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AN EVALUATION OF A MODIFIED SPEED ENHANCEMENT TECHNIQUE FOR OBJECTIVE SURFACE WIND FORECASTING

Barry E. Schwartz and Gary M. Carter

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1. INTRODUCTION

Since May 1973, the Techniques Development Laboratory (TDL) has provided National Weather Service (NWS) aviation and public weather forecasters with objective surface wind guidance (Carter, 1975). This guidance is based on application of the Model Output Statistics (MOS) technique (Glahn and Lowry, 1972). Since July 1975, a procedure known as inflation (Klein et al., 1959) has been used operationally to increase wind speed forecasts if they are greater than the mean wind speed from the developmental sample and to decrease the forecasts if they are less than the mean.

Recently, we tested a new method of inflation called "modified" inflation. With this procedure wind speed forecasts greater than the mean were increased while speeds below the mean were not altered. The results of these experiments are presented here.

2. DISCUSSION

The enhancement of objective wind speed forecasts by the traditional method of inflation is expressed by the following formula:

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

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

Before inflation was used operationally, verification scores indicated the guidance tended to underforecast wind speeds greater than 18 knots (Carter, 1975). After the introduction of inflation in July 1975, we found that the bias[1] of strong wind speed forecasts improved, although the accuracy in terms of mean absolute error (MAE), root mean square error (RMSE), and Heidke skill score deteriorated slightly (Gilhousen et al., 1979). Glahn and Allen (1966) have shown this is an inevitable consequence of inflation.

The traditional method of inflation decreases the magnitude of wind speed

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1 Bias is defined as the number of forecasts of a particular category (event) divided by the number of observations of that category. (The wind speed categories are: category 1, less than 8 knots; category 2, 8-12 knots; category 3, 13-17 knots; category 4, 18-22 knots; and category 5, greater than 22 knots.) A value of 1.0 denotes unbiased forecasts for that particular category.

forecasts below the station's developmental mean. Since, at most locations, the mean wind speed from the developmental sample is about 8 knots, many forecasts which, without inflation, would have fallen into category 2, are "deflated" into category 1. This consequence has had some undesirable effects over the years. Figs. 1a and 1b are profiles of the category 1 and category 2 biases, respectively, for approximately 90 U.S. stations for all warm season (April to September) and cool season (October to March) Limited-area Fine Mesh (LFM) model (Newell and Deaven, 1981) based guidance forecasts since 1978. In general, especially for the 18-h projection, the inflated guidance tended to slightly overforecast category 1 and underforecast category 2 wind speeds. Since the 1979-80 cool season, however, this tendency has not been as noticeable in the bias results. We believe this change is associated with the introduction of new forecast equations during both the 1979-80 and 1980-81 cool seasons. The 1979-80 equations were derived with more LFM model data than were available previously. In addition, an improved version of TDL's screening regression program was used to prevent the selection of very highly correlated predictor variables. For the 1980-81 equations, we also omitted LFM boundary layer predictors from the derivation.

Table 1 shows the bias-by-category results for a test involving forecasts for 56 stations produced by equations with and without boundary layer fields (Janowiak, 1981). Table 2 is a comparison of the bias-by-category results for the operational guidance during the last two cool seasons (approximately 90 U.S. stations). Note that the 1979-80 cool season was the last cool season in which boundary layer variables were used as predictors. Both tables indicate that the removal of the boundary layer fields only slightly modified the biases of category 1 and 2. However, the removal of these predictors seemed to improve the bias of wind forecasts greater than 22 knots (category 5, Tables 1 and 2). Hence, we think the improved bias characteristics for categories 1 and 2 shown in Figs. 1a and 1b are probably related to the use of more stable prediction equations, that is, equations derived from larger samples of data.

3. EXPERIMENTAL DISIGN

Although the bias characteristics for categories 1 and 2 have improved considerably since the 1979-80 cool season, one result of the operational inflation technique has been the slight overforecasting of the lower wind speed categories. As we mentioned earlier, modified inflation should result in better bias characteristics for categories 1 and 2, as well as higher skill scores, lower MAE, and lower RMSE. To test this hypothesis, we applied the modified inflation technique on an independent sample of forecasts from the 1980 warm season and the 1980-81 cool season. The current operational warm and cool season surface wind prediction equations (National Weather Service, 1980) were used to generate the test forecasts. The regions in which the test stations were grouped for verification purposes are shown in Fig. 2.

4. RESULTS

Six verification statistics, namely, bias for category 1 and 2, MAE, RMSE, Heidke skill score, and percent correct were used to compare the forecasts enhanced by traditional and modified inflation. Tables 3 and 4 show these scores for the 18-h and 30-h projections from 0000 GMT for the warm and cool seasons, respectively. For the 18-h projection, the category 1 and 2 biases produced by traditional inflation were superior overall on the national level. Regionally, the modified inflation biases were better only for the Southeast during the warm season, and for the Central Plains (category 1 only) during the cool season. In contrast, as expected, in nearly all cases for both cool and warm seasons, the MAE, RMSE, skill score, and percent correct were better for modified inflation.

For the 30-h projection, there was little difference in the bias characteristics for the two types of forecasts except in the West where regular inflation was substantially better for category 2. As with the 18-h results, modified inflation generally produced better MAE, RMSE, and skill scores. The type of inflation made little difference in regard to percent correct.

5. CONCLUSIONS

Past verification studies have shown that the wind speed guidance tended to overforecast the occurrence of low wind speeds. However, biases for the forecasts of 12 knots and less have improved considerably since the start of the 1979-80 cool season, despite the use of inflation.

In this study, we have shown that modified inflation improves the MAE's and RMSE's, but generally worsens the bias characteristics for speed forecasts of 12 knots and less. We observed a few exceptions to these results in the regional breakdown. Explaining these exceptions requires examination of observed wind speed profiles for each station. In particular, modified inflation appears to improve the forecasts for locations with lower mean wind speeds.

In conclusion, since the traditional method of inflation produces desirable effects on the national level, we will not alter the technique used to inflate the operational wind speed guidance. However, a station-by-station (or region-by-region) application of modified inflation may be considered in conjunction with future enhancements of the operational surface wind prediction system.

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Table 1. Wind speed bias-by-category for test forecasts made from equations with and without boundary layer predictors (b.l.p.) for 56 U.S. stations during the 1980 warm season (data from Janowiak, 1981).

Projection (h)	Equation Type	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5
18	With b.l.p.	1.04	1.04	0.90	0.81	0.84
	Without b.l.p.	1.05	1.04	0.88	0.83	0.91
30	With b.l.p.	1.04	0.99	0.92	0.68	0.58
	Without b.l.p.	1.03	1.00	0.91	0.76	0.70

Table 2. Wind speed bias-by-category for the operational surface wind speed guidance for approximately 90 U.S. stations.

Projection (h)	Cool Season	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5
18	1979-80	1.08	0.95	0.94	0.97	0.90
	1980-81	1.07	0.99	0.90	0.93	0.93
30	1979-80	1.01	1.01	1.00	0.85	0.52
	1980-81	1.03	0.96	0.99	0.86	0.88
42	1979-80	1.05	0.98	0.97	0.95	0.95
	1980-81	1.05	0.97	0.95	1.03	1.10

Table 3. Verification results of forecasts made from 1980 warm season data by using the traditional inflation or the new modified inflation. Scores were computed for all 56 stations combined and for the composite regions shown in Fig. 2.

Proj (h)	Region	Type	Bias Cat 1	Bias Cat 2	MAE	RMSE	Skill Score	% Correct
18	National	Traditional	1.08	0.98	2.77	3.62	.295	54.4
		Modified	0.88	1.19	2.58	3.38	.302	54.8
	Southeast	Traditional	1.17	0.85	2.39	3.13	.277	56.7
		Modified	1.00	1.00	2.27	2.97	.281	57.3
	Northeast	Traditional	1.10	1.05	2.62	3.36	.326	55.8
		Modified	0.77	1.28	2.46	3.16	.327	56.8
	Central Plains	Traditional	1.16	0.96	2.99	3.88	.257	48.1
		Modified	0.74	1.27	2.84	3.68	.258	49.1
	West	Traditional	0.98	1.08	3.02	3.95	.271	55.9
		Modified	0.89	1.25	2.70	3.59	.275	55.3
30	National	Traditional	1.00	0.99	2.90	3.78	.311	67.0
		Modified	0.97	1.08	2.48	3.35	.323	67.0
	Southeast	Traditional	1.01	0.91	2.61	3.38	.382	79.4
		Modified	1.01	0.92	2.16	2.94	.384	79.4
	Northeast	Traditional	1.02	0.98	2.70	3.45	.297	69.0
		Modified	1.00	1.03	2.38	3.14	.301	68.8
	Central Plains	Traditional	1.04	0.92	3.00	3.92	.329	63.9
		Modified	1.00	0.98	2.56	3.51	.342	64.3
	West	Traditional	0.96	1.08	3.15	4.10	.230	58.2
		Modified	0.88	1.23	2.69	3.62	.247	58.1

Table 4. Same as Table 3 except for tests on the 1980-81 cool season.

Proj(h)	Region	Type	Bias Cat 1	Bias Cat 2	MAE	RMSE	Skill Score	% Correct
18	National	Traditional	1.06	1.02	3.09	4.01	.351	56.3
		Modified	0.87	1.24	2.80	3.71	.357	56.3
	Southeast	Traditional	1.14	0.97	2.69	3.51	.310	55.2
		Modified	0.79	1.24	2.56	3.35	.291	54.8
	Northeast	Traditional	1.08	1.01	2.81	3.57	.317	52.0
		Modified	0.73	1.24	2.67	3.43	.317	52.9
	Central Plains	Traditional	1.31	0.98	3.35	4.33	.291	48.9
		Modified	0.72	1.24	3.03	3.99	.297	50.2
	West	Traditional	0.97	1.14	3.41	4.40	.331	64.3
		Modified	0.92	1.26	2.93	3.96	.328	63.3
30	National	Traditional	1.03	0.95	3.09	3.99	.320	63.6
		Modified	0.99	1.05	2.70	3.62	.328	63.4
	Southeast	Traditional	1.06	0.86	2.78	3.56	.353	68.9
		Modified	1.04	0.89	2.44	3.24	.355	68.8
	Northeast	Traditional	1.00	1.05	2.93	3.78	.345	59.9
		Modified	0.93	1.16	2.68	3.54	.358	60.3
	Central Plains	Traditional	1.09	0.87	3.33	4.31	.297	57.3
		Modified	1.00	1.02	2.94	3.93	.292	56.5
	West	Traditional	1.00	1.01	3.25	4.20	.257	65.7
		Modified	0.96	1.13	2.73	3.72	.273	65.6

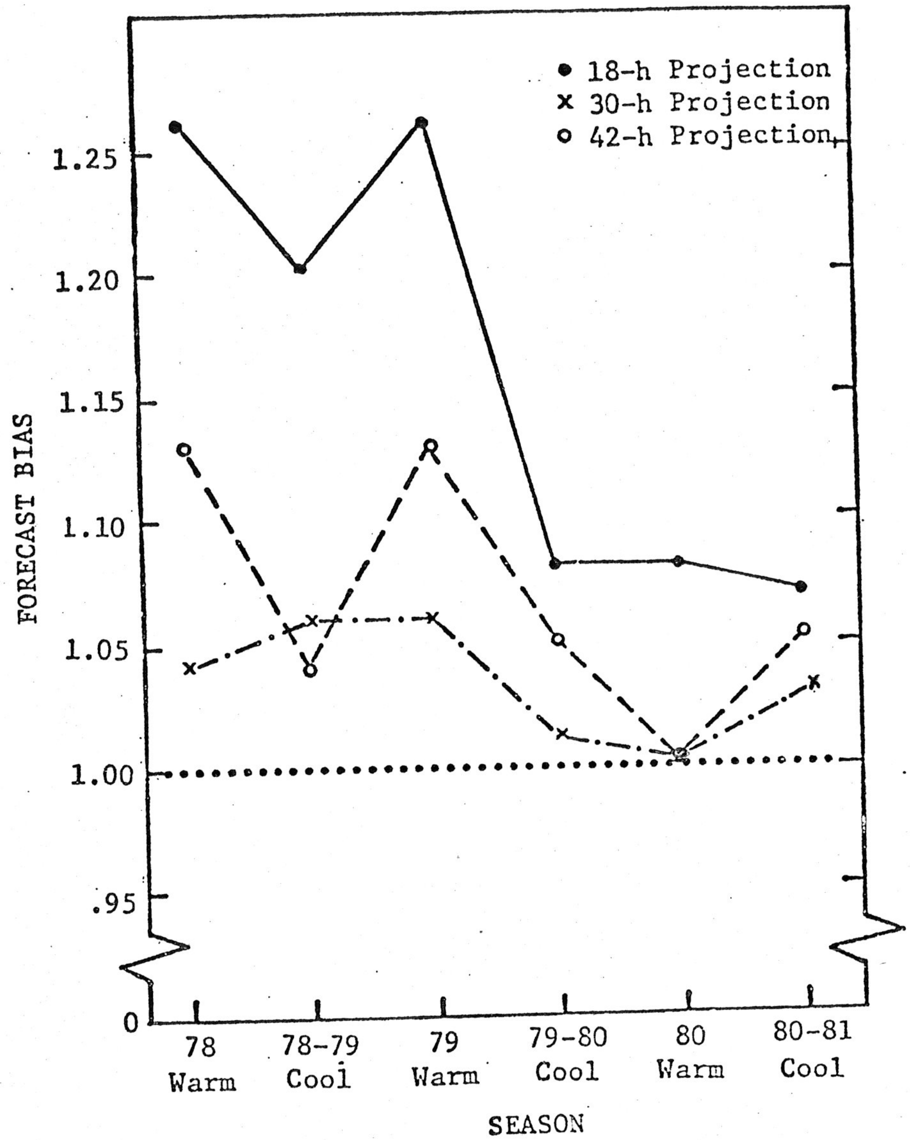

Figure 1a. Bias of wind speed forecasts for category 1 (< 8 knots) for the cool and warm seasons from 1978 to present for approximately 90 U.S. stations.

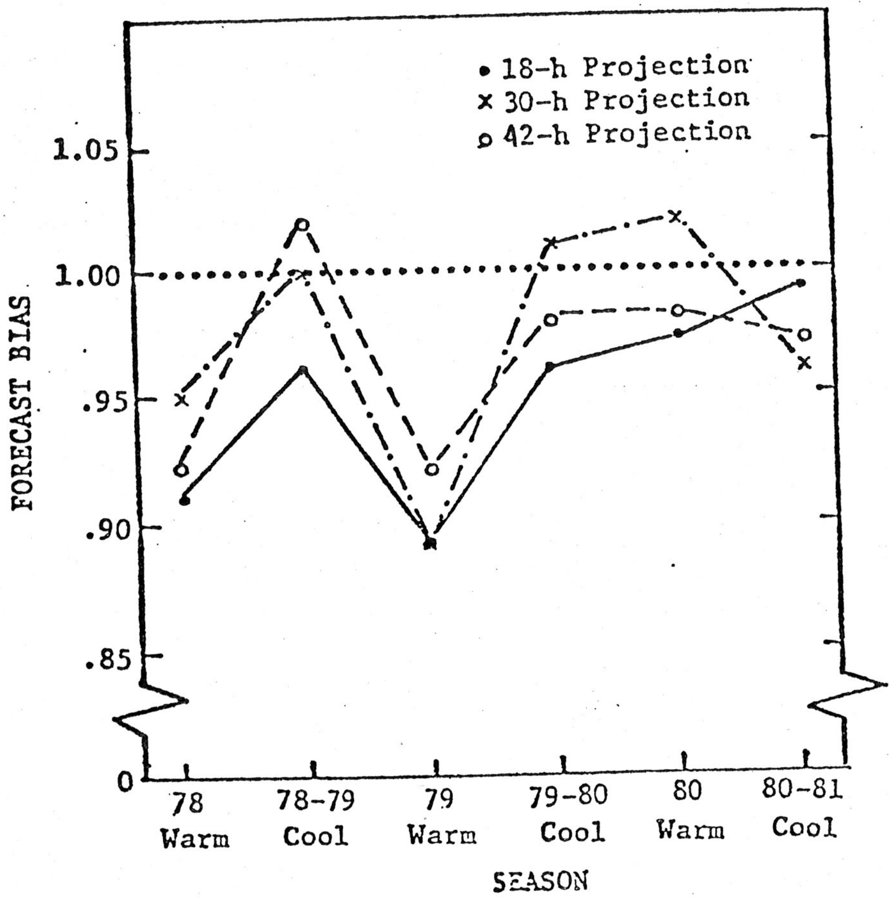

Figure 1b. Same as Fig. 1a, except for category 2 (8-12 knots).

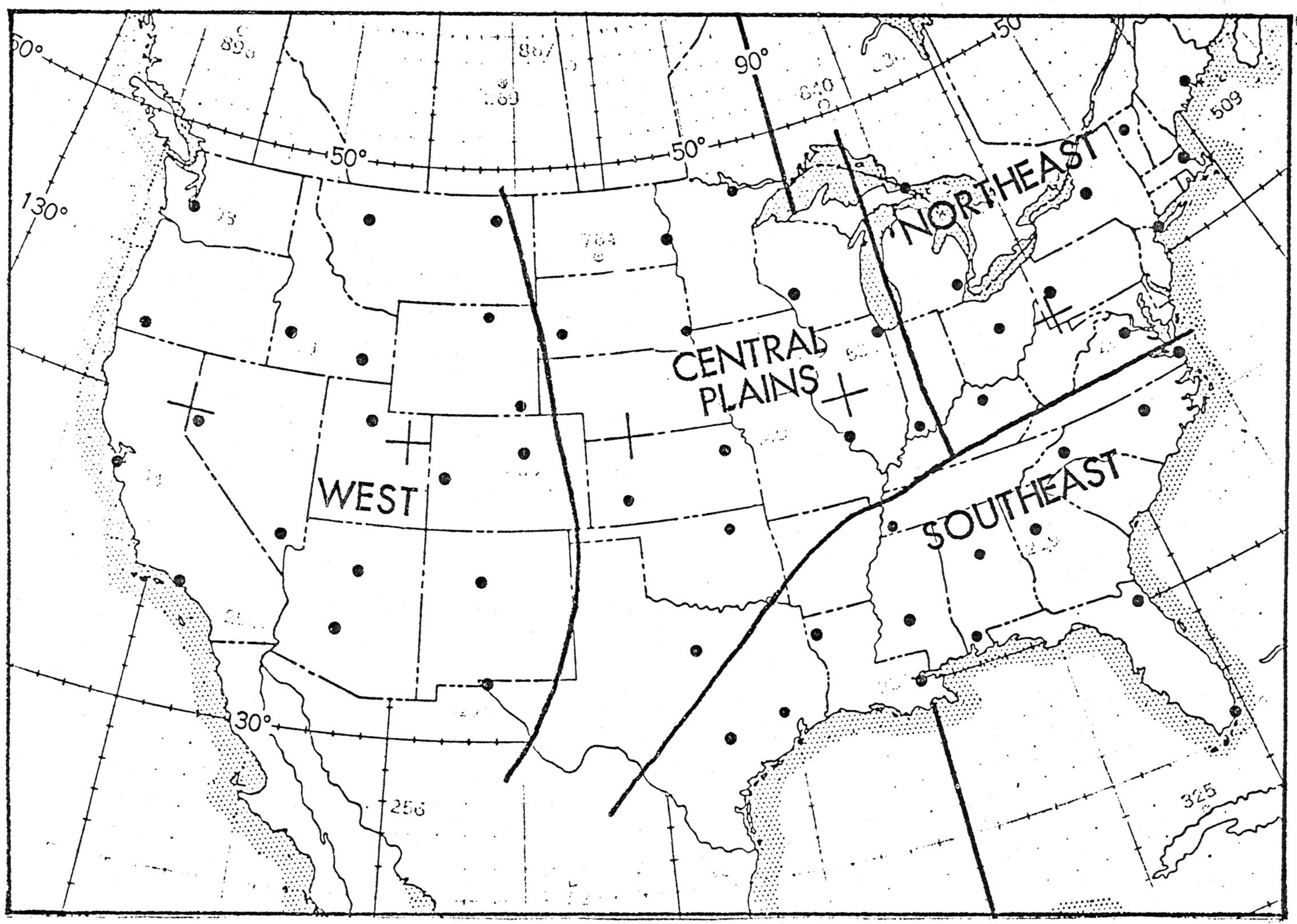

Figure 2. Stations and regions used to test the enhancement of objective wind speed forecasts.