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UPDATED MOS CEILING HEIGHT AND VISIBILITY FORECASTS FROM THE LOCAL AFOS MOS PROGRAM (LAMP)

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1. INTRODUCTION

The most recent observations are very important for any short range forecasting system. Most MOS guidance is issued only twice daily, about 2 hours after 0000 or 1200 GMT, and, therefore, may be up to 12 hours old at the time a forecaster must issue a forecast. Even though more recent upper air observations are not yet available, new surface and radar information can be used to provide better short range objective guidance between MOS cycle times. The Techniques Development Laboratory (TDL) is currently developing a system to update the central MOS products with information from the most recent observations to provide more effective short range guidance. This system, named the Local AFOS MOS Program (LAMP) (Glahn and Unger, 1986) can be initialized at any hour to provide forecasts for hourly projections from 1 to about 20 hours. LAMP is being designed to run locally on minicomputers at local Weather Service Offices.

LAMP uses regression equations that relate the local weather conditions to the values of the MOS, observations, and output from simple, locally run numerical models to provide short range guidance. The LAMP procedure is similar to that used for MOS guidance, except that it will be produced locally and will use the existing MOS guidance as a predictor. MOS already contains much of the information from the large scale models and upper air data, so that LAMP is actually blending information from the recent observations with that from the large scale models.

The development and performance of the LAMP ceiling height and visibility forecast equations are reviewed in this paper. Forecasts are provided both in continuous and probabilistic form. The accuracy of these forecasts is compared to that of MOS and persistence to determine the value of the information from the more recent data. Continuous ceiling height forecasts are produced by a new procedure developed for LAMP and are compared to the MOS categorical forecasts.

2. OVERVIEW OF LAMP

The LAMP system will contain a series of programs to objectively analyze recent surface data, provide output from numerical models, and evaluate regression equations to produce forecasts. Guidance updates will be produced for all elements for which the centrally-produced MOS is available and will be developed for all stations for which data are available, not just those which currently receive MOS. In addition, output from the models and analyses can be displayed locally to help evaluate the weather situation. While the current AFOS equipment cannot adequately support the full LAMP system, we are currently developing a test system to implement on an enhanced AFOS minicomputer.

Two types of objective analysis techniques are used in LAMP. Continuous fields, such as sea level pressure, are analyzed by a successive correction technique. Discontinuous fields, such as ceiling height or visibility, are analyzed by a nearest neighbor technique, in which a gridpoint is assigned the value of the hourly observation closest to it. A polar stereographic map projection with a grid spacing of 95 km at 60°N is used for LAMP. Details of the analysis procedure can be found in Glahn et al. (1984).

One simple numerical model used in LAMP that predicts the 1000-mb heights with a potential vorticity equation was adapted from the Reed Sea Level Pressure (SLP) Model (Reed, 1963; Unger, 1982). Forecast values of 500-mb height are needed to provide upper air conditions to the model. These are currently obtained from LFM model forecasts interpolated in space and time to hourly projections on the LAMP grid. The model uses the sea level pressure analysis to estimate the initial 1000-mb heights and, therefore, is referred to as the LAMP SLP model. A 1-h timestep is used for this Lagrangian model.

An advection model forecasts ceiling height, visibility, sky cover, and three precipitation type fields--liquid, freezing, and frozen (Grayson and Bermowitz, 1974). The fields are advected by a combination of the 1000- and 500-mb geostrophic winds from the SLP and LFM model forecasts, respectively. The initially binary precipitation type fields can, because of interpolation, assume any value between 0 and 1 in the advection model forecast. The model is run primarily to supply upstream information to the regression procedure.

The LAMP moisture model is derived from the SLYH model (Younkin et al., 1965; Unger, 1985) and predicts the saturation deficit (Sd) which is a measure of the degree of saturation in the 1000-500 mb layer. Sd is defined as the difference between the actual thickness and the thickness at which precipitation can be expected to begin for a given atmospheric moisture content, the latter estimated by a statistical procedure described by Lewis et al. (1985). The initial field is obtained from a forecast of precipitable water and 1000-500 mb thickness, and then is revised on the basis of surface observations of precipitation and surface dew point. An advecting wind, identical to that used in the advection model, is used to find the trajectory of the moisture. The thickness and advecting winds are computed from the LAMP SLP and NMC's LFM model forecasts, and the precipitable water is taken from the LFM model forecast. Manually digitized radar data are used to further define the Sd.

Changes in thickness and elevation along a trajectory defined by the advecting wind are used to forecast Sd under the assumption of moisture conservation. Negative Sd values forecast by the model are set to zero at the start of each timestep and indicate precipitation. Sd ranges from 0 to about 500 m, with values below about 120 m an indication of mostly cloudy conditions. The Lagrangian moisture model uses a 1-h timestep.

3. EQUATION DEVELOPMENT

The development and testing of the LAMP equations are done on NOAA's central computing facility. Analysis and model forecasts are archived to provide a historical series of data with which to develop the regression equations. The hourly observations and LFM model forecasts needed to run the LAMP analyses and models and to generate MOS forecasts are available in TDL's archives.

Initial experiments with the LAMP system have been for a start time of 0800 GMT and for the cool season. The area of study, bounded roughly by 105°W longitude, 90°W longitude, 45°N latitude, and 29°N latitude, was selected to include the area planned by the National Weather Service for the Modernization and Restructuring Demonstration (MARD). Four cool seasons (October through March) of data, beginning in October 1977, were used to develop the equations presented here.

The initial time of 0800 GMT was selected because it is near the scheduled release time of the morning aviation terminal forecasts. MOS forecasts used here are from the 0000 GMT LFM and use observations from 0300 GMT, so the 0800 GMT LAMP start time provides a 5-h update of the MOS guidance. The operational MOS forecasts frequently use the 0200 GMT observations, so in application, the 0800 GMT start time would usually provide a 6-h update.

MOS forecasts for ceiling height and visibility are currently available each 6 hours for about 60 stations within the test area. The guidance consists of a forecast probability of occurrence of the given element within each of the 6 categories listed in Table 1. A forecast of the best category, determined from the MOS probabilities, is also issued as a part of the regular MOS guidance.

The MOS forecasts, including the best category, were linearly interpolated in time to each station to provide MOS forecasts at each hour. Additional interpolation was required for the approximately 80 stations within the MARD area that do not have MOS guidance but have hourly data available for equation derivation. Forecasts at the non-MOS stations were provided by space interpolation of forecasts from nearby MOS stations followed by time interpolation. The MOS stations used for the space interpolation were determined subjectively based on synoptic considerations.

Table 1. Category definitions used for MOS forecasts.

Category	Ceiling Height (ft)	Visibility (mi)
1	0 - 100	<.5
2	200 - 400	.5 - .875
3	500 - 900	1.0 - 2.75
4	1000 - 2900	3.0 - 4.0
5	3000 - 7500	5.0 - 6.0
6	>7500 or unlimited	>6.0

The predictors from the LAMP models and analyses were interpolated to each station location. Predictors obtained from forecasts were usually, but not always, from the projection concurrent with the predictand observation. Occasionally, terms from model projections which verified either before or after the time of the predictand observation, called time-offset predictors, were used to help compensate for time biases in the numerical model.

Derived predictors were formed from one or more basic predictors. Two types of derived predictors were used for this equation derivation--binary and interactive. A binary predictor was set to the value one when the basic predictor from which it was derived was less than a given value, and was set to zero otherwise. These predictors were used to help capture nonlinear relationships between the basic predictors and the predictands. Interactive predictors were formed from the product of two other predictors and were used to simulate stratification in the sample (Glahn, 1986).

Stations were grouped into regions, and the data from each region were pooled to form a single relationship for the stations within that region. This enabled a larger sample to be used for any particular equation than would be possible with single station equations. The relationships between the most important predictors and the predictand were investigated to help group the data.

A screening regression procedure was used to derive the equations. Predictors were screened simultaneously for all projections and regions for a given element. This helped to produce forecasts which were consistent, both from projection to projection and for adjacent regions. It also simplified the equation derivation and evaluation procedure. Unfortunately, simultaneous derivation increased the number of terms required for each equation, since predictors needed for some projections and regions, may not have been beneficial for others.

The simultaneous screening procedure selects the predictor with the greatest reduction in variance for any single equation. This assures that the important predictors for each equation will be selected. Once a predictor is selected for a particular equation, it is forced into the other equations and the screening procedure continues. In these experiments, the screening process was terminated when either 20 terms were selected or the additional reduction in variance explained by the next best term failed to meet a minimum criteria of 0.5%. Equations were carefully examined to eliminate predictors that might have been selected by chance relationships between predictor and predictand. A predictor was eliminated when its reduction in variance was very low except for a few individual equations that did not fit a discernible pattern. So, for example, a predictor that had a high reduction in variance for one equation and explained very little variance for any other equation, even those for adjacent regions and projections, was eliminated.

Sometimes the regression procedure was forced to select a predictor in a specific order, independently of the screening procedure. This was done mainly to organize equations so that the screening procedure would only select information not already included in other predictors. For example, MOS predictors were frequently forced into an equation as a group so that the screening procedure would only consider information not already contained in the basic MOS predictors. Forcing was also done to assure that the basic predictors for an important interactive term were included in the equations.

3.1 Ceiling Height Probability Equations

Seven equations were derived, one to predict the probability of each of the first five ceiling height categories shown in Table 1, a sixth category for ceiling heights above 7500 ft, and a seventh category for unlimited ceilings. All seven probability equations were derived simultaneously. The predictand was defined as a binary variable which assumes a value of either 1 or 0 depending on whether or not the observation falls within the specified category. This definition of the predictand enables a regression estimation of event probabilities (REEP) (Miller, 1964) to be developed for each category.

Two regional ceiling height equations were derived, one for stations in the mountainous area of the MARD region (mountain region), and one for the remaining portion of the area (non-mountain region). These areas are shown in Fig. 1.

The predictors selected are shown in Table 2. A binary predictor, identified by the decision criterion in parentheses, is assigned the value one when the original variable meets the criterion, and is assigned the value zero otherwise. A predictor labeled "OBS" is from the observation and one labeled "MODEL" is from a LAMP numerical model unless it is marked "initial," in which case it is from an analysis. A predictor labeled "MOS" is from the centralized MOS forecast from the 0000 GMT LFM model.

The additional reduction in variance for each predictor, averaged over all regions and categories, is also shown in Table 2 along with

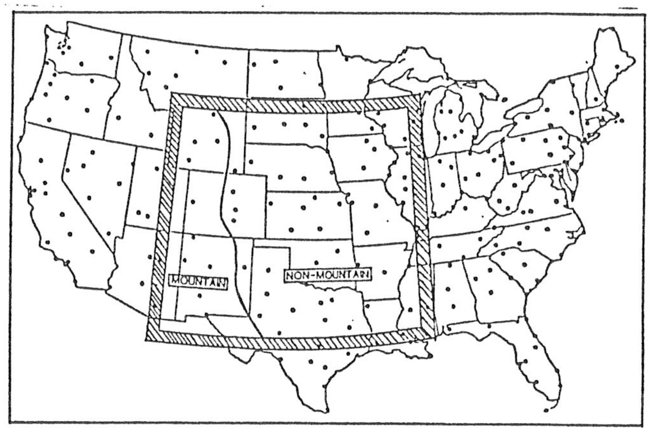

Figure 1. The areas used to derive LAMP ceiling height equations. All stations within the shaded area were used to derive the relationships. Points indicate the location of stations for which centralized MOS forecasts are available. Equations are based on about 120 (20) stations in the non-mountain (mountain) region.

Table 2. Order of selection and additional reduction in variance (RV) of predictors selected, averaged over all regions and categories, for the probability of ceiling height equations for three of the 20 projections.

Order	Predictor	Average Additional RV 1-h	7-h	20-h
1	LAMP sky cover	.1775	.0839	.0270
2	OBS ceiling ht. (<200 ft)	.0832	.0130	.0016
3	OBS ceiling ht. (<500 ft)	.0677	.0112	.0424
4	OBS ceiling ht. (<1000 ft)	.0662	.0099	.0022
5	OBS ceiling ht. (<3000 ft)	.0750	.0134	.0026
6	OBS ceiling ht. (<7600 ft)	.0609	.0070	.0027
7	MOS category 3 probability	.0009	.0115	.0428
8	OBS ceiling ht. (not unlimited)	.0142	.0030	.0011
9	MOS category 5 probability	.0010	.0069	.0197
10	MOS category 4 probability	.0008	.0031	.0046
11	MODEL ceiling ht. (<7600 ft)	.0001	.0034	.0006
12	MODEL ln(visibility +.001)	.0011	.0017	.0002
13	MODEL 1000-mb geostrophic V	.0002	.0026	.0011
14	MOS best category (<2)	.0001	.0003	.0004
15	MOS category 1 probability	.0001	.0010	.0011
16	MODEL ceiling ht. (<3000 ft)	.0003	.0011	.0004
17	MOS best category	.0001	.0016	.0026
18	MODEL sky cover (<.25)	.0001	.0013	.0011
19	MOS category 2 probability	.0001	.0001	.0011
20	MODEL frozen precip.	.0001	.0001	.0011
Total		.5394	.1775	.1167

the average total reduction in variance for all equations for that projection. The explained variance for any one equation may vary greatly from the value shown. The actual total reduction in variance ranges from 76% for the 1-h category 7, non-mountain region equation to about 0.5% for the 14-h category 1, mountain region equation. The sample consisted of about 10,000 and 60,000 cases in the mountain and non-mountain regions, respectively.

3.2 Visibility Probability Equations

Visibility equations were derived in a manner similar to those for ceiling height. One equation was derived for each MOS category listed in Table 1. As for ceiling height, all equations and projections were derived simultaneously.

Data were grouped into three regions shown in Fig. 2. The mountain region is identical to the mountain region for ceiling height. The remaining stations were grouped into either the plains or the eastern region.

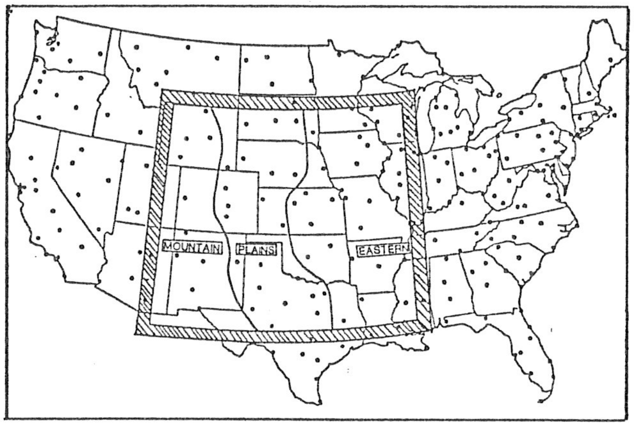

Figure 2. Similar to Fig. 1 except for visibility equations. The equations are based on about 75, 45, and 20 stations for the eastern, plains, and mountain areas, respectively.

The predictors selected are shown in Table 3. The interactive predictor is the product of the terms inside the parentheses. Term numbers refer to the order of selection for that equation set. Note that the average reductions in variance for these equations are lower than for ceiling height. Time offset predictors are indicated by the phrase "T = -6h" which indicates that this predictor is from 6 hours before the valid time of the equation. The value at 0800 GMT was used for this predictor for projections before 6 hours. There were about 37,000, 20,000, and 14,000 cases in the eastern, plains, and mountain regions, respectively.

3.3 Continuous Ceiling Height Equations

Terminal aviation forecasts require a specific value of ceiling height to be given. An equation to forecast the specific value of ceiling height (hereafter referred to as a continuous ceiling height equation) was developed for LAMP to meet this requirement.

Earlier work by Bocchieri and Glahn (1972) showed that a logarithmic transformation of ceiling heights produced best results. This made the equations more sensitive to the operationally significant lower ceiling heights. The transformation used for that work was

$$Y = \ln(C + .001), \qquad (1)$$

where C is the ceiling height in hundreds of feet. The value of .001 was necessary because C can equal zero. C was assigned the value of 350 (35,000 ft) when the ceiling was unlimited. Experiments showed that these equations produced forecasts which were generally not as successful as best category predictions derived from probability equations.

Table 3. Same as Table 2 except for probability equations for visibility. An asterisk indicates that the predictor was forced into the equations.

Order	Predictor	Average additional RV 1-h	7-h	20-h
*1.	MOS category 1 probability	.0613	.0499	.0410
*2.	MOS category 2 probability	.0411	.0307	.0290
*3.	MOS category 3 probability	.0256	.0177	.0066
*4.	MOS category 4 probability	.0073	.0045	.0006
*5.	MOS category 5 probability	.0018	.0026	.0003
*6.	OBS visibility (<7. mi)	.1189	.0133	.0016
*7.	OBS obstruction to vision (none or haze)	.0018	.0003	.0000
8.	OBS visibility (<.5 mi)	.0764	.0071	.0004
9.	OBS visibility (<1. mi)	.0450	.0012	.0003
10.	OBS visibility (<3. mi)	.0487	.0008	.0002
11.	OBS visibility (<5. mi)	.0337	.0002	.0001
12	OBS obstruction to vision (no fog)	.0012	.0018	.0004
13	MOS cat. 4 prob., T = -6h	.0000	.0026	.0005
14	MODEL visibility (<7. mi)	.0005	.0030	.0004
15	INTERACTIVE (term 6)*(term 7)	.0005	.0029	.0004
16	MODEL visibility (<.5 mi)	.0005	.0007	.0001
17	MOS best category (<5)	.0002	.0008	.0021
18	OBS dew point depression (<3°F)	.0004	.0013	.0002
19	MODEL Sd (≤0. m)	.0006	.0013	.0014
20	MOS cat. 1 prob., T = -6h	.0000	.0014	.0003
Total		.4663	.1415	.0888

Because a continuous equation would be highly advantageous, especially for short range predictions, the approach was reexamined for LAMP. For this work the transformation shown in Eq. (1) was also used.

Initial experiments indicated that the assignment of an artificial value for unlimited ceiling heights causes problems. Conditional equations which use only cases where a ceiling was observed at the valid time were derived to help eliminate the problem. In application, a probability forecast for unlimited ceiling can be used to determine when the conditional equations are appropriate.

Two conditional equations for ceiling height were developed. One equation was derived from only cases for which a ceiling height was reported at both the initial and verifying time. This equation was applied whenever there was a ceiling at the initial time. A separate equation was derived from cases in which the initial ceiling height was unlimited. This equation, also conditional, but without the initial ceiling offered as a predictor, was developed from all cases, whether or not the initial ceiling was unlimited. It was applied when the initial ceiling height was unlimited or missing.

Table 4 shows the predictors selected and their average additional reductions in variance for the conditional equation for Y with the initial ceiling included. The equation was developed with a sample size of about 2,000 and 15,000 cases in the mountain and non-mountain regions, respectively. The equation with no initial ceiling (results not shown) relies more heavily on the advection model forecasts but is quite similar otherwise.

The continuous ceiling height equations have a fairly low reduction in variance which causes the forecasts to occur near the sample

Table 4. Similar to Table 2 except for the continuous ceiling height equation with the initial ceiling height included as a predictor. The averages are over both regions. An asterisk indicates a forced predictor.

Order	Predictor	Average Additional RV 1-h	7-h	20-h
*1	MOS category 1 probability	.1637	.1295	.1060
*2	MOS category 2 probability	.0563	.0440	.0345
*3	MOS category 3 probability	.0213	.0232	.0070
*4	MOS category 4 probability	.0165	.0066	.0061
*5	MOS category 5 probability	.0005	.0009	.0014
*6	MODEL ln(C+.001)	.5214	.0297	.0040
7	OBS ln(C+.001)	.0174	.1166	.0107
8	MOS initial cat. 1 prob.	.0000	.0056	.0019
9	OBS obstruction to vision (obstruction reported)	.0039	.0070	.0062
10	OBS precip. (precip observed)	.0001	.0005	.0058
11	MODEL initial surface V wind	.0001	.0018	.0007
12	MOS best category (<4)	.0001	.0017	.0003
13	MOS initial cat. 4 prob.	.0000	.0007	.0002
14	MODEL Sd	.0001	.0011	.0031
15	MODEL initial dew point	.0001	.0008	.0031
16	MODEL initial temperature	.0013	.0060	.0026
17	MODEL ln(visibility + .001)	.0024	.0007	.0001
18	MODEL sky cover	.0002	.0006	.0001
19	MODEL 500-mb ht. from LFM	.0001	.0006	.0009
20	MOS best category	.0000	.0005	.0002
Total		.8050	.3775	.1945

mean too frequently. Inflation (Klein et al., 1959) is used to produce a more realistic distribution by moving the regression estimates away from the mean. The centralized MOS inflation procedure adjusts the forecasts so the variance of the inflated estimates is equal to that of the observations on the dependent data. The inflation procedure was modified for the LAMP ceiling heights so that the number of forecasts which fell into the lowest category was equal to the number that actually occurred on the dependent sample.

The modified inflation procedure is given by,

$$\hat{\hat{Y}} = \bar{Y} + \frac{\hat{Y} - \bar{Y}}{A}$$

where A is the modified inflation factor, $\bar{Y}$ is the mean value of the predictand on dependent data, $\hat{Y}$ is the regression estimate and $\hat{\hat{Y}}$ is the inflated estimate. To determine the value of A, a value, y, such that $P(\hat{Y} \leq y) = P(C \leq 1)$ (recall that C is in hundreds of feet) is found from the cumulative probability distribution functions of $\hat{Y}$ and C. This value is substituted for $\hat{Y}$ into the equation with $\hat{\hat{Y}} = \ln(1.5)$, and the equation is solved for A.

An additional modification was required to make the forecasts more persistent in the first few projections. Ceiling heights frequently remain constant for a period of hours and then jump discontinuously to a new level. However, $\hat{Y}$ changes gradually from one level to another. Therefore, in order to place more emphasis on the initial observation, an empirical procedure was used in which the forecast was set to the initial observation when that observation was within the 50% confidence interval of the regression estimate. The confidence interval was determined by the assumption that the errors, $(\hat{Y} - Y)$, were normally distributed. The 50% confidence interval for a normal distribution is given by its mean ± 67% of its standard deviation. The standard deviation was assumed to be the average standard error of estimate of the two regional equations for the 1-h projection prior to inflation. The average standard error for the equations with initial ceilings included as a predictor, for example, was about 1.0, so the 50% confidence interval was $\hat{Y} \pm .67$.

The skill of the persistence forecasts falls considerably below those of LAMP and MOS shortly after 6 hours, so the persistence adjustment was eliminated by the 6-h projection. To provide a smooth transition to the unmodified forecasts, the persistence adjustment was reduced linearly from its initial value to zero by the 6-h projection.

3.4 Continuous Visibility Equations

At the time of writing, continuous equations for visibility have not been completed. The results for continuous prediction of visibility will be presented at the conference.

4. RESULTS

All results presented here are from one cool season of independent data (October 1981–March 1982). The equations used to produce the centralized MOS forecasts were developed from data from October 1972–March 1980, so this season is also independent of the MOS derivation.

All projections are with reference to the 0800 GMT initial time. The most recent observations used in the MOS forecasts are 0300 GMT, so that the 0-h LAMP projection corresponds to a 5-h MOS projection.

4.1 Ceiling Height Probability Forecasts

The LAMP probability forecasts were compared to forecasts from MOS, climatology, and MOS+OBS--a special system of LAMP equations which includes predictors from only the observation and MOS forecast, and none from the LAMP forecast models. The MOS+OBS equations were tested to determine how important the simple LAMP models are to the LAMP forecasts system. The probabilities for categories 6 and 7 from the LAMP forecasts were combined for comparison with the MOS forecasts. All scores were computed from matched samples.

The Ranked Probability Skill Score (RPSS) (Murphy and Daan, 1985) was used to verify the forecasts. The Ranked Probability Score (RPS) is a quadratic score that measures the value of a multiple category probability forecast of an event. The score differs from the more familiar Probability Score in that it accounts for the closeness of the observation to the forecast category. The RPSS measures the improvement of the RPS over that from the the sample climatology. Note that, in our use, the sample climatology is based on the independent data and, therefore, may represent a stronger forecast than one based on the climatology from the dependent data.

Figure 3 compares the RPSS for the MOS, LAMP, and MOS+OBS forecasts for the non-mountain stations in the MARD area. The sample size consists of about 15,000 cases. The LAMP scores in the early projection show the heavy influence of the observation. The skill sharply declines until about 7 hours when the decline becomes more gradual. The slight but constant improvement in the LAMP forecasts past the 16-h projection is probably the result of calibration of the forecast probabilities to the MARD regional climatology by the regression equations. MOS equations were derived from stations both inside and outside the MARD region and, therefore, will not match the regional climatology as closely as will the LAMP equations. The fact that the skill of the LAMP forecasts in relation to MOS becomes independent of the projection past about 16 hours suggests that the advantage of the more recent observation has largely disappeared by that time.

The LAMP models make the greatest improvement to the forecasts from about 4 to 12 hours. Before the 4-h projection, the predictors from the observation dominate the relationship, and after 12 hours the MOS predictors dominate.

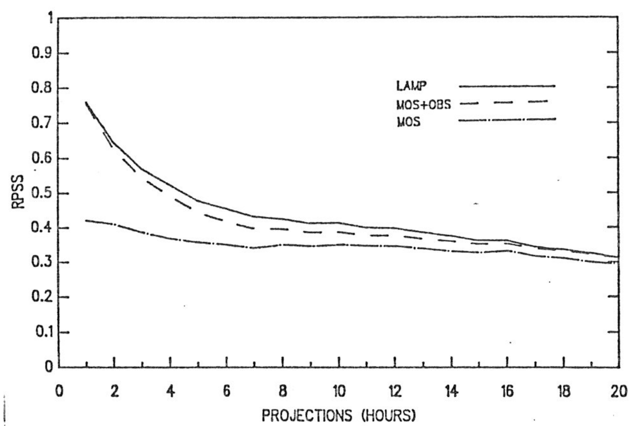

Figure 3. Ranked Probability Skill Scores (RPSS) for LAMP, MOS+OBS, and MOS cool season ceiling height forecasts in the non-mountain region. The initial time is 0800 GMT. Scores are computed on the categories listed in Table 1.

Fig. 4 shows relationships for the mountain region. Significant differences in the performance of the LAMP model predictors are obvious. The forecasts in the mountains do not benefit from the LAMP numerical models. Qualitatively, however, the performance of the LAMP equations is about the same in relation to MOS. All systems are considerably less accurate in the mountains than to the east. These results are based on about 1700 cases.

4.2 Visibility Probability Forecasts

The RPSS for visibility forecasts for the eastern, plains, and mountain regions are shown in Figs. 5, 6, and 7, respectively. The relative skill of the MOS and LAMP forecasts for visibility is similar to that for ceiling. The visibility forecasts are, however, generally less skillful than are the ceiling height forecasts. The improvement over MOS becomes nearly constant past the 10-h projection. The LAMP

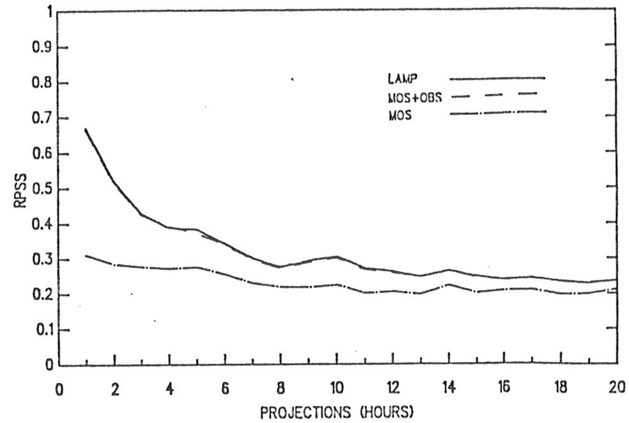

Figure 4. Same as Fig. 3 except for the mountain region.

models do not contribute in the mountainous region. The models may add some information in the plains region in the 8- to 16-h range, but the improvement is small. The eastern region shows that the models provide for a small but consistent improvement through 16 hours. These results are based on about 9,300, 4,300, and 2,400 cases in the eastern, plains, and mountain regions, respectively.

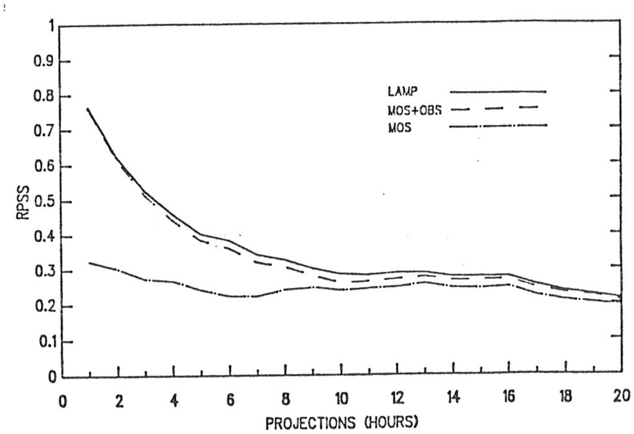

Figure 5. Same as Fig. 3 except for visibility forecasts for the eastern region.

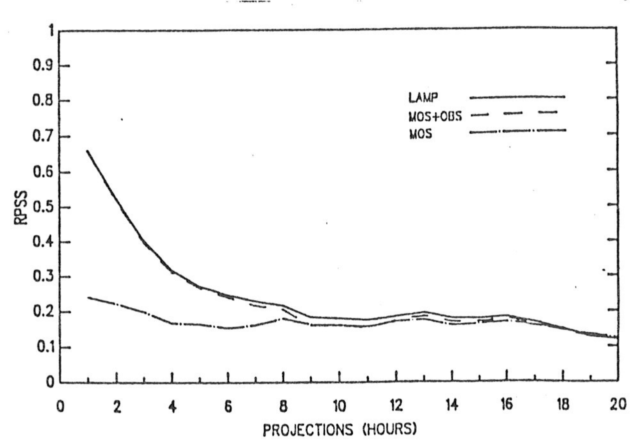

Figure 6. Same as Fig 3. except for visibility forecasts for the plains region.

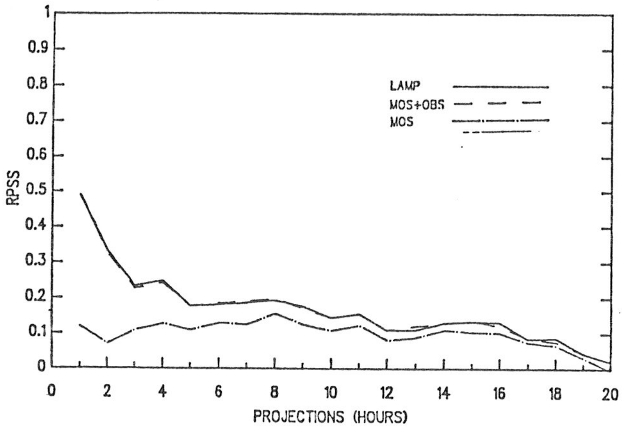

Figure 7. Same as Fig 3. except for visibility forecasts for the mountain region.

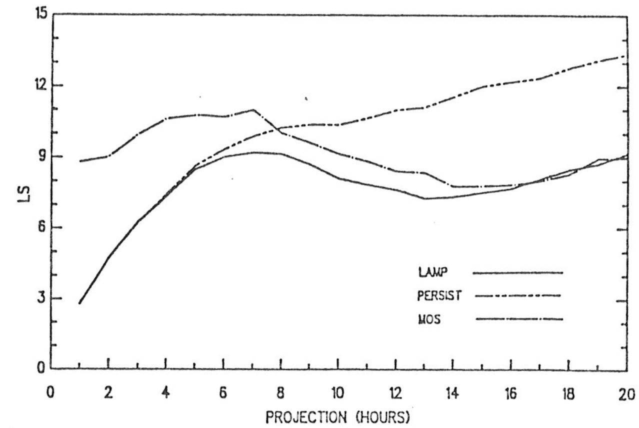

Figure 8. The Log Score (LS) for LAMP, MOS, and persistence forecasts of ceiling height for the total area.

4.3 Continuous Ceiling Height Forecasts

The Log Score (LS) (NWS, 1984) was used to evaluate the continuous ceiling height forecasts. This score is given by

$$LS = 50 \; \overline{|\log_{10}\hat{C} - \log_{10}C|}$$

where $\hat{C}$ is the forecast, C is the observation, and the overbar denotes the average over the sample. This score is more sensitive to errors in the lower ranges of the variable than the root mean squared error, for example. The emphasis on the low ranges is a desirable feature for a score to verify ceiling heights. A lower score indicates a better forecast.

Persistence, MOS, and LAMP forecasts were evaluated. The mountain and non-mountain regions were combined for this comparison. LAMP forecasts were set to unlimited when the probability of unlimited ceilings exceeded 50%; otherwise, the LAMP forecast was taken from the appropriate continuous equation, depending on the initial ceiling. The forecasts were inflated, and the persistence adjustment was made before rounding to the intervals used for ceiling height observations.

The persistence and LAMP forecasts were assigned a value according to the category in which they fell (see Table 1). The MOS forecasts were obtained from the best category forecast. The value assigned for the purpose of the score computation was the logarithmic midpoint of the forecast category except for categories 1 and 6, which were assigned the values 100 ft and 7600 ft, respectively.

Fig. 8 shows the LS for the ceiling height forecasts. The LAMP forecast is about as accurate as persistence for the first 5 hours. At projections past 16 hours, the accuracy of the LAMP forecasts is essentially the same as MOS. The LAMP system provides considerable improvement over both MOS and persistence between the 7- and 14-h projections.

For projections past 15 hours, the MOS predictors contribute most of the predictability of these equations. The probability equation results suggest that the contribution from the LAMP models and the more recent observations is negligible past 15 hours so that the continuous ceiling height forecasting procedure is efficient at processing the information from the MOS forecasts. In view of the radically different methods used here to obtain the categorical MOS and LAMP forecasts, this result certainly was not guaranteed.

5. CONCLUSIONS

The LAMP system is designed to update MOS forecasts with information from the surface hourly observations and output from simple, locally run numerical models. This system can be initialized at any hour to provide guidance for projections from 1 through 20 hours.

The skill and accuracy of the 0800 GMT LAMP forecasts (a 5-h update) were tested for stations in the midwestern United States. LAMP probability equations showed improvements in skill over the MOS guidance through all 20 projections tested. Improvements attributable to the more recent observations extend through about 16 hours past 0800 GMT for ceiling height and through about 10 hours for visibility. Beyond this, the additional skill is probably due to better calibration of the LAMP forecast probabilities to the regional climatology of the area being verified. The LAMP numerical models contributed to the skill of the equations primarily in the 4- to 15-h range in non-mountainous areas. The numerical models do not contribute in mountainous regions.

Categorical ceiling height forecasts were produced by prediction of $Y = \ln(C + .001)$. This method is radically different from the MOS procedure which obtains the best category prediction from probability forecasts. The LAMP equations for Y were conditional with the LAMP forecast probability of unlimited ceiling height used to determine when to make a continuous ceiling height forecast. The forecasts were inflated, and a persistence adjustment was applied to the early projections.

The LAMP categorical ceiling height forecasts were more accurate than those from the MOS best category through about 15 hours. Beyond 16 hours, the LAMP equations were essentially the same as the MOS forecasts. This suggests that categorical prediction of ceiling height by continuous equations can produce results comparable to those derived by probabilistic predictions. This represents a significant improvement from the results reported earlier (Bocchieri and Glahn, 1972) and is most likely due to the use of conditional equations to eliminate unlimited ceilings from the sample and to the modified inflation factor used to increase the number of lowest category ceiling height forecasts.

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