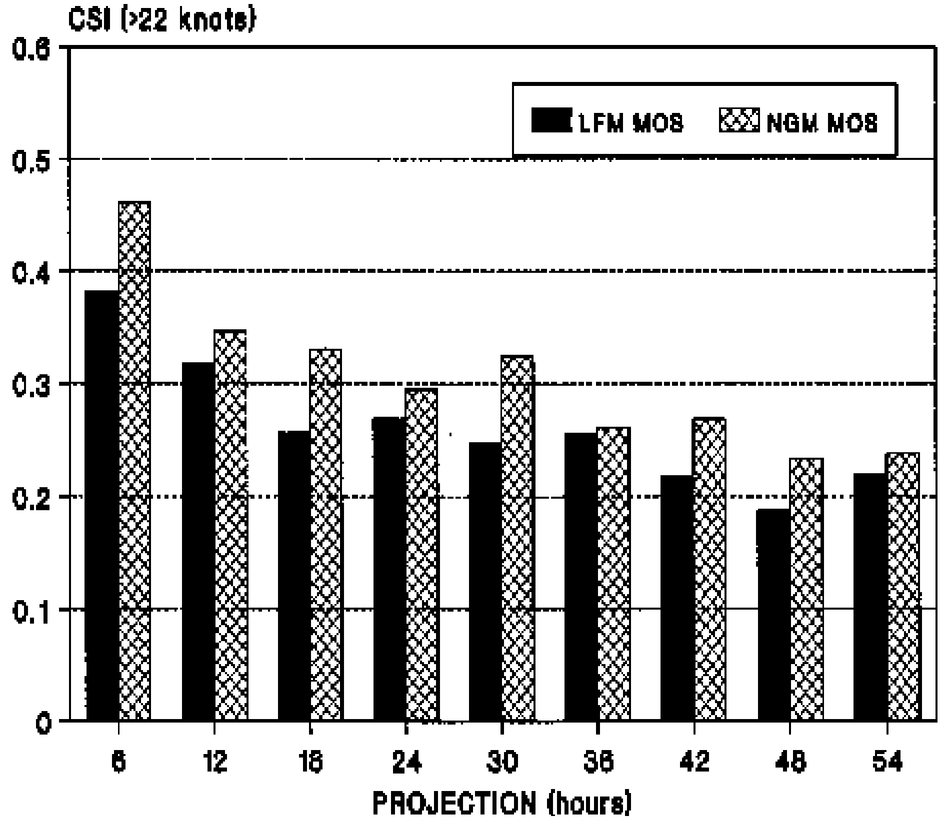

Figure 4. Same as Fig. 3 except for the 1994 warm season.

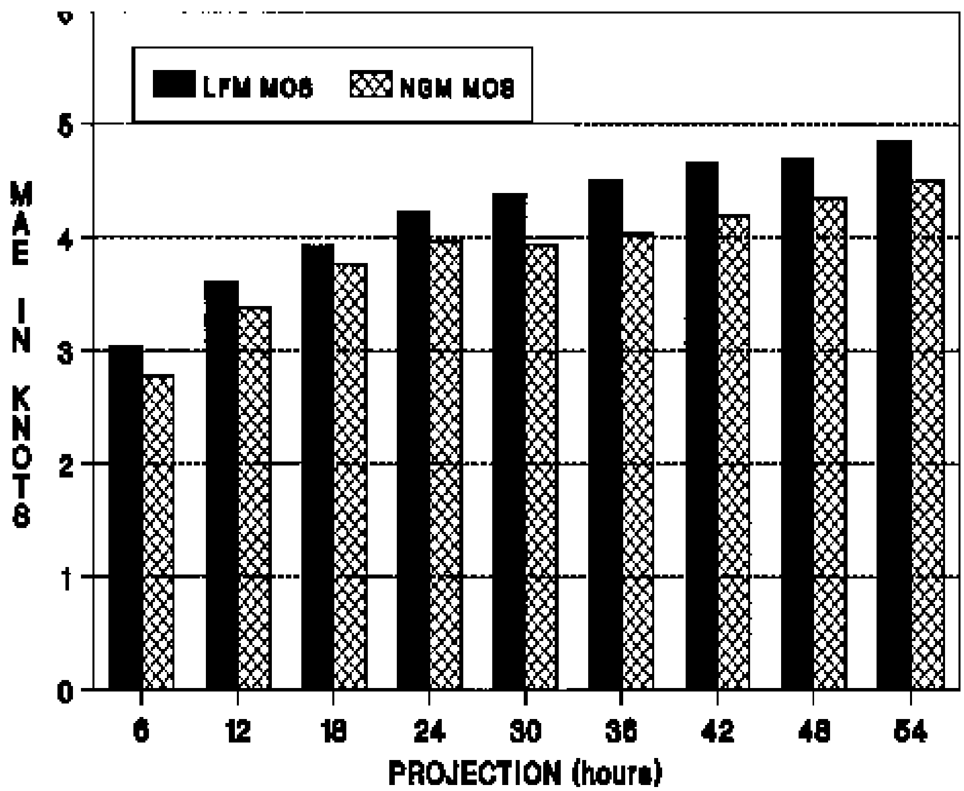

Figure 5. Mean absolute errors (MAE) for wind speed forecasts for approximately 35 Alaskan stations during the 1993-94 cool season, 0000 UTC cycle.

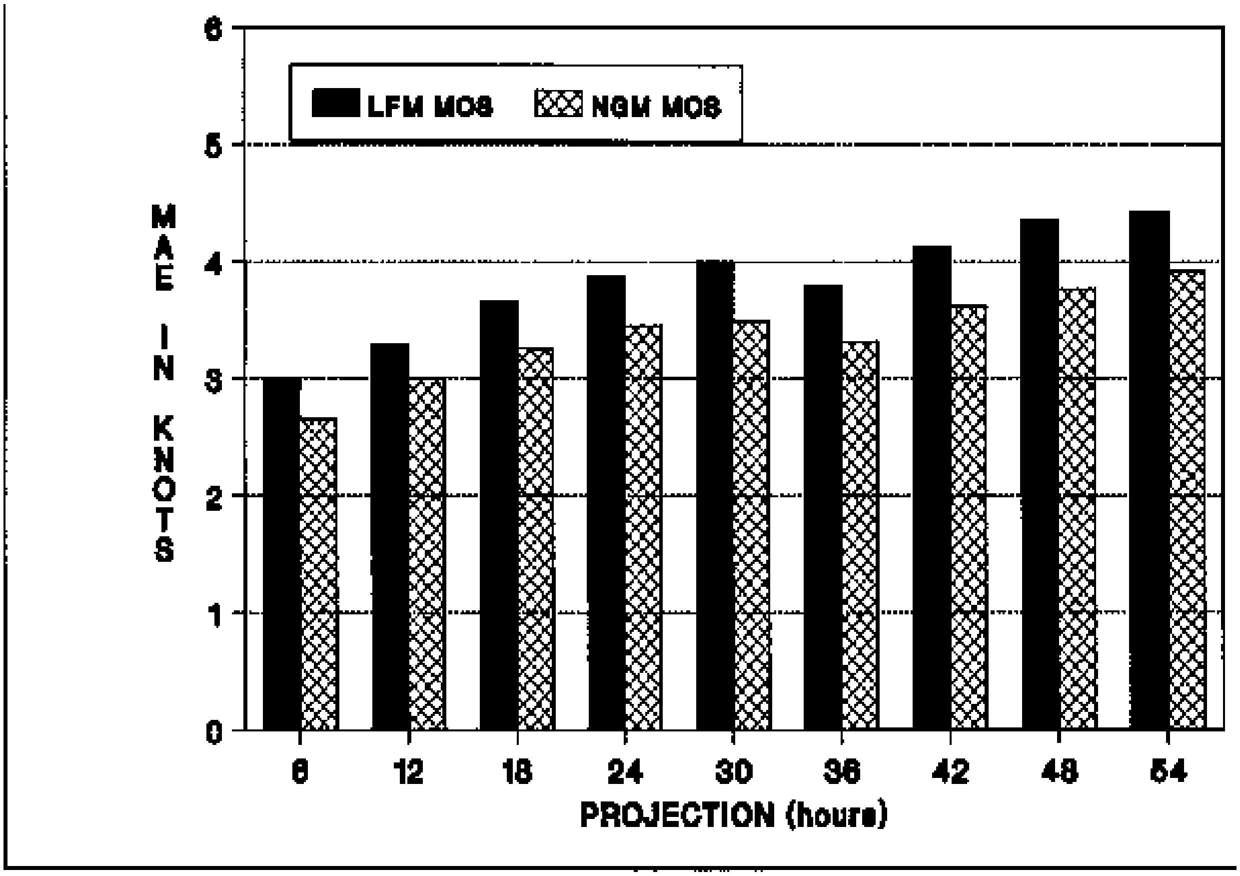

Figure 6. Same as Fig. 5 except for the 1994 warm season.

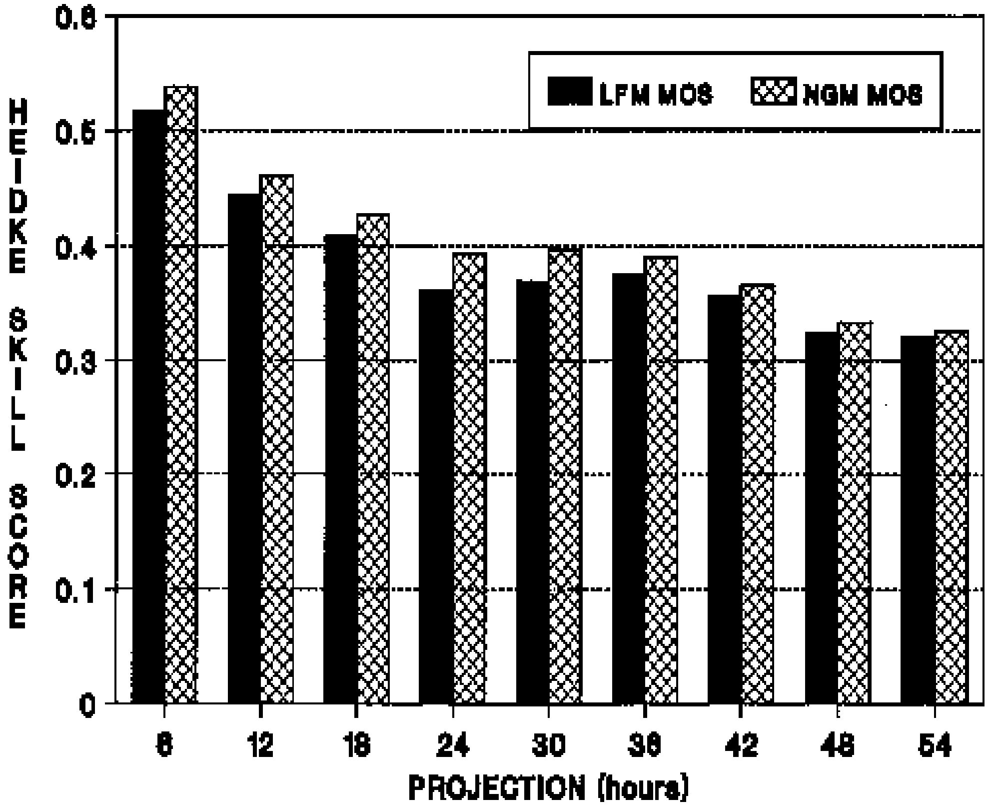

Figure 7. Heidke skill scores for wind direction forecasts for approximately 35 Alaskan stations during the 1993-94 cool season, 0000 UTC cycle.

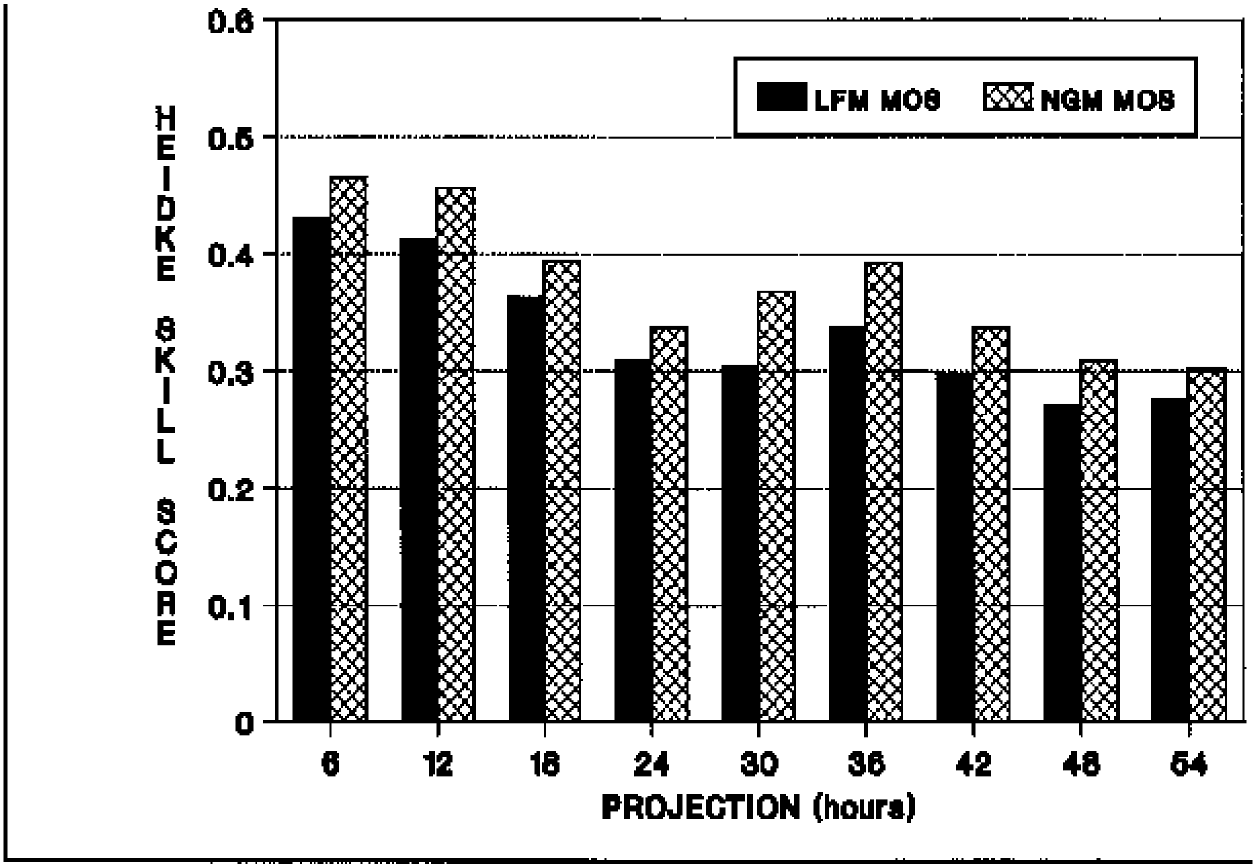

Figure 8. Same as Fig. 7 except for the 1994 warm season.

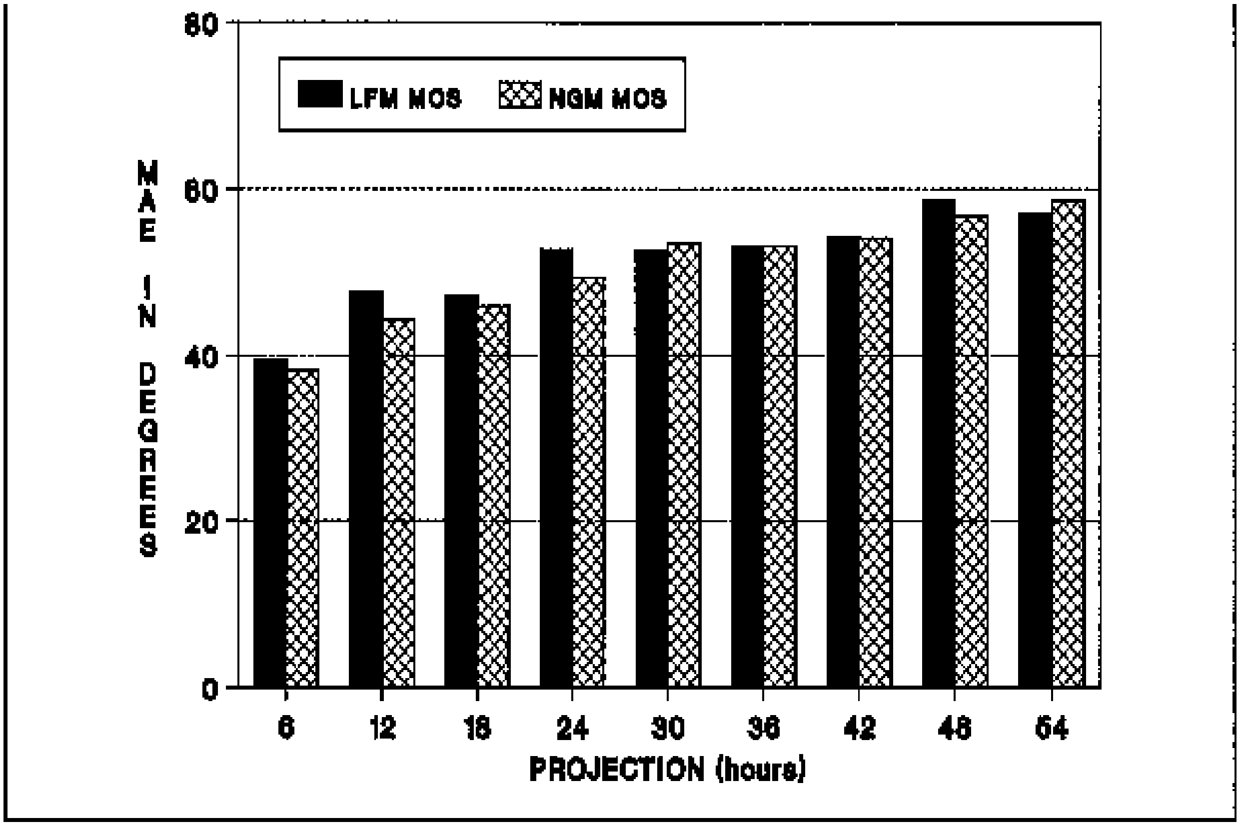

Figure 9. Mean absolute errors (MAE) for wind direction forecasts for approximately 35 Alaskan stations during the 1993-94 cool season, 0000 UTC cycle.

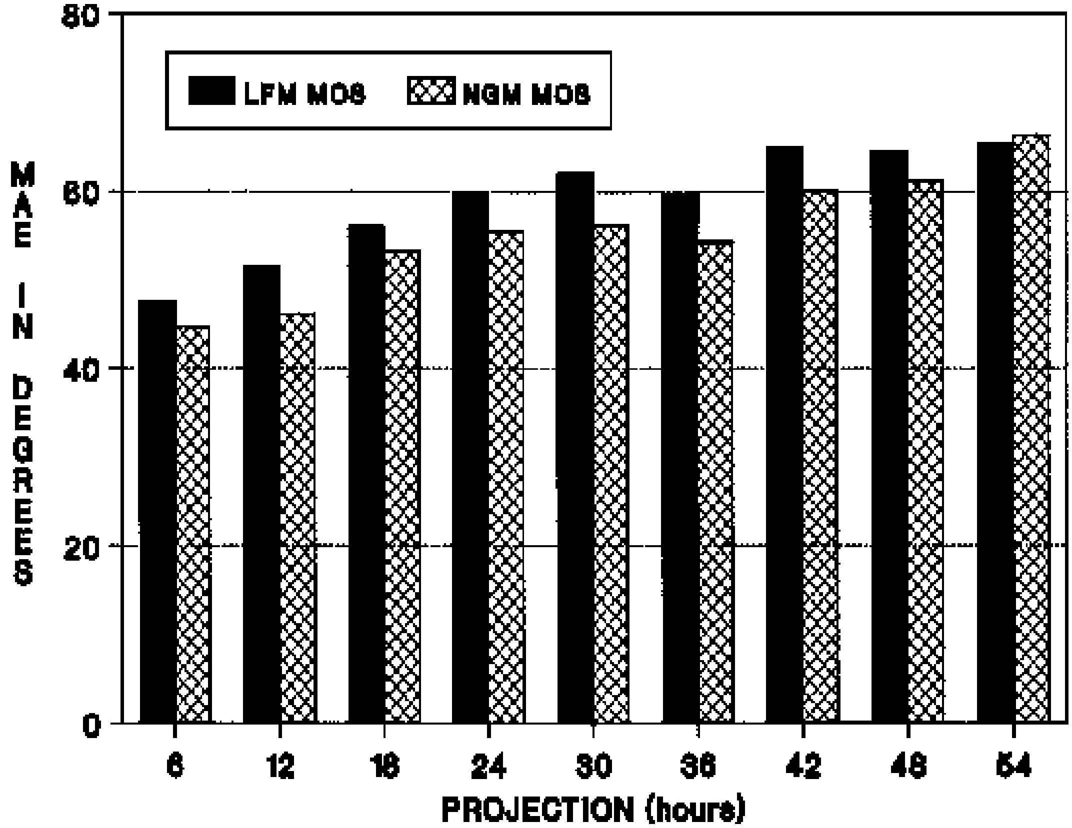

Figure 10. Same as Fig. 9 except for the 1994 warm season.