Automated Prediction of Surface Wind from Numerical Model Output

GARY M. CARTER

Techniques Development Laboratory, National Weather Service, NOAA, Sliver Spring, Md. 20910

(Manuscript received 18 November 1974; in revised form 1 July 1975)

ABSTRACT

The Model Output Statistics (MOS) technique has been applied to the prediction of surface winds. Warm and cool season forecasting equations were developed by screening as potential predictors several forecast fields from the National Meteorological Center's Primitive Equation (PE) model. Four additional weather parameters from surface reports were also screened to provide the latest observed conditions for the initial forecast projection. Separate equations for the U and V wind components and wind speed, S, were derived for each of 233 stations for projections of 12 to 48 h. For any given station and projection, the U, V, and S equations were required to use the same predictors. Initially, the first three predictors were forced to be boundary layer U, V, and S forecasts from the PE model.

Comparative verification was carried out on independent data for test forecasts at 20 widely distributed stations during warm and cool seasons. In addition, operational guidance forecasts were verified for 92 stations during November 1973 to March 1974. Both of these tests suggested that although the automated method tended to underforecast strong winds, its objective forecasts were generally more accurate than the subjective National Weather Service forecasts. Adjustment and transformation procedures to enable the automated system to produce more strong wind forecasts were also tested.

1. Introduction

Surface wind is one of the meteorological variables which few numerical models forecast directly. Even those that do forecast wind do not take the local topography and its effect on the surface wind fully into account. However, National Weather Service air pollution, aviation weather, fire weather, and public weather forecasters are all interested in the magnitude and direction of surface winds. Therefore, better objective wind forecasting techniques are needed.

A numerical-statistical method for objectively producing forecasts of surface wind has been developed at the Techniques Development Laboratory. The method uses Model Output Statistics (MOS), a technique which consists of determining a statistical relationship between a predictand and variables forecast by one or more numerical models. Glahn and Lowry (1972) and Klein and Glahn (1974) have shown how this technique has been applied to the prediction of several weather elements. In Finland, Lange (1973) has also used the MOS technique to predict surface winds.

Using MOS, we derived individual forecasting equations for each of 233 stations in the conterminous United States. Automated surface wind forecasts from these equations are currently available twice daily for projections of 12 to 48 h. The definition of our forecast wind is the same as that of the observed wind: namely, the one-minute average wind for a specific time.

2. Procedure

Interesting methods for estimating the two-dimensional surface wind vector have been proposed by Court (1958), Lewis (1968), Glahn (1970), and Lange (1973). One of the linear models discussed by Glahn (1970) consists of separate regression equations for the U and V components as follows:

$$\hat{U}=a_0+a_1X_1+a_2X_2+\cdots+a_kX_k$$
$$\hat{V}=b_0+b_1X_1+b_2X_2+\cdots+b_kX_k.$$

The caret indicates an estimate, the a_i's and b_i's are multiple regression coefficients, and X_i's are the predictors selected by the screening procedure. For most of this study, the first three predictors were specified in advance.

The screening regression technique selects as the next predictor the one which yields the highest reduction of variance for one or the other of the predictands when combined with the first in a multiple regression equation. The same procedure is followed in the selection of succeeding predictors until a specified number of predictors have been chosen. A more detailed explanation of the screening regression procedure was given by Glahn and Lowry (1972).

This approach minimizes the mean-square vector error, as well as the mean-square error of each wind component. Glahn (1970) also showed that minimizing the mean-square error of the individual components

Table 1. Sample equation for estimating the U and V wind components and the wind speed (S) 12 h in advance of 0000 GMT at Kansas City. The data sample consisted of 481 days from the warm seasons of 1970–72.

Predictor	Valid time (GMT)	Cumulative reduction of variance			Standard error of estimate (kt)			Coefficients			Units
		U	V	S	U	V	S	U	V	S	
Regression Constant	—	—	—	—	—	—	—	−1.253	−3.790	4.317	kt
1. Boundary layer U	1200	0.390	0.039	0.002	3.70	5.89	3.53	0.105	0.154	−0.018	m s^{-1}
2. Boundary layer V	1200	0.402	0.521	0.060	3.66	4.16	3.43	−0.300	0.018	0.044	m s^{-1}
3. Boundary layer S	1200	0.402	0.524	0.303	3.66	4.15	2.95	−0.069	0.111	0.286	m s^{-1}
4. Observed S	0600	0.413	0.525	0.389	3.63	4.14	2.76	0.148	−0.008	0.274	kt
5. Observed U	0600	0.482	0.531	0.394	3.41	4.12	2.75	0.300	0.056	0.054	kt
6. Observed V	0600	0.491	0.566	0.394	3.38	3.96	2.75	0.114	0.261	0.049	kt
7. Boundary layer V	1800	0.496	0.595	0.397	3.36	3.83	2.75	0.151	0.370	−0.050	m s^{-1}
8. 850 mb relative vorticity $\times 10^5$	1800	0.496	0.595	0.421	3.36	3.82	2.69	−0.020	0.194	0.263	s^{-1}
9. Boundary layer U	1800	0.519	0.596	0.422	3.28	3.82	2.69	0.336	−0.070	−0.058	m s^{-1}
10. Stability (850–1000 mb Temp)	1200	0.520	0.602	0.432	3.28	3.79	2.66	−0.091	−0.285	0.228	K

does not minimize the mean-square error of the direction computed from those estimates. However, we assumed that this is not a serious limitation, and for the purposes of this study the wind direction was always computed from estimates of the components.

For the wind speed, both Glahn (1970) and Barrientos (1970) have demonstrated that using the unbiased component estimates, $\hat{U}$ and $\hat{V}$, to produce the speed estimate, $\hat{S}$, results, in the mean, in underforecasting the speed since the approach does not minimize the root-mean-square error of the speed. Therefore, we derived a separate regression equation for the speed itself. This equation, similar to the equations for the individual components, is based on the same predictors, and was derived simultaneously with the equations for $\hat{U}$ and $\hat{V}$.

3. Predictors and development of forecasting equations

The MOS technique requires an extensive collection of forecasts from the relevant numerical model (or models). Such a sample of predictor data from the primitive equation (PE) model (Shuman and Hovermale, 1968), as well as the corresponding predictand (surface wind) data, were available for the period October 1969 to March 1973 (Glahn, 1973).

Potential predictors were chosen to include many elements which influence surface winds—numerically forecast wind components and wind speed, constant pressure heights, relative humidities, geostrophic winds, temperatures, potential temperatures, and stabilities at various projection times and levels throughout the atmosphere. The first and second harmonics of the sine and cosine of the day of the year were also included. Surface observations available six hours after PE model input time were used in the equations for the first projection only.

Every predictor from the PE model was interpolated to the location of each individual station. To focus on local effects, only data for that given station were then used in developing its forecasting equation. However, some of the predictors were space smoothed over five, nine, or twenty-five PE grid points in order to reduce the influence of the small scale noise inherent in the numerical model. The amount of smoothing also increased with increasing projection time.

The first three predictors of each equation were forced to be the boundary layer U, V, and S from the PE forecast for the valid time of the predictand. These predictors are essentially the PE forecast of the surface wind.

Using this approach, regression equations were derived separately for the 0000 GMT and the 1200 GMT runs of the PE model, and for each of seven projections—12, 18, 24, 30, 36, 42, and 48 h. Separate equations were derived for each station, for U, V, and S, and for each season. The warm season is April to September and the cool season is October to March. Furthermore, backup equations free of observed predictors were derived for the initial (12 h) projection in order to handle those situations when surface observations were missing or garbled.

All equations have exactly ten terms, since previous research (Bocchieri and Glahn, 1972; Annett *et al.*, 1972) indicated that this is reasonably close to the optimum number of predictors for a continuous predictand with a data sample of similar size. Also, to help insure overall consistency within stations and projections, some constraints were imposed on the selection of predictors. For any given station, projection, season, and initial time, the three equations for U, V, and S were required to contain the same ten predictors. Of course, the regression coefficients and constants differed. The first three predictors were forced and the remaining seven predictors were selected in sequence by using as the next predictor the one which reduced the variance of any one of the three predictands by the largest fractional amount. Thus, in most cases, only three or four predictors were chosen on account of any one of the predictands. It should also be noted that the physical significance of an additional predictor (beyond the first

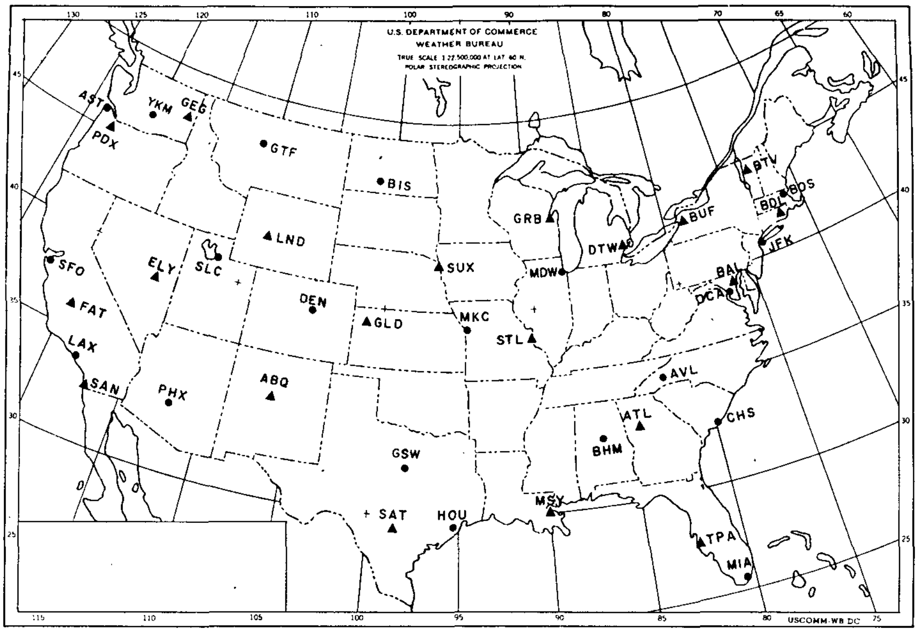

FIG. 1. Forty stations used to test the surface wind forecasting equations. Warm season test stations, ●; cool season test stations, ▲.

three or four) may be masked by the interdependence of the terms, even though its inclusion may add significant prediction capability to the overall forecast equation.

As an example, the warm season equations valid 12 h after 0000 GMT at Kansas City are shown in Table 1. Column 1 gives the selected predictors and columns 9, 10, and 11 give the coefficients. For these particular equations, the three PE boundary layer predictors U, V, and S resulted in reductions of variance of 40, 52, and 30% for the U, V, and S predictands respectively. Next, as was the case for most of the other stations for the 12 h forecasting equations, the 0600 GMT observed U, V, and S were selected. These predictors, along with four others from the PE model, produced an additional reduction of variance of approximately 10% for each predictand.

TABLE 2. Predictors selected by screening, listed in approximate order of frequency of selection for 0000 GMT equations, 233 cities, both seasons, and all seven projections (9786 equations). In addition, the surface observed U and V wind components and speeds were most often selected for 12 h forecasts. PE boundary layer U, V, and S values were forced to be the first three predictors in every case.

PE relative vorticity at 850 mb
PE geostrophic wind speed at 850 mb
PE geostrophic U wind component at 850 mb
PE geostrophic V wind component at 850 mb
PE mean relative humidity 1000–400 mb
Cosine of day of year
PE 500 mb height
Sine of day of year
PE 850 mb wind speed
PE stability (850 mb temperature minus
  1000 mb temperature)
PE 850 mb U wind component
PE 850 mb V wind component

The predictors which were selected for the cool season for Kansas City were similar to those for the warm season, and the standard errors for the warm and cool seasons differ little. However, the final reductions of variance were 12 to 21% larger for the cool season. This may be associated with the higher frequency of organized synoptic scale weather systems during the cool season which tends to result in more reliable forecasts from the PE model.

Table 2 lists the predictors selected most frequently for the 0000 GMT equations for both warm and cool seasons for all projections and for 233 stations. The various combinations of smoothings and projection times have been combined for each predictor. Also, the PE forecast boundary layer wind quantities U, V, and S for the forecast valid time are not listed because they were always the first three predictors. The observed surface U, V, and S values were next most frequently selected for the initial (12 h) projection. Table 2 also shows the importance of the relative vorticity and 850 mb geostrophic wind fields as forecast by the PE model, and the climatological contribution represented by the sine and cosine terms.

4. Testing the forecasting equations

In order to evalute this system, equations were derived for 40 widely distributed test stations. Twenty stations were used for the warm season and 20 for the cool season (see Fig. 1). The developmental data sam-

Table 3. Comparative verification scores for FT and objective surface wind forecasts at 20 stations (see Fig. 1) for April and May 1972. Forecasts were made from the 0000 GMT PE model run using warm season equations.

Valid time (GMT)	Type of forecast	Direction mean absolute error (degrees)	Speed (kt)					No of cases	
			Mean absolute error	Skill score	Percent correct	Mean forecast	Mean observed	Mean absolute error	Skill score and percent correct
1200	Objective	31	2.7	0.36	78	8.8	9.9	395	1169
	FT	25	3.5	0.33	69	12.3		396	1170
1800	Objective	38	3.0	0.26	54	10.8	11.0	681	1174
	FT	39	3.9	0.22	49	13.1			
0000	Objective	38	3.0	0.26	52	10.8	11.0	658	1168
	FT	44	4.0	0.13	42	13.2			

ples consisted of 303 days during the two warm seasons of 1970–1971 and 449 days during the three cool seasons of 1969–1972. Test data for the warm season were 59 days during April and May, 1972. Test data for the cool season were 55 days during December 1972 and January 1973.[1] Only the 0000 GMT runs of the PE model were used. The forecasts for the same 40 stations in the National Weather Service official terminal forecasts (FT's) were used for comparison purposes.[2] Surface observations at 0600 GMT were used in the objective forecasts for the initial projection, while in most cases the National Weather Service forecasters had 0900 GMT surface observations available.

Since the FT's do not mention wind if the speed is expected to be less than 10 kt, the comparison was made in two ways. First, for all those cases where the FT's included wind and for which objective forecasts were available, the mean absolute errors of direction (computed from the $\hat{U}$ and $\hat{V}$ equations) and speed (direct from the $\hat{S}$ equation) were computed.[3] Second, for all cases when the FT's and the objective forecasts were available, contingency tables for speed were prepared by considering the FT's to be under 10 kt whenever the wind was not specifically mentioned. From these contingency tables, which had categories of less than 10, 10–12, 13–17, 18–22, and greater than 22 kt, the skill score and percent correct were computed. These scores are presented in Tables 3 and 4.

The direction mean error was slightly less for the objective forecasts for 18 and 24 h projections, but greater for 12 h than the FT wind forecasts in Tables 3 and 4. For the forecasts of speed, the mean error, skill score, and percent correct all consistently indicated an edge for the objective forecasts. Also, there was some indication that the margin of improvement by the objective speed forecasts was greater for 24 h than for 18 or 12 h projections.

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[1] At the time the warm season test was conducted, April and May (the beginning of the season) were the only months for which data were available. However, during the cool test time deadlines were not as severe, so the months of December and January (the middle of the season) were used.

[2] Several fundamental differences exist between the objective forecasts and the FT's. The FT's are not as precise for a specific valid time as the objective forecasts. Also, the aviation forecasters tend to concentrate on the stronger winds, since they are of greater operational importance. Due to these and other differences, only conclusions of a general comparison nature should be drawn from the test results.

[3] Cases where the observed wind speed was less than 2 kt were omitted from the wind direction calculations.

Table 4. Comparative verification scores for FT, objective, and 24 h persistence surface wind forecasts at 20 stations (see Fig. 1) for December 1972 and January 1973. Forecasts were made from the 0000 GMT PE run using cool season equations.

Valid time (GMT)	Type of forecast	Direction mean absolute errors (degrees)	Speed (kt)					No. of cases	
			Mean absolute error	Skill score	Percent correct	Mean forecast	Mean observed	Mean absolute error	Skill score and percent correct
1200	Objective	24	2.8	0.41	73	9.9	10.9	481	1091
	FT	21	3.3	0.36	64	13.0			
1800	Objective	34	3.1	0.34	60	10.9	11.2	633	1085
	FT	38	3.9	0.27	52	13.3			
0000	Objective	38	3.2	0.24	64	9.3	9.7	565	1084
	FT	48	4.7	0.15	48	13.3			
	Persistence	75	4.6	0.12	55	9.1			

TABLE 5. Comparative verification scores for objective wind forecasting systems at 20 stations across the United States for October 1972 through March 1973 (3160 cases). All results apply to 0000 GMT input data. In System A the forecasts of wind speed were obtained directly from the wind speed equation. In System B the larger of the two speeds, the resultant of $\hat{U}$ and $\hat{V}$ or the equation forecast, $\hat{S}$, was used as the forecast speed.

Valid time (GMT)	Type of forecast	Mean absolute error	Skill score	Percent correct	Speed (kt) Mean forecast	Mean observed
1200	System A	2.32	0.377	75.2	7.1	7.3
	System B	2.32	0.396	75.2	7.3	
1800	System A	2.83	0.327	60.4	9.1	9.2
	System B	2.82	0.332	60.1	9.4	
0000	System A	2.83	0.255	64.5	8.1	8.2
	System B	2.78	0.286	64.8	8.4	

Persistence forecasts were verified for the 24 h projection in the cool season, and confirmed that, particularly for direction, persistence alone is a poor forecast.

In general, the overall results indicate that these objective forecasts are probably more accurate than the subjective aviation forecasts. Although our verification on independent data is not extensive, we believe it is sufficient to demonstate the usefulness of this technique.

5. Operational forecasting equations

Because of the encouraging test results, warm and cool season wind forecasting equations were developed for 233 stations throughout the conterminous United States for projections of 12–48 h. These equations were derived by the procedure just described, based on the full available period of record, October 1969 to March 1973. Since May 1973, forecasts have been available on teletypewriter on a request basis through the Federal Aviation Administration's Weather Message Switching Center at Kansas City. Since August 1975, surface wind forecasts for the first four projections (12, 18, 24, and 30 h) have also been on facsimile. These forecasts are updated every twelve hours.

a. Forecast wind speed adjustment

Contingency tables from the test experiments indicate that this objective system tends to underestimate the occurrence of strong winds. Since these winds are of considerable importance to aviation and public weather interests, a method for partially correcting this problem was investigated.

As mentioned before, a separate regression equation is used for $\hat{S}$ to avoid underforecasting the speed in the mean. However, this equation sometimes forecasts a speed smaller than that obtained from the resultant of $\hat{U}$ and $\hat{V}$. A small average increase in forecast speed can be made by using the resultant speed or the $\hat{S}$ from the equation, whichever is greater.

In order to test this technique, the cool season test equations for 20 stations were again evaluated on independent data. This time, data for October 1972 to March 1973 were available (3160 forecasts from 0000 GMT data).

Mean absolute error was computed for all cases. Skill scores and percent correct were computed from contingency tables which had the same categories as described previously. These scores are presented in Table 5, where system A refers to the unmodified objective forecasting system and system B is the one where the forecast has been modified in the manner described. The corresponding contingency tables valid at 1800 GMT are presented in Table 6.

As shown in Table 5, the forecasts for system B are equal to or slightly better than those for system A for all the scores, except for a small deterioration in percent correct at 1800 GMT. In particular, the skill scores associated with system B are higher than those for system A. The approach used in system B also introduces a small positive bias in the forecasts.

TABLE 6. Contingency tables for objective wind forecasting systems A and B for 20 stations across the United States for October 1972 through March 1973. All results apply to forecasts valid 18 h from 0000 GMT.

System A

Observed	Forecast 1	2	3	4	5	T
1	1443	323	63	0	0	1829
2	280	236	84	3	0	603
3	112	197	200	31	1	541
4	12	36	69	25	3	145
5	4	6	18	10	4	42
T	1851	798	434	69	8	3160

Bias = No. fcst./No. obs.

CAT 1 = 1.01
CAT 2 = 1.32
CAT 3 = 0.80
CAT 4 = 0.48
CAT 5 = 0.19

Total number correct = 1908

System B

Observed	Forecast 1	2	3	4	5	T
1	1411	346	72	0	0	1829
2	266	238	91	8	0	603
3	100	182	210	41	8	541
4	11	31	65	33	5	145
5	3	5	16	11	7	42
T	1791	802	454	93	20	3160

Bias = No. fcst./No. obs.

CAT 1 = 0.98
CAT 2 = 1.33
CAT 3 = 0.84
CAT 4 = 0.64
CAT 5 = 0.48

Total number correct = 1989

CAT 1 <10 (kt)
CAT 2 10–12
CAT 3 13–17
CAT 4 18–22
CAT 5 >22

Table 7. Verification of subjective local and objective guidance surface wind forecasts at 92 stations during November 1973 through March 1974. Objective forecasts were made from the 0000 GMT PE run.

Direction				Speed (kt)										
								Contingency table						
										Bias by category				
Projection (h)	Type of fcst.	Mean abs. error (deg.)	No. of cases	Mean abs. error	Mean fcst.	Mean obs.	No. of cases	Skill score	Percent correct	CAT 1	CAT 2	CAT 3	CAT 4	CAT 5	No. of cases
18	Guidance	31	8356	3.2	11.9	11.8	8440	0.28	51	0.64	1.48	0.94	0.59	0.23	11 764
	Local	35		3.8	13.3			0.22	45	0.57	1.23	1.23	1.22	0.66	
30	Guidance	36	4833	3.4	10.5	10.4	4941	0.29	57	0.91	1.40	0.61	0.18	0.05	10 994
	Local	42		4.1	11.9			0.21	49	0.69	1.49	1.07	0.91	0.56	
42	Guidance	43	8482	3.6	11.4	11.3	8611	0.20	46	0.51	1.71	0.88	0.31	0.09	11 778
	Local	51		4.1	12.3			0.15	41	0.58	1.45	1.08	0.66	0.26	

Table 6 indicates the extent to which system A tends to underestimate winds of 13 kt or more. System B partially corrects this inadequacy without significantly decreasing the general accuracy of the forecasts. Based on these results, system B replaced A as the operational system in December 1973.

b. *Verification of operational guidance forecasts*

Archiving of operational surface wind forecasts was begun routinely in November 1973. Subsequently, these forecasts were verified in conjunction with the National Weather Service's combined aviation/public weather verification system. The objective guidance forecasts were compared with local forecasts[4] prepared at various Weather Service Forecast Offices for 92 widely distributed stations (Carter *et al.*, 1974).

Since the local forecasts were recorded as calm if the wind speed was expected to be less than 8 kt, the comparison was made in two ways. Whenever both the local and guidance forecasts were at least 8 kt, the mean absolute errors of direction and speed were computed.[5] Also, contingency tables of speed were prepared for all cases when local and guidance forecasts were available. The categories were less than 8, 8–12, 13–17, 18–22, and greater than 22 kt. Skill score, percent correct, and bias by category were computed from the contingency tables for 18, 30, and 42 h forecasts from 0000 GMT during the five months from November 1973 to March 1974. The verification scores for the 92 stations combined are shown in Table 7.

This comparison is in general agreement with the results of the test verification presented in Tables 3 and 4. The mean direction error shows an advantage for the guidance forecasts which increases from 4° for 18 h to 8° for 42 h. The mean error, skill score, and percent correct of the speed forecasts are better for guidance at all three projections, but these scores do not exhibit the relative improvement of guidance with longer projections that is shown for direction forecasts.

The guidance forecasts were unbiased in the mean, whereas the local forecasts tended to forecast speeds about a knot too high on the average. However, the objective techniques made substantially too few forecasts of speeds greater than about 18 kt (category 4 and above). Therefore, the forecasts of wind speed were recomputed using an inflation technique similar to that described by Russo *et al.* (1964). This transformation increased the variance of the forecast speed to equal (or nearly equal) the variance of the observed speed, and in the process it increased the number of forecasts of speed in categories 1, 4, and 5.

The verification results for both the old and new forecasts of speed for the 18 h projection are shown in Table 8. These contingency tables show that categories 1 and 3 are still somewhat underforecast although greatly improved over the uninflated forecasts. Contingency tables for the 30 and 42 h projections were similar. This was achieved at very little cost in skill score or percent correct and, therefore, the inflation technique was incorporated into the operational system in July 1975.

6. New warm season equations

Derivation of a new set of equations for the warm season was completed in April 1975. Two additional years of data (the warm seasons of 1973 and 1974) were added to the developmental sample. Also, five new fields—boundary layer wind divergence, 1000–500 mb thickness, surface pressure, 12 h surface pressure change, and the G index (1000 mb height+500 mb height −2×850 mb height)—were added to the original list of PE predictors (see Section 3). Other changes incorporated into the development of these equations involved removing the forcing constraint on the first three predictors and increasing the number of terms in each equation from ten to twelve.

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[5] Cases where both the local and guidance forecasts were at least 8 kt, but the observed wind was calm, were eliminated from the wind direction calculations.

[4] The local forecasts were prepared for verification purposes and may not always have coincided with publicly issued wind forecasts.

TABLE 8. Contingency tables for 18 h objective (guidance and inflated guidance) surface wind forecasts at 92 stations across the United States during November 1973 through March 1974. All forecasts were made from the 0000 GMT PE run using cool season equations.

	Guidance							Inflated guidance					
Observed	1	2	3	4	5	T	Observed	1	2	3	4	5	T
1	1748	1909	185	10	0	3852	1	2271	1285	268	25	3	3852
2	613	2972	687	33	2	4307	2	1171	2156	832	130	18	4307
3	85	1281	1056	155	8	2585	3	183	1002	1011	326	63	2585
4	9	168	423	160	14	774	4	20	114	305	256	79	774
5	1	29	84	99	33	246	5	3	15	64	73	91	246
T	2456	6359	2435	457	57	11764	T	3648	4572	2480	810	254	11764

Forecast system	Bias = (No. fcst./No. obs.) CAT 1	CAT 2	CAT 3	CAT 4	CAT 5	Percent correct	Skill score
Guidance	0.64	1.48	0.94	0.59	0.23	50.7	28
Inflated	0.95	1.06	0.96	1.05	1.03	49.2	7.1
guidance							2.9

CAT 1	<8 (kt)
CAT 2	8–12
CAT 3	13–17
CAT 4	18–22
CAT 5	>22

As mentioned earlier, the first three predictors were always forced to be the PE boundary layer forecasts of U, V, and S. Originally, this had been done to promote consistency within stations and projections. However, two years of monitoring this system in an operational environment indicated that this feature was of minor importance in contrast to allowing each station the freedom to select the most useful predictors.

The inclusion of two more seasons of dependent data meant that each equation could reasonably sustain a few more predictors. Since there are three separate predictands (U, V, and S), it seemed appropriate to increase the number of terms to twelve and improve the likelihood that each predictand would select four predictors.

The reductions of variance and standard errors associated with these new equations are similar to those for the old equations. However, the root-mean-square errors of forecasts from the new equations should deteriorate less from the developmental standard errors due to the larger data sample, thus producing improved forecasts.

7. Summary and conclusions

Strong winds will be forecast by this system primarily in association with well organized synoptic scale weather systems. In general, high winds associated with special situations such as thunderstorms or hurricanes will not be forecast. Objective estimates of surface wind gusts are not provided, since the data necessary for derivation of such equations are not being saved in the proper form.

In general, the results of this study indicate that the MOS technique is useful in forecasting surface winds. Comparison tests on independent data of objective forecasts produced by this system with National Weather Service aviation forecasts suggest that the objective estimates were more accurate than the subjective forecasts. Similar results were obtained after the objective system had been put into operation and a comparison made with subjective local forecasts.

Based on testing, it appears that application of an inflation technique can produce relatively unbiased objective forecasts (i.e., as many strong winds are forecast as are observed) with verification scores nearly as good as those of the uninflated regression estimates.

Any substantial improvement in this objective system will most likely result from the inclusion of predictors from new or improved numerical forecast models. Considerable planning and organization will be necessary, since this will involve archiving more data and deriving new regression equations.

Acknowledgments. The author was assisted in various aspects of this study by many persons in the Techniques Development Laboratory. In particular, I wish to thank Dr. William Klein, Dr. Harry Glahn, Mr. Frank Lewis, Mr. Roger Allen, Mr. Gordon Hammons, Mr. George Hollenbaugh, Capt. Frank Globokar, Dr. Celso Barrientos, Mrs. Anna Booth, and Mrs. Brenda Eastridge.

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