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COMPARISON OF LAMP AND GEM WIND FORECASTS

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1. INTRODUCTION

Two of the methods under development within the Techniques Development Laboratory for making objective short range weather forecasts are discussed in this paper. One is the Local AFOS MOS Program (LAMP) (Glahn, 1980); the other is the Generalized Exponential Markov (GEM) model (Miller, 1981). After briefly discribing both methods, this paper compares surface wind forecasts made by those methods with each other, with persistence, and with a simple persistence regression model.

2. LAMP

A. Description of Method

The purpose of LAMP is to provide to a Weather Service Forecast Office (WSFO) Model Output Statistics (MOS) forecasts for essentially all locations for which the WSFO makes routine forecasts. These forecasts will be for most weather elements and for projections of 1 to 20 hours. Inputs will include centralized MOS forecasts (NWS, 1983); hourly observations; a few forecast fields from the National Meteorological Center's (NMC's) primary short-range guidance model; and, when available, radar and satellite data.

LAMP includes three rather simple forecast models--(1) a sea level pressure (or 1000-mb height) model (Unger, 1982), (2) a moisture model, and (3) a trajectory model called CLAM (Grayson and Bermowitz, 1974). These models are driven by 500-mb height forecasts from an NMC model, currently the Limited Area Fine Mesh (LFM) model (Gerrity, 1977). They are basically initialized by analyzing surface data. Output from these models, hourly observations, and centralized MOS forecasts are then combined statistically to produce updated MOS guidance forecasts.

B. Application to Wind Prediction

Rather extensive experimentation has been done in predicting surface wind in the Washington WSFO area of responsibility (see Glahn, 1983). The predictands were the U- and V-components and speed, S, at hourly projections of 1 to 20 hours from initial data times of 0800 and 1300 GMT. It was found that the U, V, and S from the surface observation at the initial time; the central MOS guidance forecasts of U, V, and S valid at the same time as the predictand; and the U, V, and S of the geostrophic winds predicted by the sea level pressure model valid at the same time as the predictand all furnished useful predictive information. Therefore, the LAMP predictions compared with GEM and persistence in this study were made by regression equations containing nine terms each. The U- and V-component forecasts were used to compute direction, and the speed was inflated (Klein et al., 1959) according the usual practice in MOS application to wind prediction (NWS, 1983). All directions and speeds of the wind vector can be predicted by this model.

3. GEM

A. Description of Method

GEM is a statistical technique for predicting the probability distribution of all local surface weather elements hour by hour. It uses only the elements in the current local surface weather observation as predictors. From these probability distributions, categorical predictions are made for each weather element.

A basic characteristic of GEM is that all predictors and predictands are binary. Those weather elements that are by nature continuous are broken up into two or more discrete categories, each category then forming a "new" variable that can be represented by a "1" when it occurs or a "0" when it does not. A set of linear regression equations is then developed from a large historical data sample. There is one equation for each (binary) predictand, and each binary predictor is in each equation.

GEM equations have been developed to make a 1-h forecast, although the technique is not limited to that interval. To make a 1-h forecast, elements in the surface observation are transformed into their binary counterparts, and those values are used in the equations. Then, the (probability) forecasts of the predictands are used in the same set of equations to make a forecast for the next hour--in effect, a 2-h forecast from the observation time. Thus, by iteration, a forecast can be made as far into the future as desired.

The total predictand and predictor set in the current version of GEM consists of 228 binary variables. In addition to variables derived from the surface weather observation, the month and initial hour were also input. A very large data set was used to develop a generalized set of equations by pooling data from 41 stations in the conterminous United States.

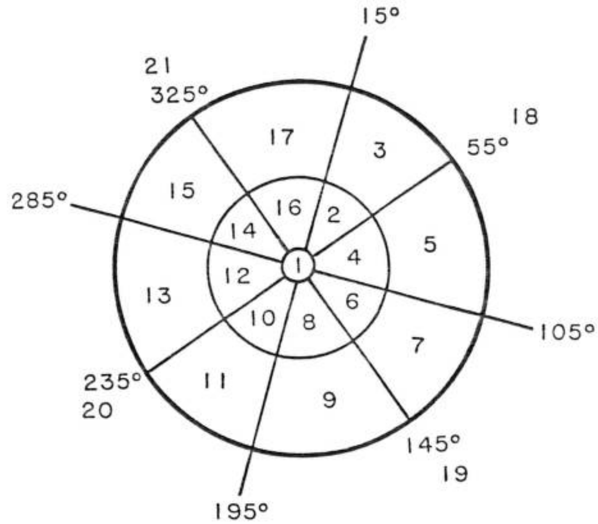
B. Application to Wind Prediction

Although a general set of equations existed, Miller preferred to derive single station equations for testing against LAMP. He had available data from seven stations in and near the Washington WSFO area which he used to develop the equations. These stations are: Atlantic City, N.J.; Baltimore, Md.; Norfolk, Va.; Philadelphia, Pa.; Raleigh-Durham, N.C.; Roanoke, Va.; and Washington, D.C.

Prediction of the wind vector by objective techniques presents special problems. Since GEM is based on binary predictands and a similar set of predictors, it was necessary to categorize the wind vector. Miller (1981) did this according to the diagram on the next page (see Perrone and Miller, 1983).

Winds of calm (actually speed $\leq$ 1 kt) fell into one category; there were eight categories according to direction when speeds were 2 to 9 kt; there were eight categories according to direction when speeds were 10 to 19 kt; and there were four categories according to direction when speeds were $\geq$ 20 kt.

When categorical forecasts are to be made from probability forecasts, some algorithm must be specified to perform the transformation. The skill or accuracy of the categorical forecasts may depend just as heavily on this



algorithm as on the method to produce the probabilities. Several such algorithms have been tested in connection with GEM. The one used by Miller and Perrone to produce the forecasts for projections 1 thru 20 hours verified in this report is described by Perrone and Miller (1983, Section 6.C).

4. EXPERIMENTAL DESIGN

Since a GEM forecast is based only on the local observation, it can be made at any time there is an observation available. LAMP can be tailored to run at any time a synoptic set of hourly observations is available over a portion of the United States. However, the statistical analysis is done (in theory) for each initialization time (in practice, the analysis would probably be limited to, say, eight times per day). LAMP data sets are currently available for start times of 0800, 1300, and 2000 GMT. Wind prediction testing has been done on the first two of these for the Washington WSFO area (Glahn, 1983), and, therefore, forecasts were available for comparison with GEM forecasts. The LAMP single station equations were developed on four winter seasons (October 1-March 31) of data from the consecutive 4 years starting October 1, 1977.

The LAMP equations furnish forecasts for each hour for projections 1 thru 20 hours from start time. Because LAMP would probably be implemented locally on a minicomputer, the forecasts might not be available for nearly an hour after the initializing observations were made. A 2-h forecast would be, then, a 1-h forecast from the time of its availability. GEM can produce a forecast quite rapidly once the input observation is available. Therefore, we used as input to GEM the 0900 and 1400 GMT observations to compare with the 0800 and 1300 GMT LAMP start times.

The major portion of the LAMP processing time is consumed in making the objective analyses, running the numerical models, and interpolating the model output to station locations. If this process will actually take nearly an hour on the implementation computer, it is conceivable, even likely, that the observation used in the LAMP statistical equations will be 1 hour later than the observations used to initialize the models. Therefore, in addition to using 0800 and 1300 GMT observations exclusively in LAMP, a combination of 0800 and 0900 GMT observations was used for the nominal 0800 GMT start time, and a combination of 1300 and 1400 GMT observations was used for the nominal 1300 GMT start time.

This use of 0900 and 1400 GMT data in LAMP regression equations is entirely compatible with the use of 0900 and 1400 GMT data in GEM, since all of the LAMP processing except the addition of the observation into the regression equation could be completed prior to the arrival of the 0900 or 1400 GMT observation.

In addition to verifying GEM and LAMP forecasts, we also verified persistence and a set of regression forecasts in which the only predictors were the U, V, and S from the local observation (persistence regression). In some comparisons, the persistence observation was taken at 0800 (1300) GMT, and in other comparisons it was taken at 0900 (1400) GMT. The verification was carried out on the one season sample of October 1, 1981 to March 31, 1982. All scores were computed on matched samples.

The original plan was to verify the wind speed forecasts by forming forecast-observed contingency tables of six or seven categories compatible with the National Verification Plan (NWS, 1982) and computing Heidke skill scores, percents correct, and biases by category. However, GEM provides only four categories of speed, so those four categories were used in forming the speed contingency tables. These categories are: ≤ 1, 2-9, 10-19, and ≥ 20 kt.

Also, the plan was to determine the percents of direction forecasts correct to within 30°. Accordingly, results for all cases and for those cases when the verifying wind was ≥ 10 kt are presented.

Since GEM's definition of direction is to eight points of the compass for forecasts of < 20 kt and to four points for forecasts of ≥ 20 kt (in contrast to 36 points for LAMP forecasts, persistence, and the verifying observations), GEM was at a disadvantage to be verified in more precise terms. Therefore, some results are presented based on 21-category contingency tables--the same 21 categories defined for GEM.

5. RESULTS AND EVALUATION

For equations requiring only 0800 (1300) GMT data as input, 1-h forecasts are shown. Pure persistence (OBS) would, of course, be available immediately, and forecasts made by persistence regression could be made available very rapidly. However, the forecasts based on observations, MOS, and geostrophic winds would not be available operationally until, perhaps, nearly the 1-h verifying time.

A. Wind Speed Skill

LAMP 0800 and 1300 GMT Input

Figs. 1 and 2 show the skill scores based on four-category contingency tables for projections 1 thru 20 hours for the 0800 and 1300 GMT start times, respectively. All input was at 0800 (1300) GMT except for GEM which used 0900 (1400) GMT data. Accordingly, the GEM forecasts start at the second hour.

For both 0800 and 1300 GMT, all forecasts based only on the local observation decrease in skill rapidly with time, and at similar rates. The decrease in skill with time is less rapid with LAMP except for the first 4 hours from 0800 GMT. LAMP forecasts are always better than those based only on the 0800 (1300) GMT observation, generally by a considerable margin.

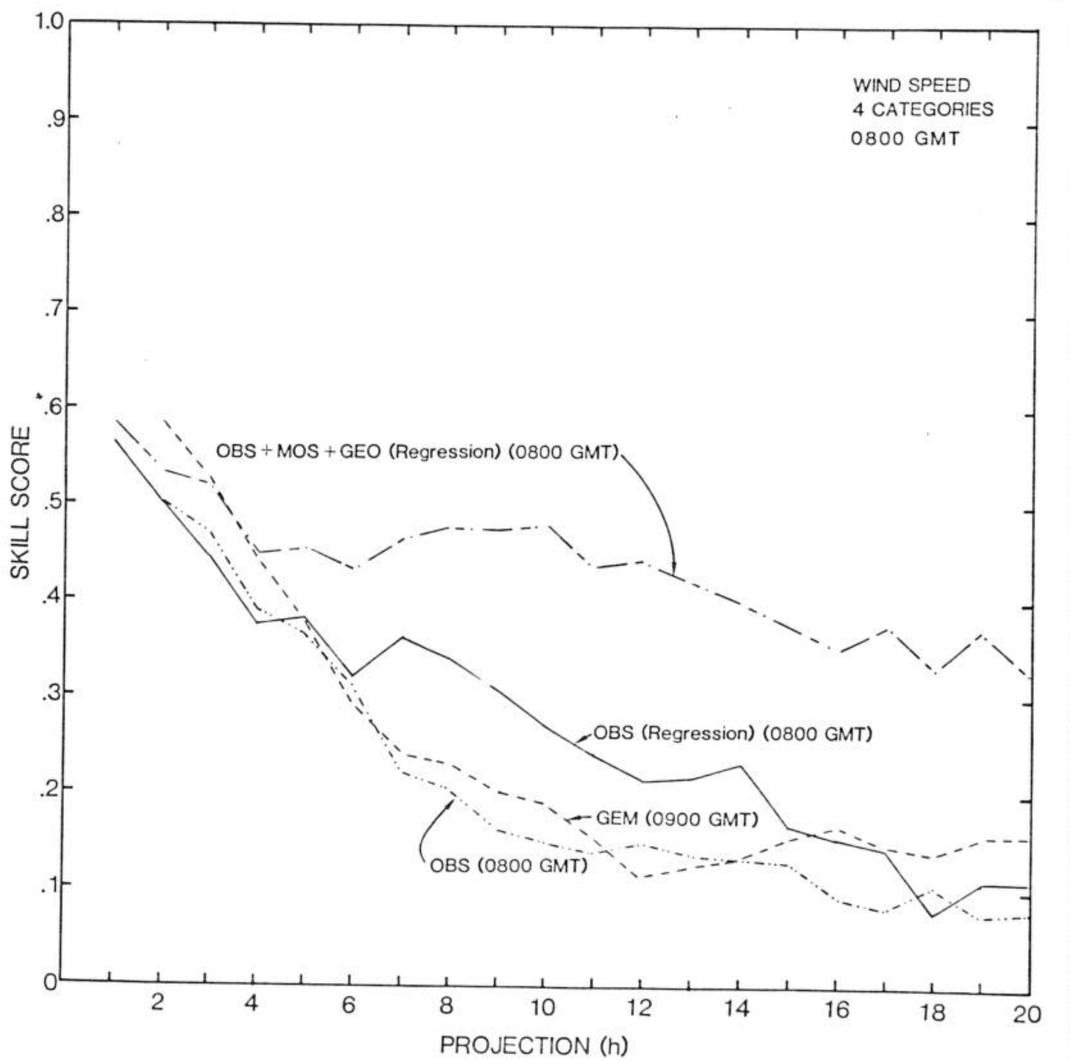


Figure 1. Skill scores for persistence, regression forecasts based on the initial (persistence) observation, GEM, and LAMP for the 0800 GMT start time. The LAMP forecasts are based on the initial observation (OBS), centralized MOS, and geostrophic winds from the sea level pressure model (GEO). All observational input was at 0800 GMT, except for GEM which used 0900 GMT data.

The 3-term (persistence regression) equation based on only the observed wind is no better than persistence for up to 6 hours after 0800 GMT; thereafter, it is somewhat better. At 1300 GMT, persistence regression is generally better than persistence, especially at 2 to 12 hours.

From 0800 GMT, GEM, having 1 hour later data, is better than LAMP at 2 hours and equal to it at 3 and 4 hours; otherwise LAMP is substantially more skillful than GEM. From 1300 GMT, LAMP and GEM are comparable in skill at 2 hours; thereafter, LAMP is superior.

It's surprising to note that the 3-term persistence regression based on 1300 GMT data is of comparable skill to GEM based on 1400 GMT data, the former being generally better at 4 to 11 hours and the latter being generally better at 13 to 20 hours. At 0800 GMT, GEM uses the later observation effectively for hours 2 thru 4; however, for hours 7 thru 14, persistence regression is superior, and GEM is more nearly comparable to straight persistence.

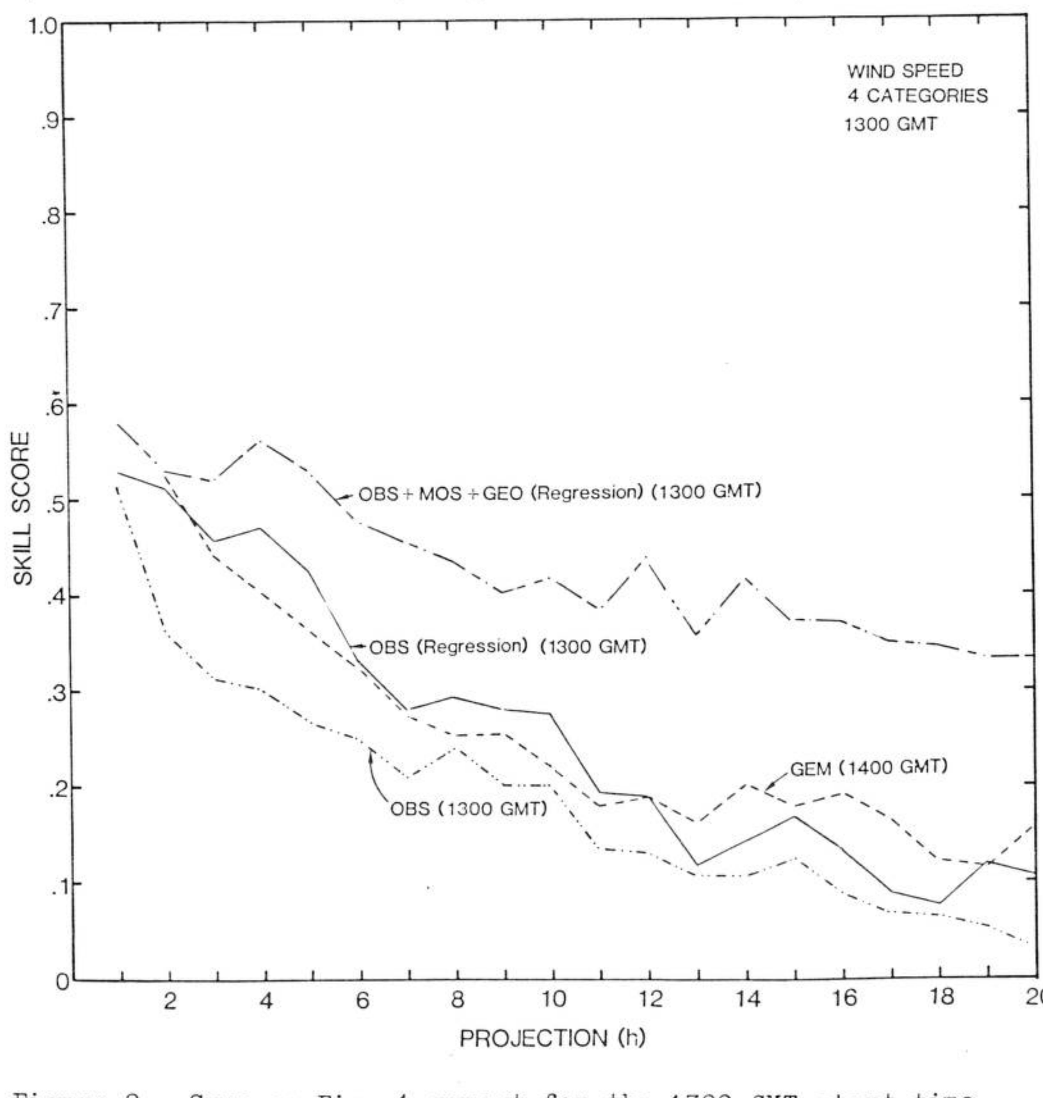


Figure 2. Same as Fig. 1 except for the 1300 GMT start time.

LAMP 0900 and 1400 GMT Input

Figs. 3 and 4 are similar to Figs. 1 and 2 except that the only 0800 (1300) GMT input was to the LAMP sea level pressure model; all other observational input was at 0900 (1400) GMT. Therefore, in LAMP, the MOS predictors were from the 0000 GMT LFM run, the geostrophic wind predictors were from 0800 (1300) GMT, and the observational predictors were from 0900 (1400) GMT. (The minor differences between GEM results in Figs. 1 and 3 and Figs. 2 and 4 are due to sample matching. This is also true for certain other pairs of figures.)

From 0800 GMT, GEM, persistence, and persistence regression have nearly equal skill for hours 2 thru 5 (these are actually projections 1 thru 4 hours); for hours 6 thru 15, persistence regression is considerable more

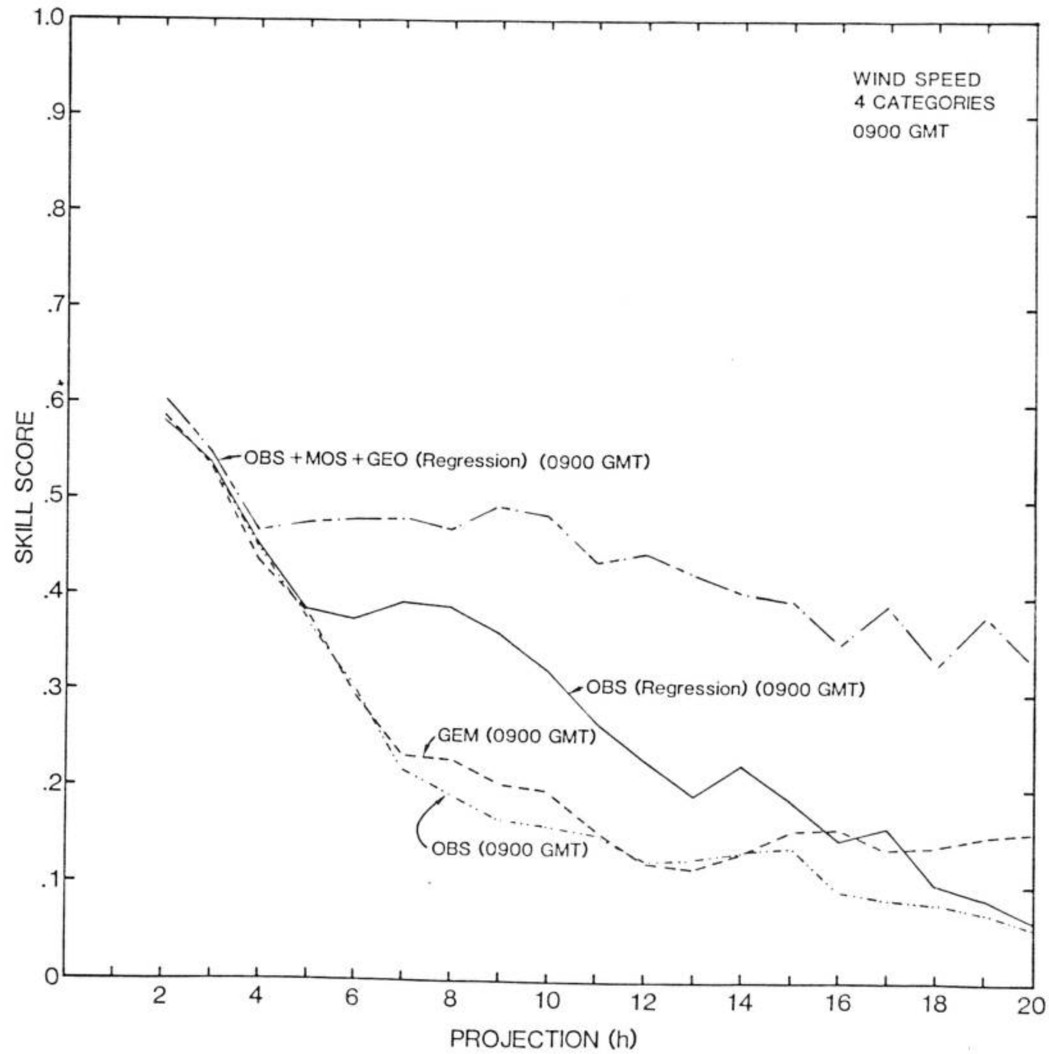


Figure 3. Same as Fig. 1 except all observational input was at 0900 GMT except the data entering the sea level pressure model.

skillful than GEM and raw persistence which show similar skill. GEM becomes superior to persistence at hour 16 and to persistence regression at hour 18. LAMP is better than the other forecasts, but only slightly at hours 2 thru 4.

From 1300 GMT, GEM is not generally better than persistence until about hour 12; at hours 14 thru 20, GEM is appreciably better. Persistence regression is better than GEM and raw persistence for hours 1 thru 11; at hours 14 thru 20, it is worse than GEM and better than persistence. LAMP is clearly superior at all projections.

The reason LAMP shows more improvement over the other forecasts at very short range from 1300 GMT than from 0800 GMT is undoubtably due to the greater synoptic scale influence at 1300 GMT or shortly thereafter.

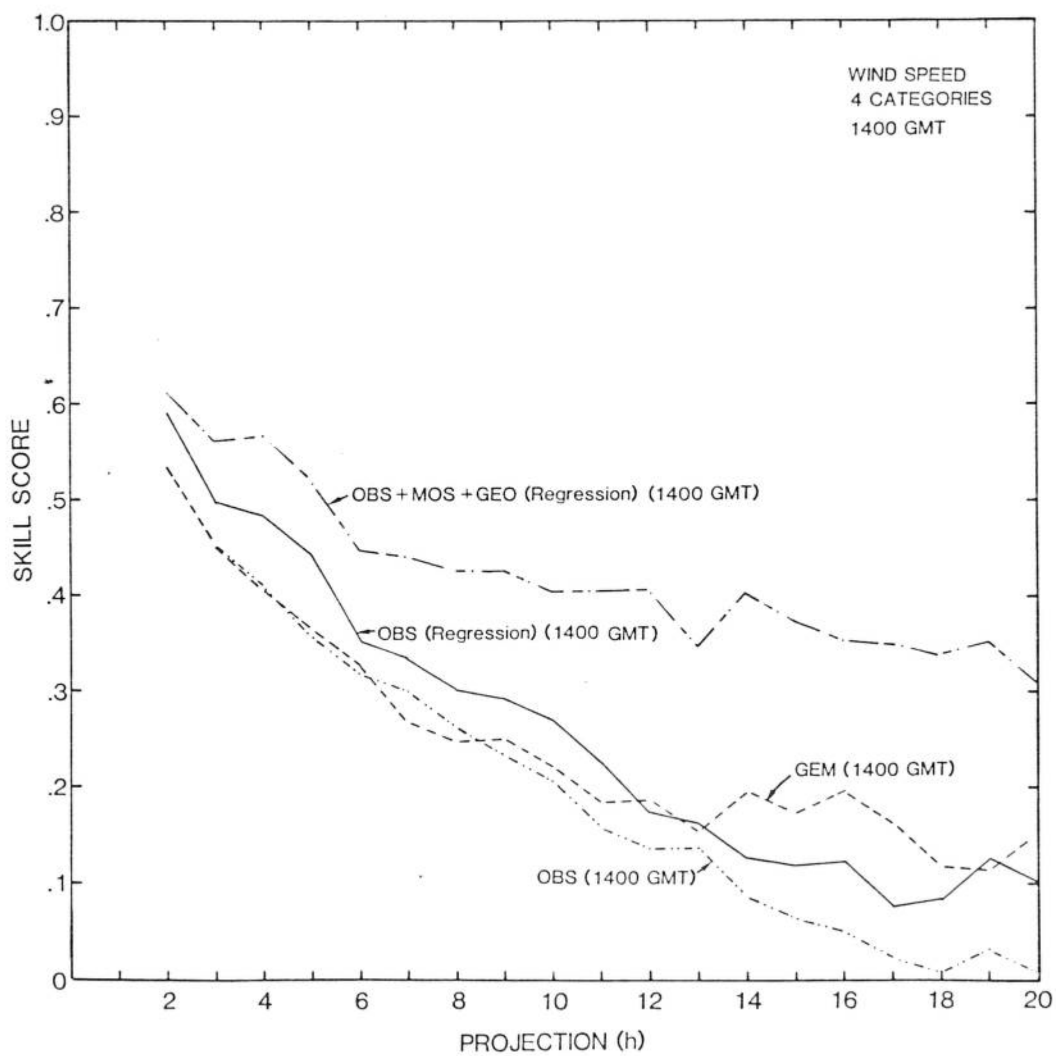


Figure 4. Same as Fig. 3 except for the 1300 GMT start time. All input was at 1400 GMT, except the geostrophic winds from the sea level pressure model.

B. Wind Speed Bias

Winds $\geq$ 10 kt

Figs. 5a and 5b (6a and 6b) show the biases of wind forecasts of $\geq$ 10 kt (categories 3 and 4 from the contingency tables) from 0800 (1300) GMT. Figs. 5a and 5b (6a and 6b) show exactly the same information, except in 5a (6a) the biases are plotted on a log scale and in 5b (6b) they are plotted on a linear

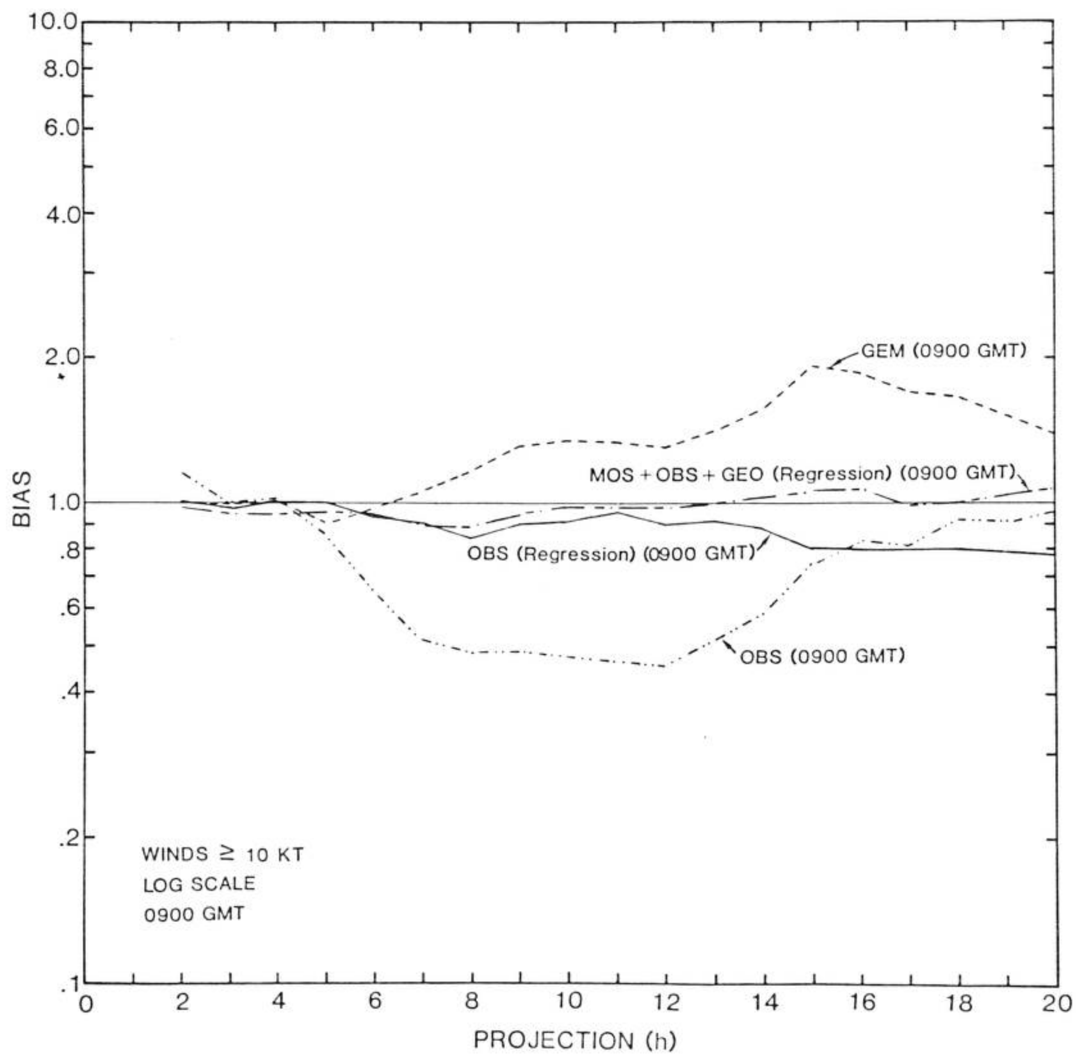


Figure 5a. Biases on a log scale for speed categories 3 and 4 combined ($\geq$ 10 kt) for persistence, regression forecasts based on the initial (persistence) observation, GEM, and LAMP for the 0800 GMT start time. All observational input was at 0900 GMT except the data entering the sea level pressure model.

scale. In comparing biases above and below unity, it seems biases of 2 and 1/2 are equally bad; a log plot will present that visually. On the other hand, when comparing biases above (or below) unity, a bias of 4 (1/4) is twice as bad as a bias of 2 (1/2); a linear plot will present that visually. Therefore, both linear and log plots are shown; the reader can rely on one or the other, or both. These results are based on 0900 and 1400 GMT data, and correspond to the skill scores shown in Figs. 3 and 4.

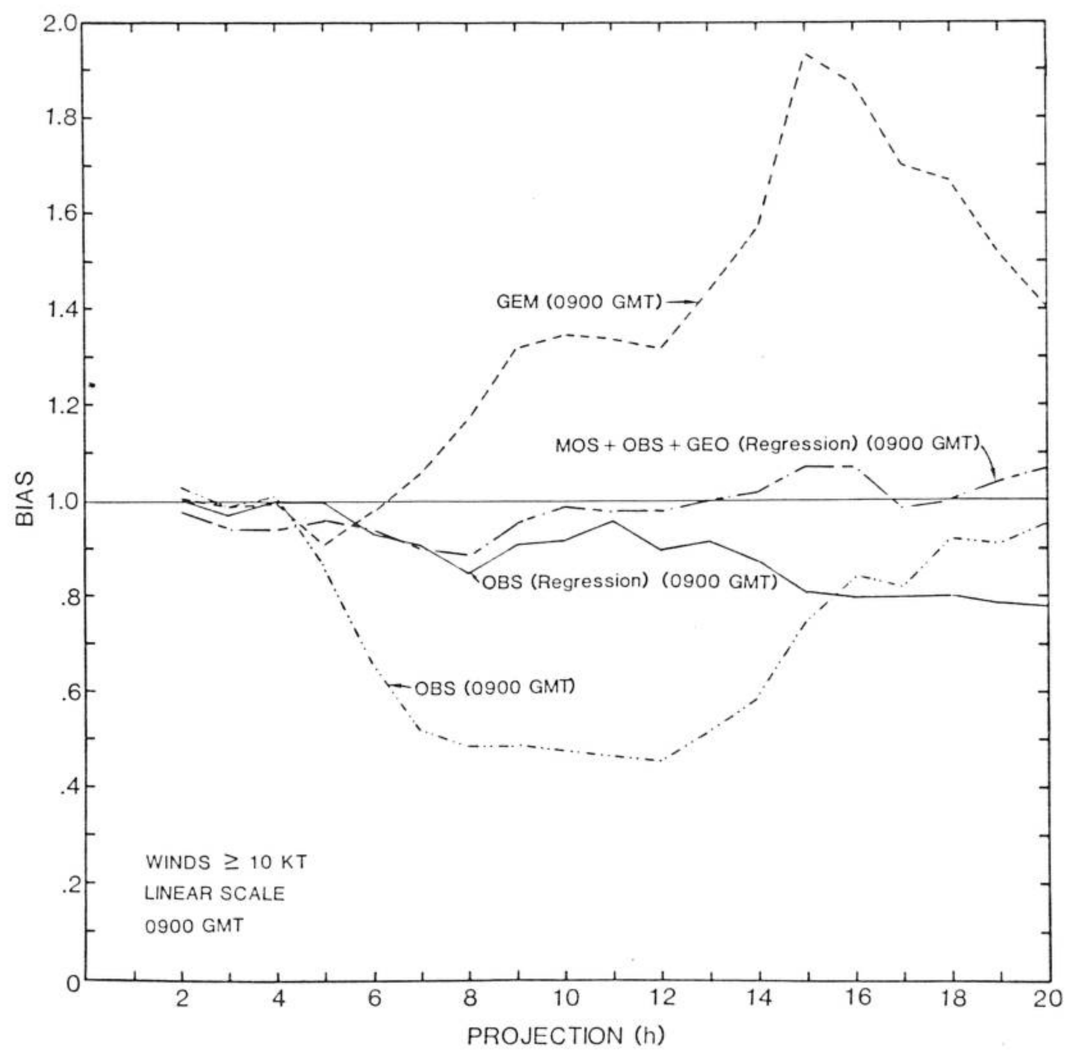


Figure 5b. Same as Fig. 5a except biases plotted on a linear scale.

From 0800 GMT, LAMP forecasts are relatively unbiased, persistence regression biases are between .8 and 1.0, while GEM is considerably above unity for many projections reaching a maximum above 1.8 at hours 15 and 16.

From 1300 GMT, LAMP and persistence regression forecasts are generally within 10% of unity, while GEM fluctuates between .7 at hour 3 to 1.8 at

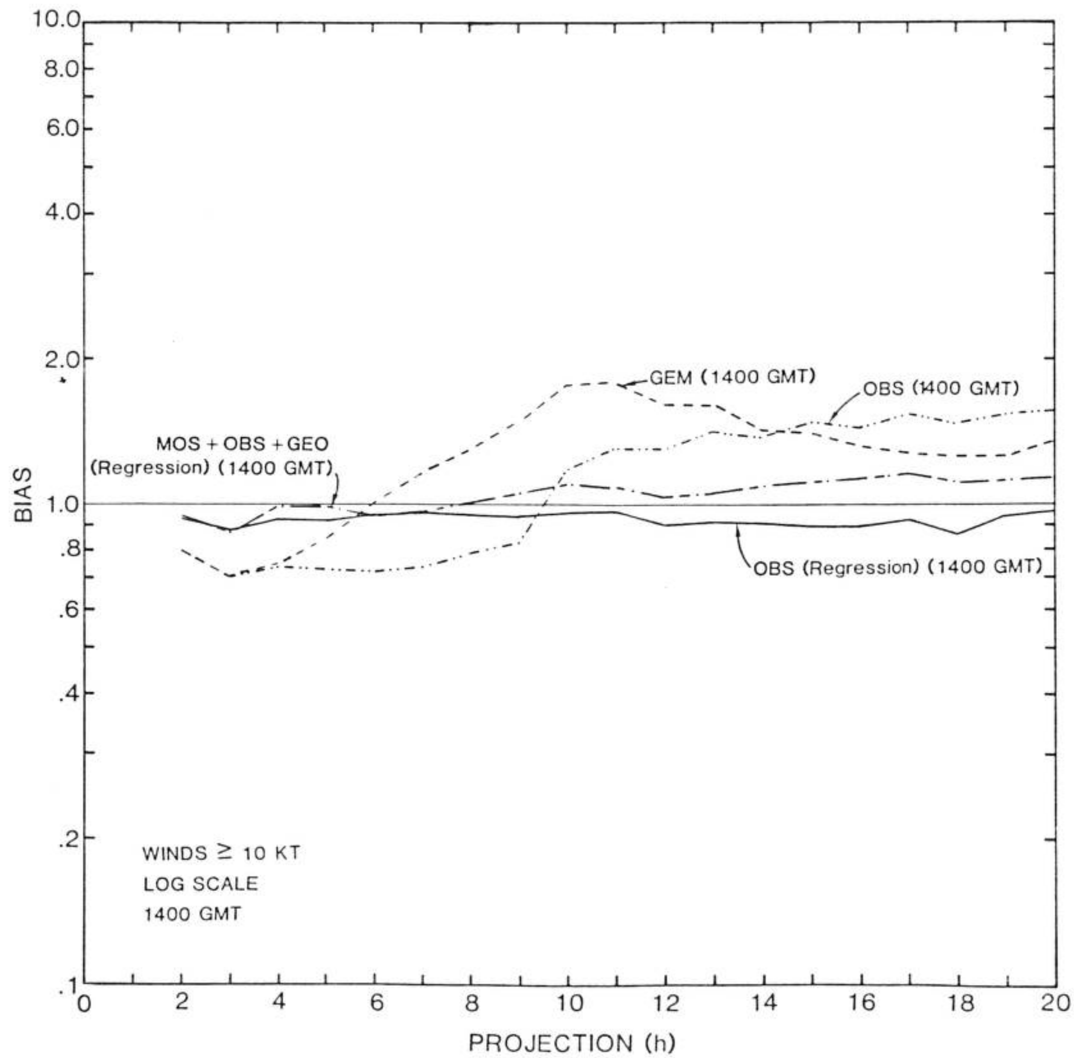


Figure 6a. Same as Fig. 5a except for the 1300 GMT start time.

hour 11. Note that the peak in GEM bias in Fig. 6b is displaced in projection by 5 hours from the peak in Fig. 5b, the difference in input times. That is, the peaks occur at the same verifying time, about 0000 GMT the next (GMT) day.

The persistence forecasts would, of course, not be expected to be unbiased; they are shown only for comparison.

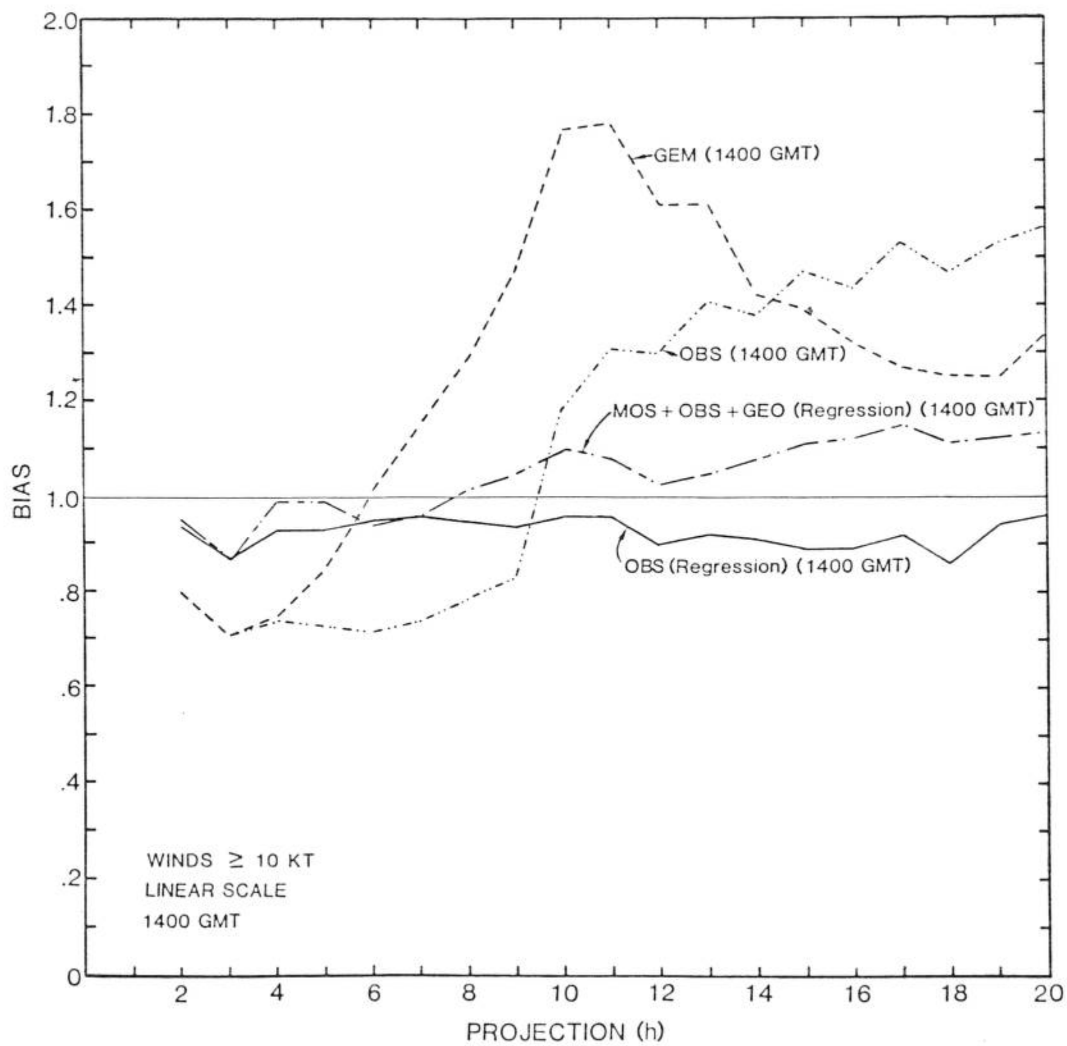


Figure 6b. Same as Fig. 6a except biases plotted on a linear scale.

Winds $\geq$ 20 kt

Figs. 7a and 7b (8a and 8b) show the biases of wind forecasts of $\geq$ 20 kt (category 4 from the contingency tables) from 0800 (1300) GMT. As before, Figs. 7a and 7b (8a and 8b) differ only by scale; the same information is in both. Because of the smaller number of cases involved, the fluctuations from hour to hour are quite large. Therefore, the values shown in Figs. 7 and 8 are smoothed; the average of two hourly values is plotted between these

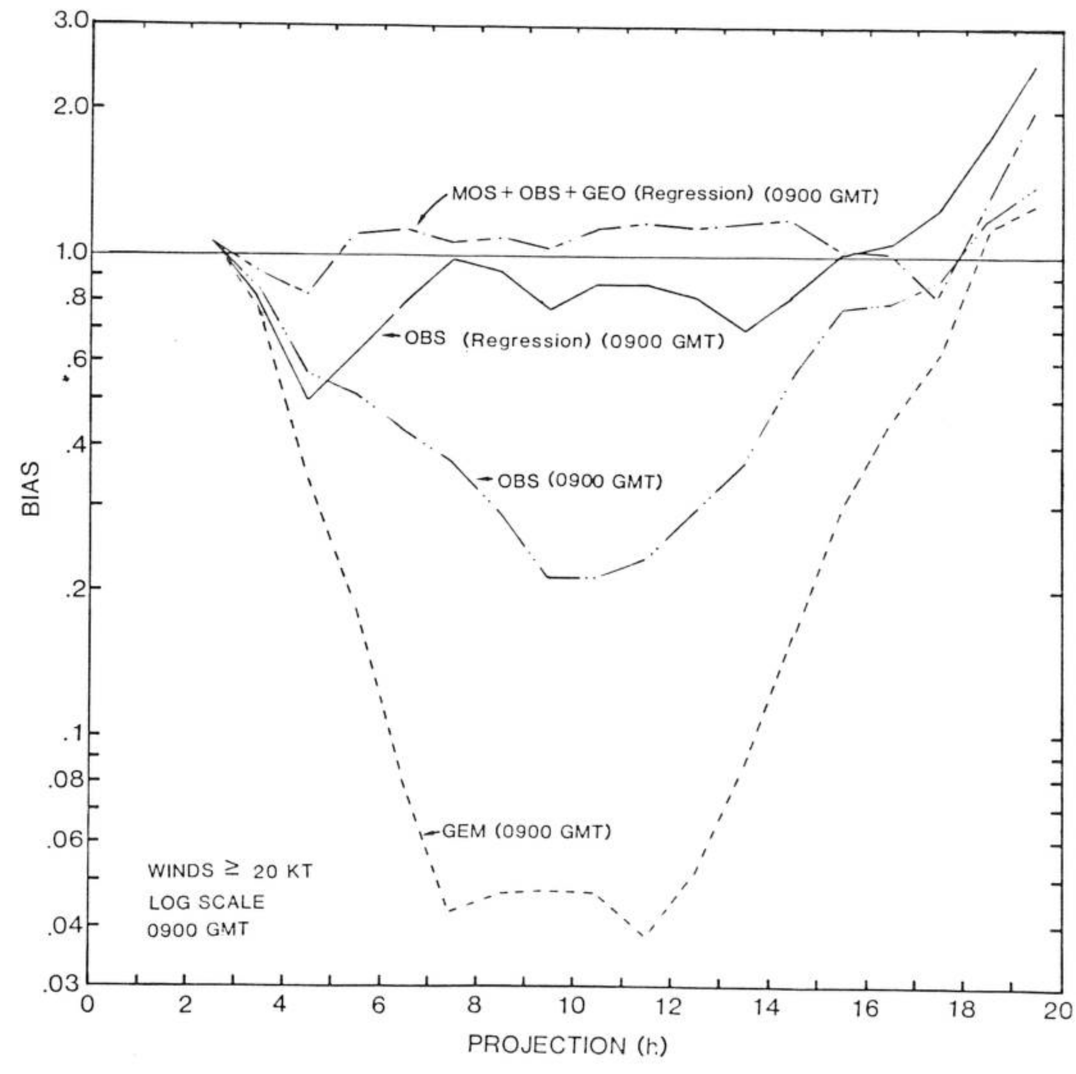


Figure 7a. Biases on a log scale for speed category 4 ($\geq$ 20 kt) for persistence, regression forecasts based on the initial (persistence) observation, GEM, and LAMP for the 0800 GMT start time. All observational input was at 0900 GMT except the data entering the sea level pressure model.

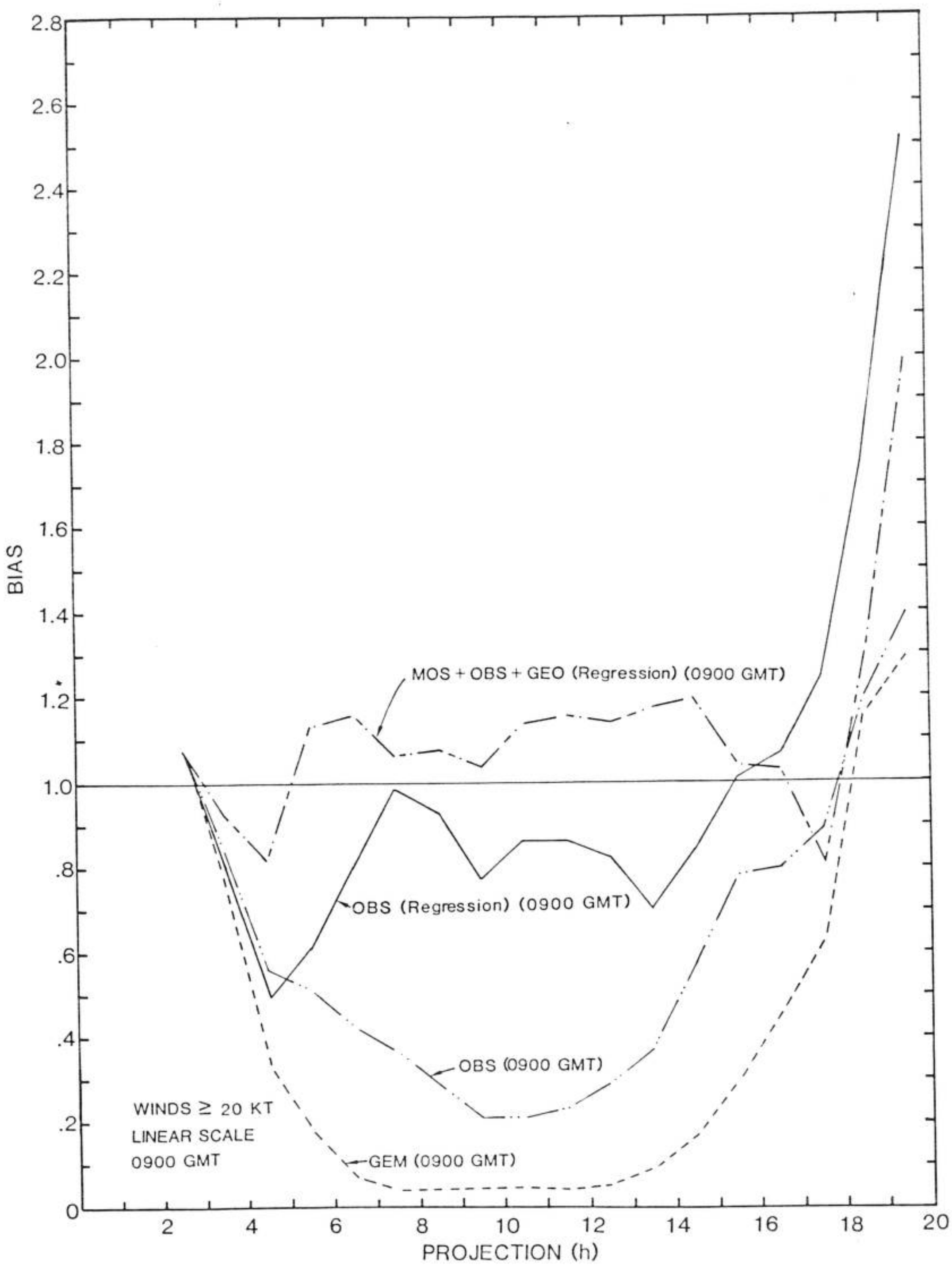


Figure 7b. Same as Fig. 7a except biases plotted on a linear scale.

hours. Even with this smoothing the fluctuations from hour to hour are greater in these figures than in Figs. 5 and 6.

Owing to the small number of cases involved, the only major conclusion one can draw is that GEM considerably underforecasts the high wind category throughout the daylight hours. For instance, for hours 7 thru 12 from 0800 GMT, less than 5% as many winds were forecast to be $\geq$ 20 kt as occurred.

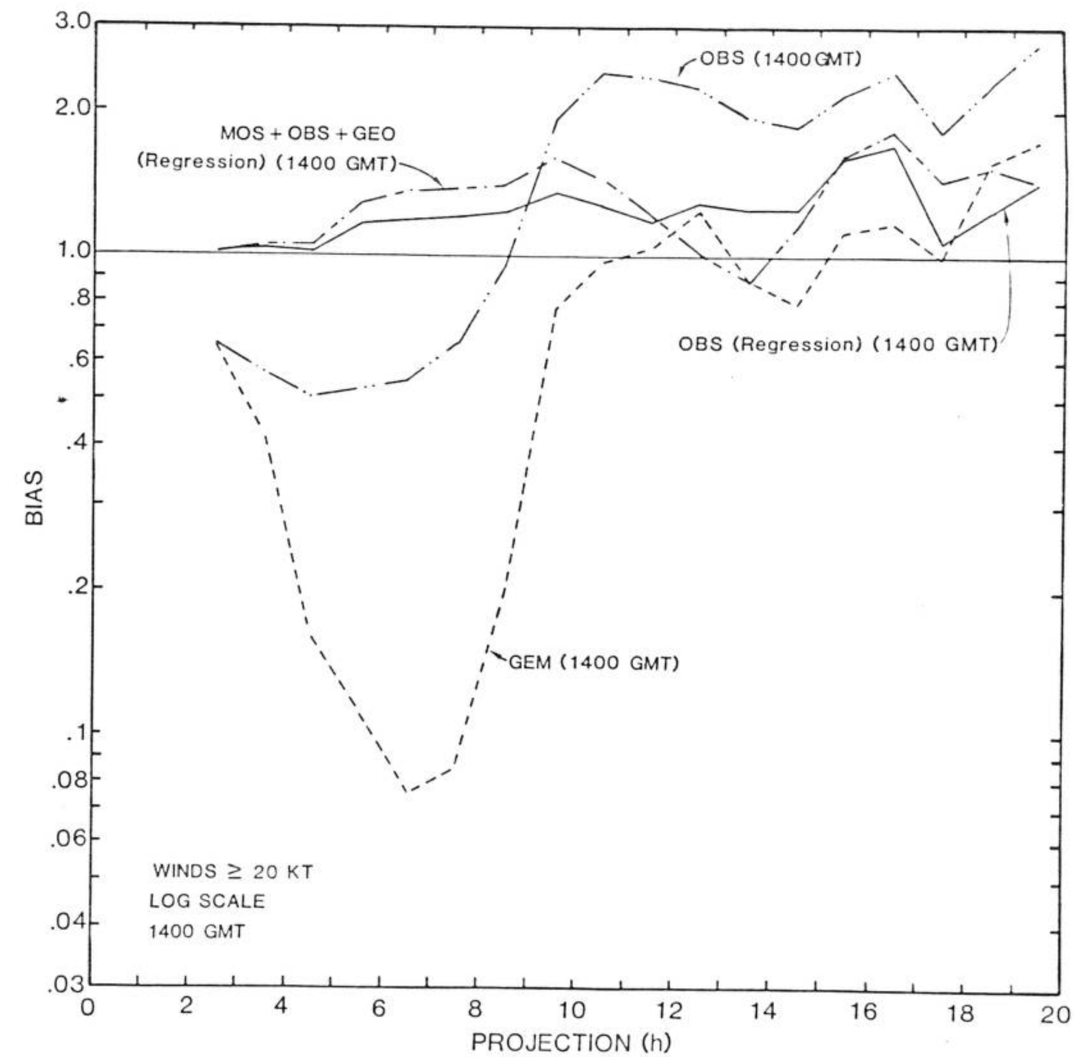


Figure 8a. Same as Fig. 7a except biases for the 1300 GMT start time.

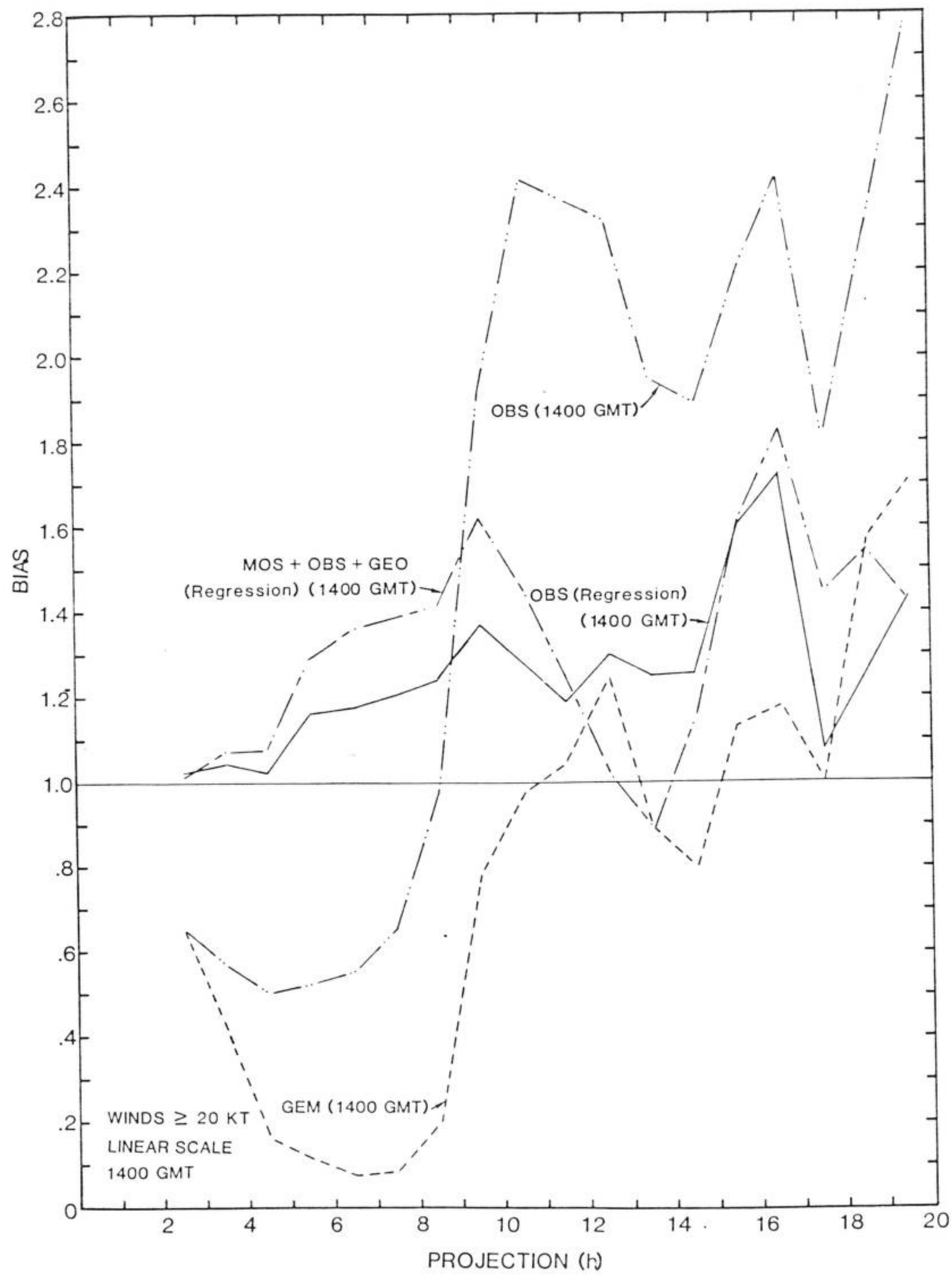


Figure 8b. Same as Figure 8a except biases plotted on a linear scale.

C. Direction Accuracy

Observed wind > 10 kt

Figs. 9 and 10 show the relative frequencies of wind forecasts correct to within 30° when only observed winds of > 10 kt are verified for the 0800 and 1300 GMT start times, respectively. All input data are from 0800 and 1300 GMT except for GEM; therefore, the results correspond to Figs. 1 and 2 rather than Figs. 3 and 4. As explained previously, pure persistence forecasts would be available essentially at initial time, and regression forecasts based on the local wind observations could be available very quickly. However, the 1-h forecast based on the observation, MOS, and the geostrophic wind would not be available operationally until, perhaps, nearly its verifying time.

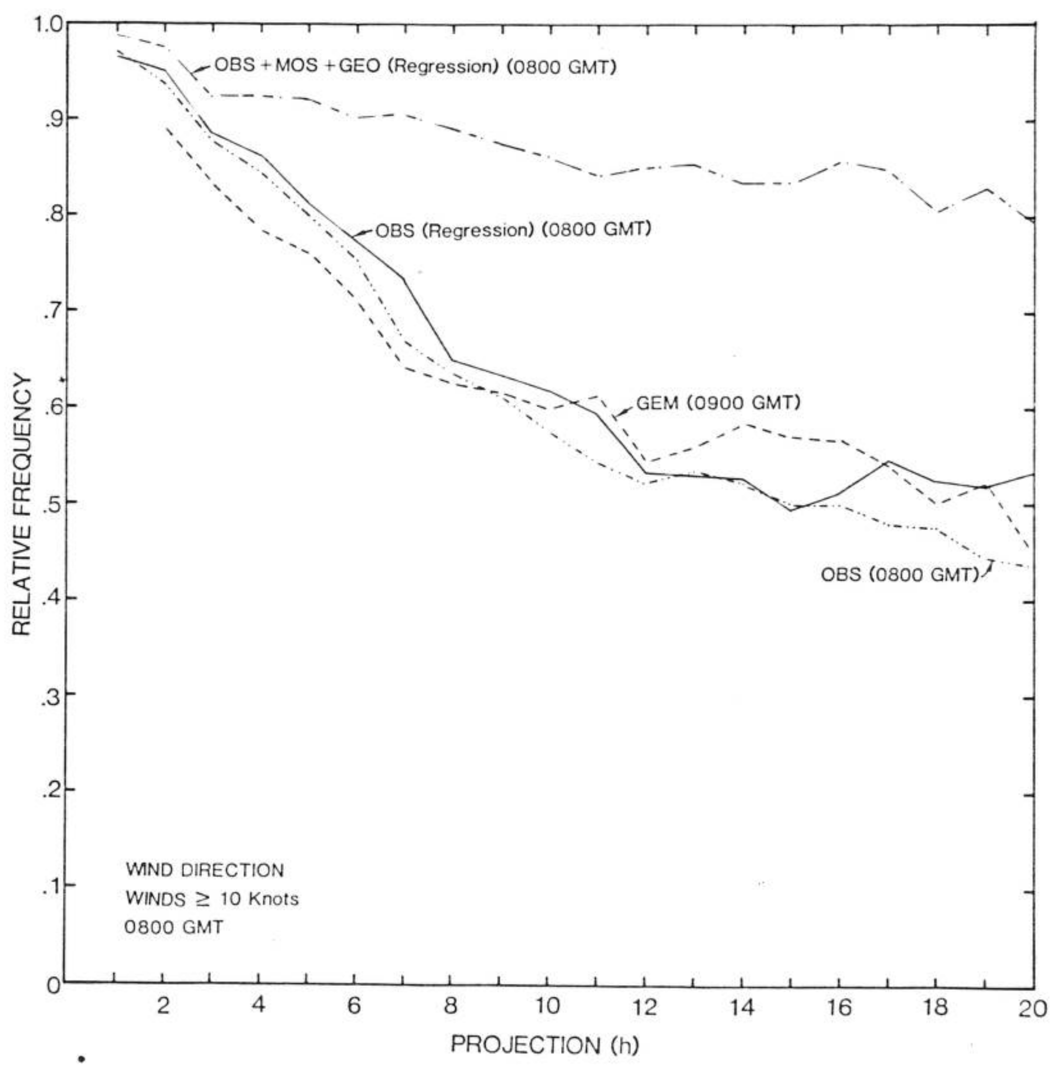


Figure 9. Relative frequency of wind direction forecasts correct to within 30° for observed winds > 10 kt for persistence, regression forecasts based on the initial (persistence) observation, GEM, and LAMP for the 0800 GMT start time. All observational input was at 0800 GMT except for GEM which used 0900 GMT data.

At 0800 GMT, LAMP is clearly superior at all projections according to this statistic, being about 98% correct at 2 hours and never going below 80%. Persistence and persistence regression are about equally skillful, the latter having a slight edge at most projections. GEM is less accurate than persistence for hours 2 thru 8, even though the 2-h persistence forecast matches with a 1-h GEM forecast. After about hour 10, GEM is generally better than persistence and persistence regression.

At 1300 GMT, LAMP is again clearly superior at all projections. Although a 1-h GEM forecast is slightly better than 2-h persistence and persistence regression forecasts, there is little reason to prefer GEM over either, especially for hours 2 thru 14.

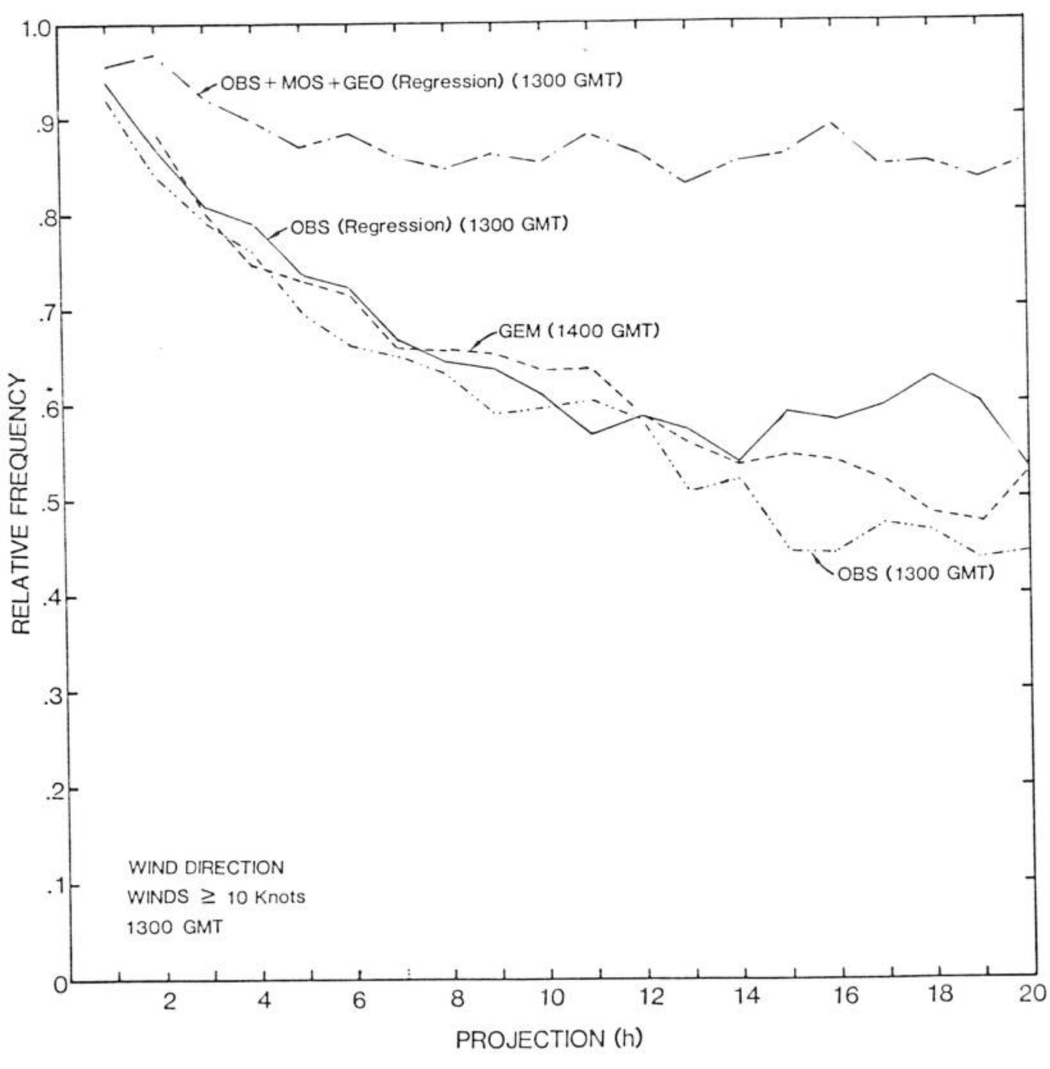


Figure 10. Same as Fig. 9 except for the 1300 GMT start time.

All Winds - LAMP 0800 and 1300 GMT Input

Figs. 11 and 12 show the relative frequencies of wind forecasts correct to within 30° for all observed winds for the 0800 and 1300 GMT start times, respectively. Similarly to Figs. 9 and 10, all input data are from 0800 and 1300 GMT except for GEM.

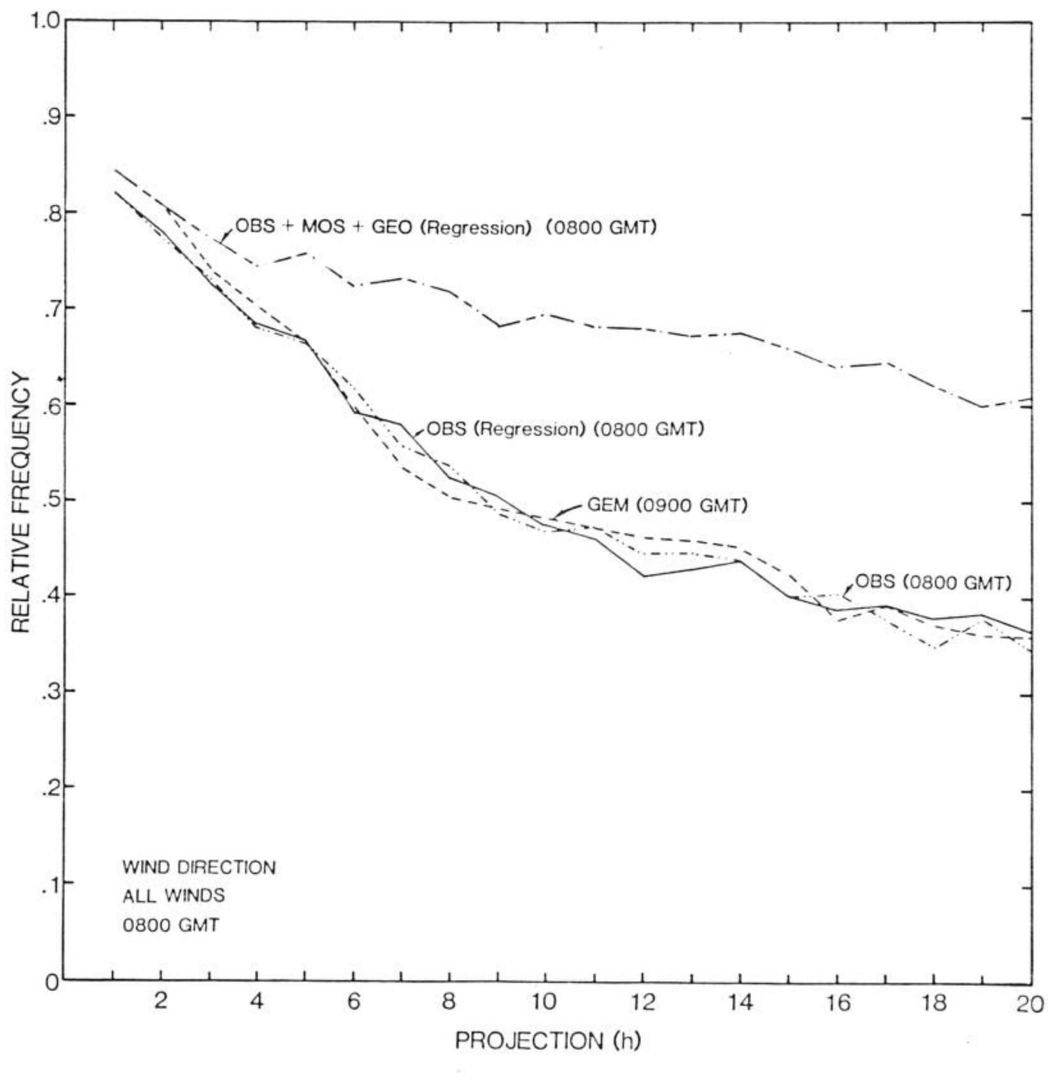


Figure 11. Same as Fig. 9 except all winds (except calm) were verified rather than just those ≥ 10 kt.

For both 0800 and 1300 GMT, there seems little reason to prefer GEM over persistence or persistence regression except at hours 2 thru 4. From 0800 GMT, the GEM (1-h) forecast is equal to the LAMP (2-h) forecast at hour 2; at all other projections from 0800 GMT and at all projections from 1300 GMT, LAMP has higher accuracy than the other forecast systems.

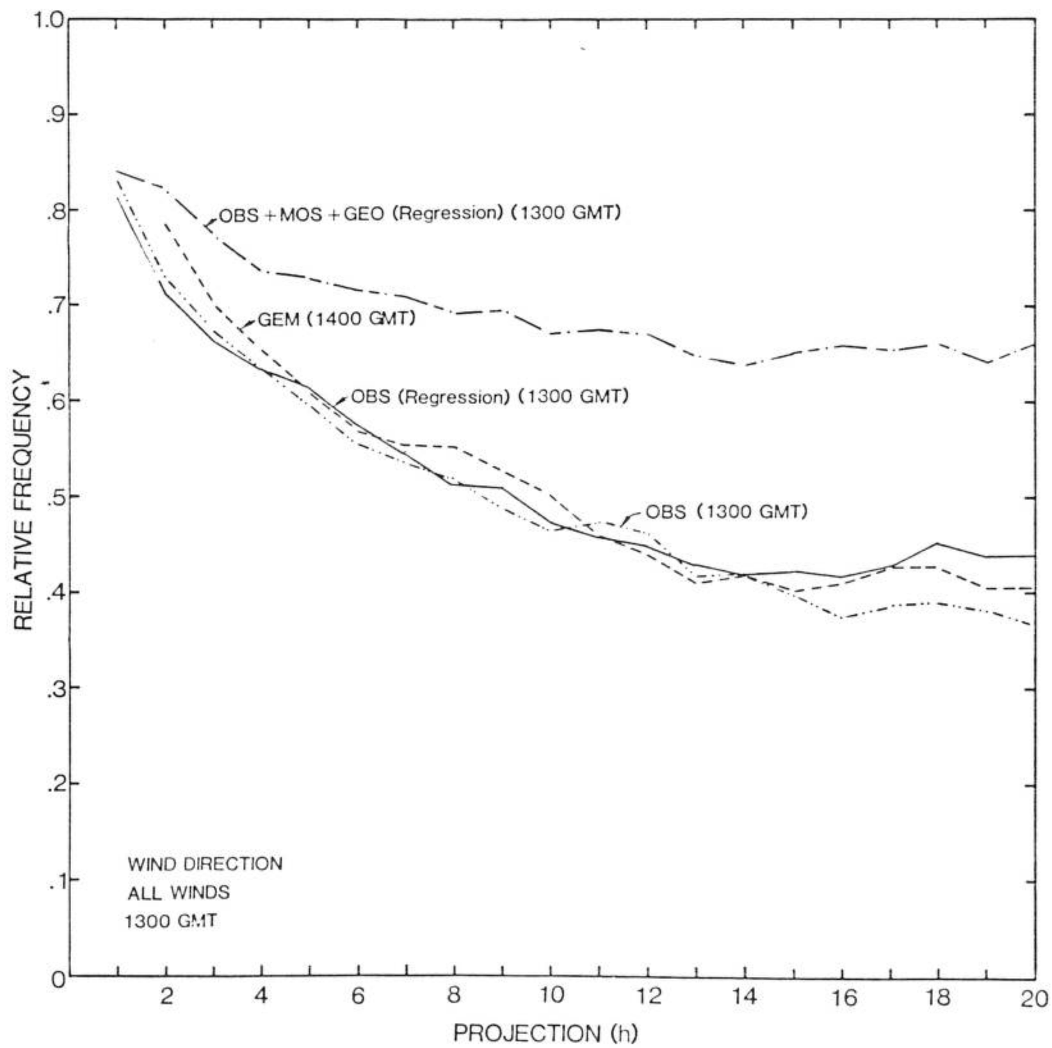


Figure 12. Same as Fig. 11 except for the 1300 GMT start time.

All Winds - LAMP 0900 and 1400 GMT Input

Figs. 13 (14) is similar to Fig. 11 (12), except the only 0800 (1300) GMT input was to the LAMP sea level pressure model; all other observational input was at 0900 (1400) GMT.

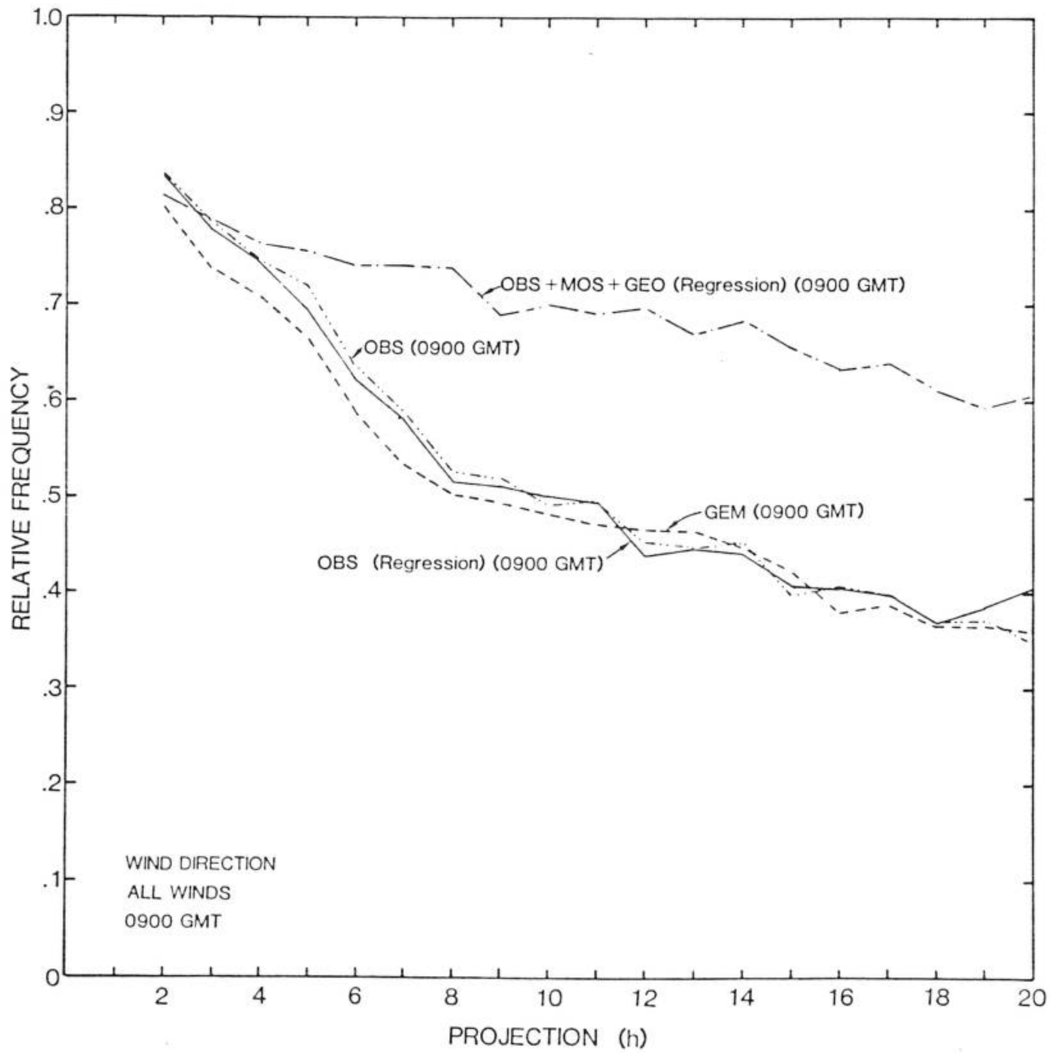


Figure 13. Same as Fig. 11 except except that all observational input was at 0900 GMT except the data entering the sea level pressure model.

LAMP is superior except for hours 2 and 3 from 0800 GMT. Persistence and persistence regression are very similar in accuracy. GEM is similar to persistence and persistence regression except at short range (approximately hours 2 thru 7) where it is less accurate.

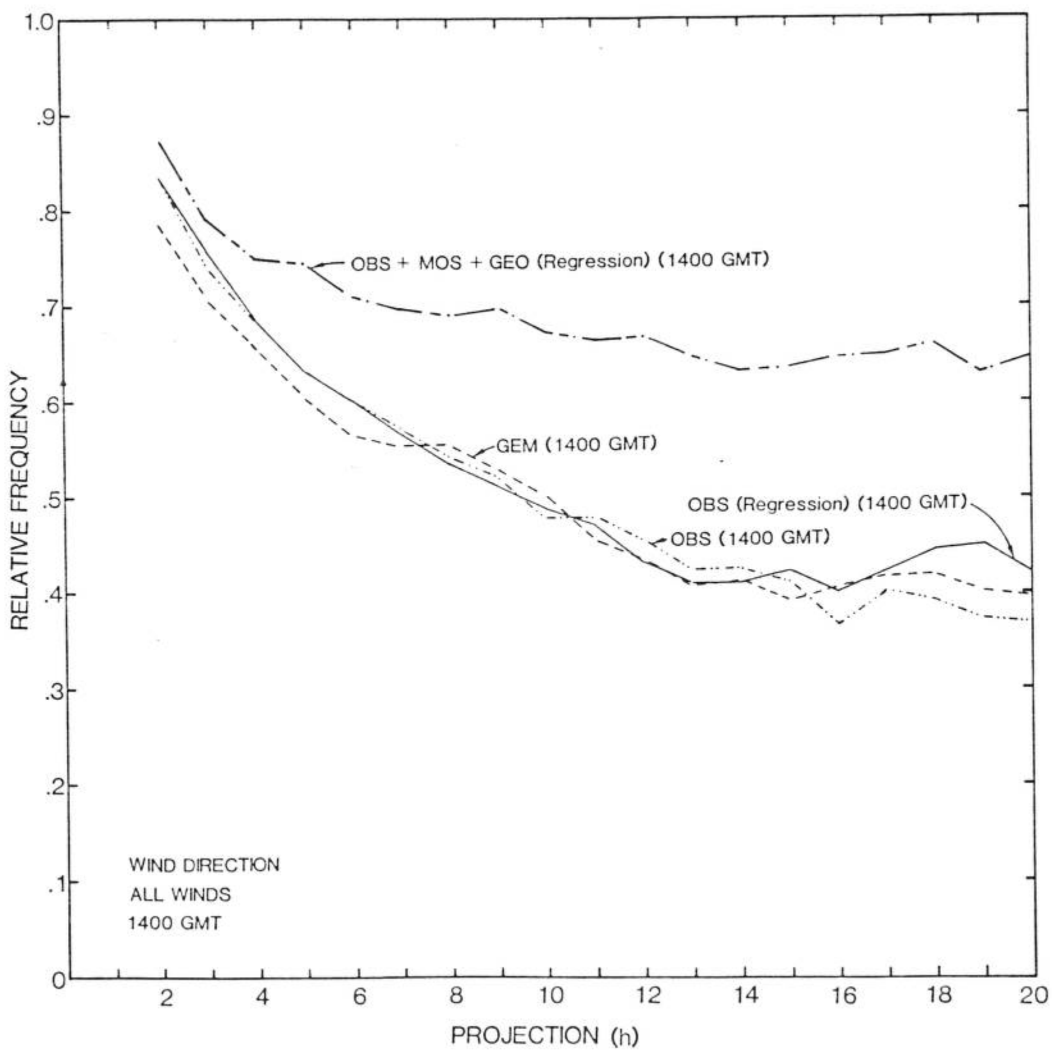


Figure 14. Same as Fig. 13 except for the 1300 GMT start time.

D. Twenty-one Categories

Although the speed forecasts had been verified in exactly the same categories as forecast by GEM, it was feared that the direction verification had penalized GEM because of its inability, as presently developed, to forecast all directions. Therefore, 21-category forecast-observed contingency tables were formed in which the categories were exactly those forecast by

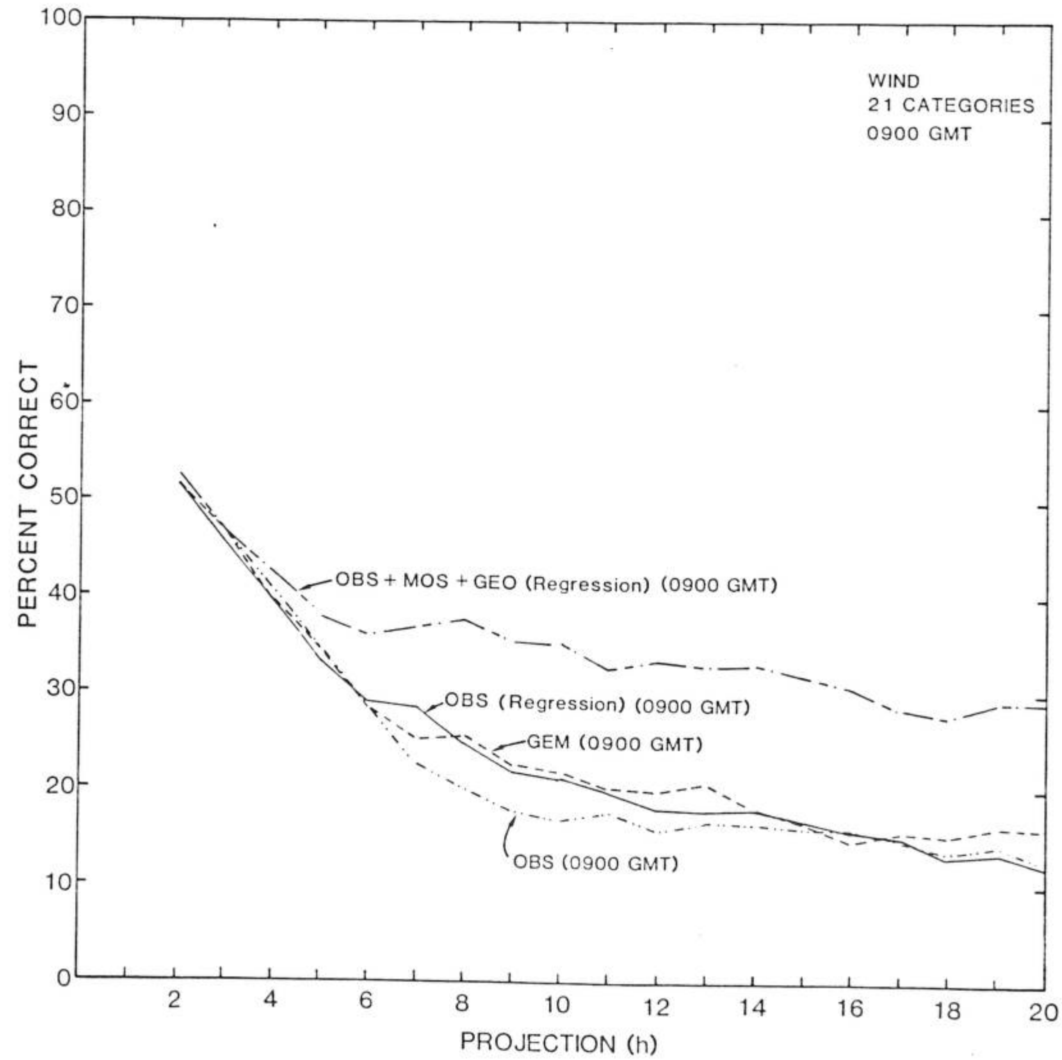


Figure 15. Percent correct for persistence, regression forecasts based on the initial (persistence) observation, GEM, and LAMP for the 21 GEM categories for the 0800 GMT start time. All observational input was at 0900 GMT except data entering the sea level pressure model.

GEM. As stated earlier, these categories encompass both speed and direction. For this purpose, most input data were from 0900 and 1400 GMT, the only 0800 and 1300 GMT input being that initializing the sea level pressure model.

Figs. 15 (17) and 16 (18) show the percents correct and skill scores respectively, computed from these tables for the 0800 (1300) GMT start time. It is readily seen that the figures showing skill scores and percents correct

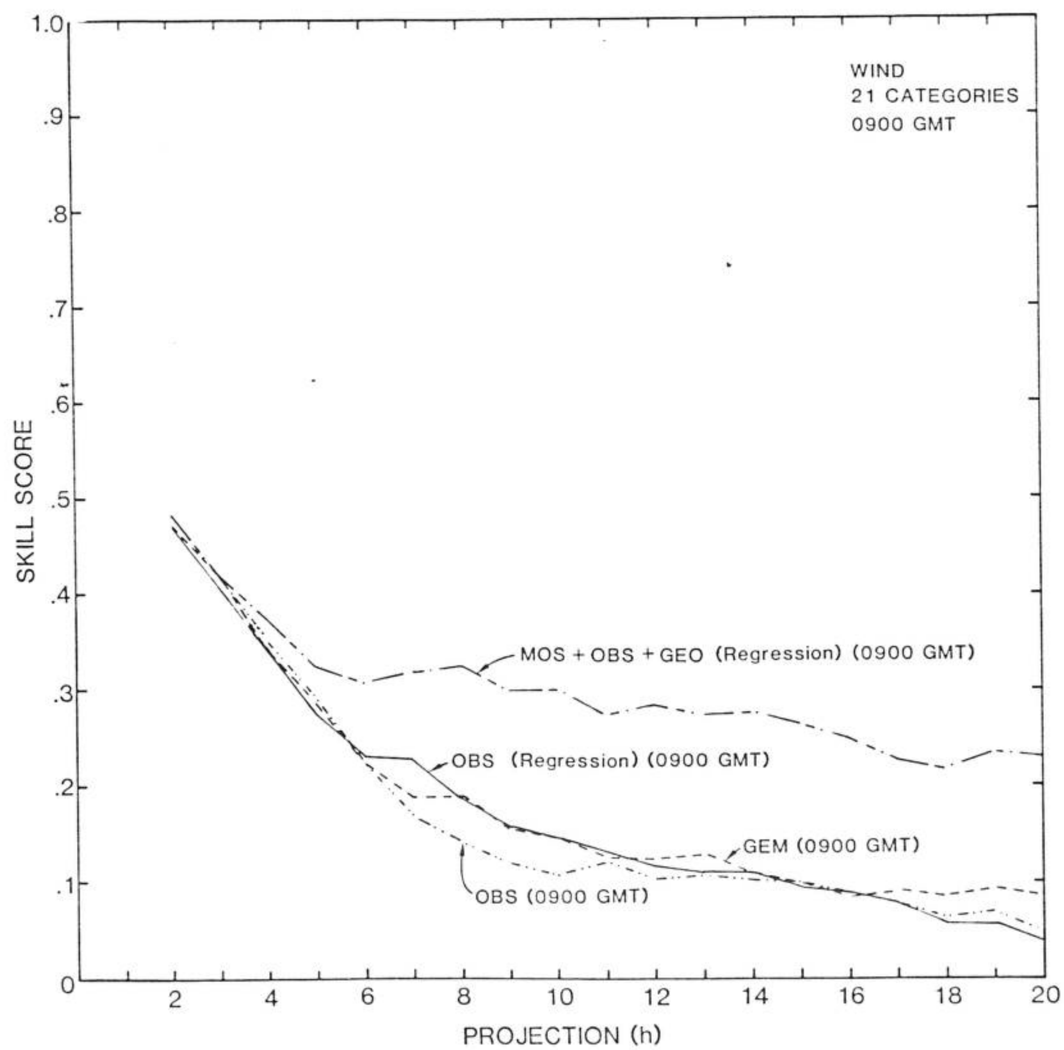


Figure 16. Same as Fig. 15 except for skill score.

from the same contingency tables present the same picture. That is, if one set of forecasts is better in terms of skill score, the same is generally true of percent correct.

At 0800 GMT, all sets of forecasts are equally skillful (accurate) at hours 2 and 3; thereafter, LAMP is better. GEM, persistence, and persistence

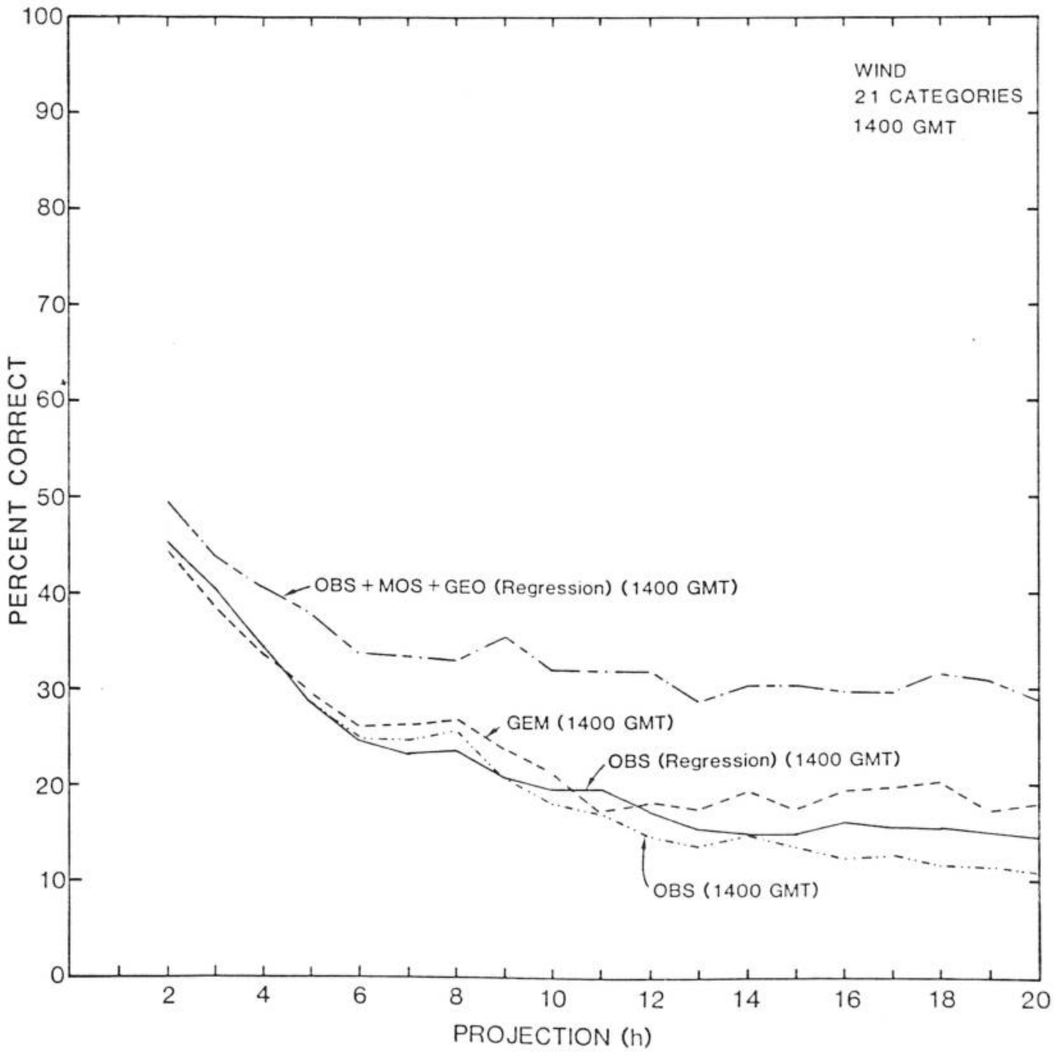


Figure 17. Same as Fig. 15 except for the 1300 GMT start time.

regression are about equally skillful, persistence being somewhat less skillful for hours 7 thru 14 and GEM being better at hours 18 thru 20.

At 1300 GMT, LAMP is definitely better at all projections. GEM, persistence, and persistence regression are about equal in skill for hours 2 thru 6; thereafter, GEM has more skill, particularly after hour 13.

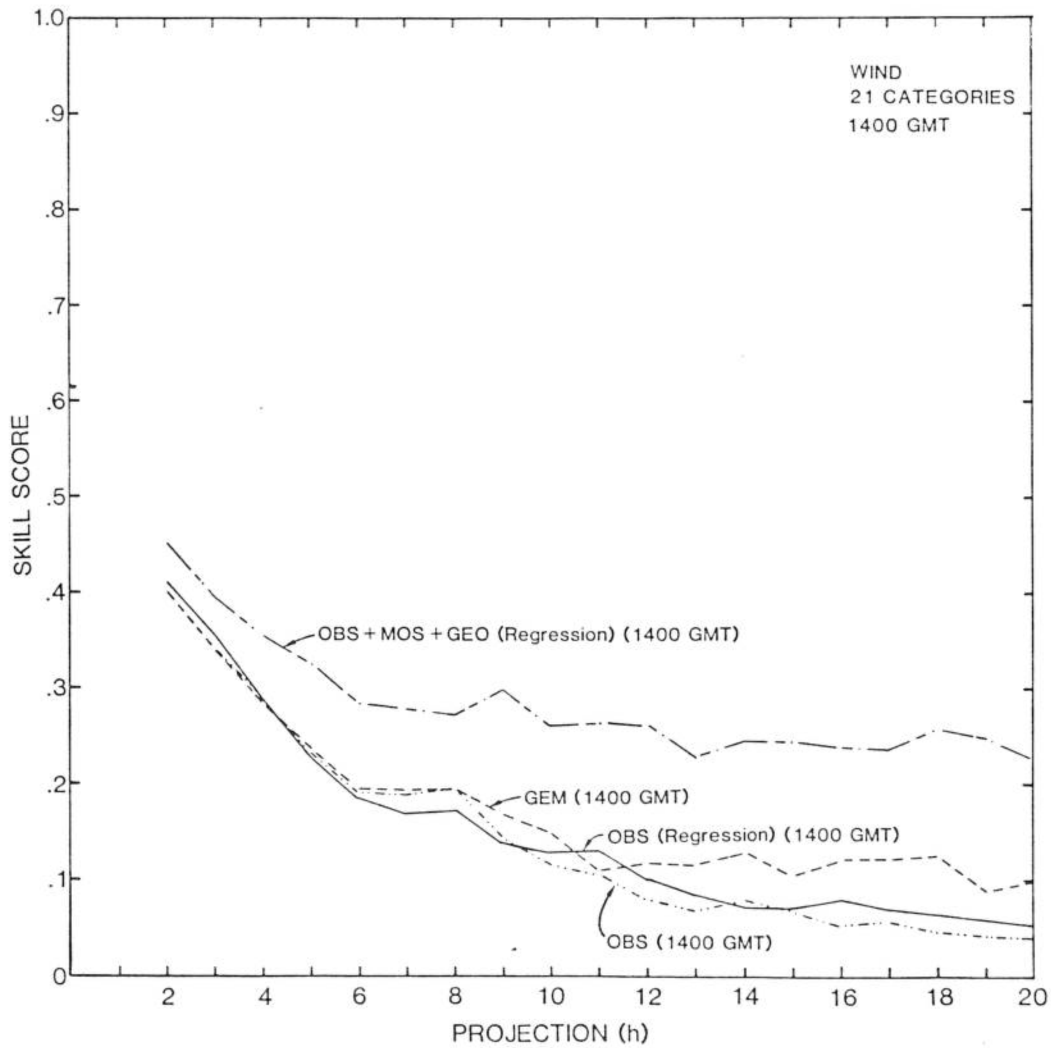


Figure 18. Same as Fig. 17 except for skill score.

6. SUMMARY AND CONCLUSIONS

In this comparative evaluation, the input data were chosen on the basis of what would be available operationally. At first it was thought that the only input to LAMP would be at 0800 (1300) GMT, while GEM should enjoy 1-h later input data because forecasts can be made so rapidly. Later, it was realized that the time-consuming portion of LAMP could be completed with 0800 (1300) GMT data, and that the contribution by the station observation could come from 1-h later data also, since this final computation should be no more time consuming than the GEM computation.

Basing persistence and persistence regression on 0900 (1400) GMT data was much more realistic in the context of this test. The only reason for using 0800 (1300) GMT data in some comparisons was to provide a control for LAMP when its entire input was at that time.

After attempting to allow for random fluctuations from hour to hour, I draw the following conclusions:

- At 0800 or 0900 GMT, the most recent observation controls the quality of the forecasts for the first 2 or 3 hours. However, even at this range, the synoptic information furnished by the centralized MOS forecasts and the sea level pressure model contributes. After the first 2 or 3 hours, and especially after the first hour at 1300 or 1400 GMT, LAMP forecasts are definitely better than the forecasts based on only the local observation. Synoptic information is more important at 1300 GMT than at 0800 GMT because 1300 GMT is near the beginning of the daylight hours and the wind is more changeable than during the few hours immediately after 0800 GMT.

- GEM, persistence, and persistence regression furnish about equal skill and accuracy for projections up to 6 hours from input times of 0900 and 1400 GMT. Exceptions to this statement are (1) persistence regression is better than the other two for 4-category wind speed from 1400 GMT (Fig. 4), and (2) GEM is less skillful in terms of the direction score computed than the other two (Figs. 13 and 14). This last result is probably due in part to the fact that GEM forecasts to only 8 points of the compass for winds < 20 kt and to 4 points for winds ≥ 20 kt, while the other forecasts are (effectively) to 36 points of the compass.

- GEM seems to have some advantage over persistence and persistence regression for hours 18 thru 20 from 0800 GMT and for hours 13 thru 20 from 1300 GMT. (The direction accuracy shown in Figs. 9 thru 14 is disregarded in drawing this conclusion.) Note that an 18-h projection from 0800 GMT and a 13-h projection from 1300 GMT both verify at the same time--at 0200 GMT the next (GMT) day, just after nightfall.

- When LAMP input is limited to 0800 (1300) GMT data, GEM, using 1-h later data, produces better wind speed forecasts for hour 2 (1-h GEM projection) from 0800 GMT. For hours 3 and 4 from 0800 GMT and for hour 2 from 1300 GMT, LAMP and GEM have equally skillful speed forecasts. Thereafter, LAMP is more skillful. (See Figs. 1 and 2.)

The direction accuracy measure computed shows LAMP to be better at all projections, especially if only observed winds ≥ 10 kt are verified (Figs. 9 thru 14). The only exeption to this conclusion is that at hour 2 from 0800 GMT when all winds are verified, LAMP and GEM are equally skillful (Fig. 11).

- o The algorithm used in GEM to produce the categorical wind forecasts from the probabilities seems to work reasonably well. However, at many (if not most) projections GEM speed forecasts are more biased than any other set of forecasts except persistence. For winds ≥ 10 kt, GEM biases range between 0.7 and 1.9, with a definite tendency to overforecast. LAMP biases range between 0.9 and 1.2. Random fluctuations associated with small sample sizes of winds ≥ 20 kt make definite statements difficult. For several projections from 0800 GMT, GEM forecast less than 5% as many winds ≥ 20 kt as occurred (bias of 0.05). LAMP biases ranged generally between 0.7 and 2.0 for these strong winds, with some tendency to overforecast.

- o Using 0900 (1400) GMT data as input to LAMP gives better speed forecasts for hours 2 and 3 than using only only 0800 (1300) GMT data. The later data seem to make less of an impact on direction forecasts, although improvement is noted at hours 2 and 3 from 1300 GMT.

The GEM forecasts verified were produced from single station equations developed specifically for this study; it is not known how the generalized equations would have fared.

In conclusion, GEM's major strength lies in its relative ease of use. LAMP, although implementable on a minicomputer, cannot be used operationally with the present AFOS system. On the other hand, it is more feasible to make GEM forecasts, for at least a few projections and stations, on current equipment. Also, development of LAMP for all of the United States, would be a large understanding.

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