13B.6 A SUMMARY OF CEILING HEIGHT AND TOTAL SKY COVER SHORT-TERM STATISTICAL FORECASTS IN THE LOCALIZED AVIATION MOS PROGRAM (LAMP)

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1. INTRODUCTION

Short-term statistical forecast LAMP guidance focusing on aviation related meteorological variables is currently being redeveloped by the National Weather Service's Meteorological Development Laboratory (Ghirardelli 2005). The new LAMP system will run every hour, with hourly forecasts generated out to the 25-h projection. The LAMP guidance serves as an update to the Global Forecast System (GFS) Model Output Statistics (MOS) guidance. LAMP guidance is derived by the same basic technique used to develop MOS (Glahn and Lowry 1972). LAMP regression equations are developed to predict the probabilities of eight ceiling height (CIG) and five total sky cover (CLD) categories. Potential predictors for these equations include the GFS MOS probability forecasts, the most current METAR observations, and advection model variables. Finally, a post processing procedure is used to generate a LAMP best category forecast for CIG and CLD. The LAMP guidance is currently being generated for the 0900 UTC start time, and will cover approximately 1500 sites over the contiguous United States (CONUS), Alaska, Hawaii, and Puerto Rico.

In this paper, we compare the accuracy and skill of the 0900 UTC LAMP and GFS MOS 0000 UTC best category forecasts, along with persistence. The comparison is done on an independent sample period, where the Threat Score is used to measure the forecast accuracy of low ceiling heights, and the Heidke Skill Score is used to estimate total sky cover forecast skill. We also discuss the procedure used to develop the LAMP guidance, which includes equation development and the process used to generate best category forecasts.

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2. PREDICTAND AND PREDICTOR VARIABLE DEFINITIONS

The CIG and CLD predictands are divided into distinct categories. The observed ceiling height is divided into seven binary cumulative predictands representing the ceiling heights of < 200 feet, < 500 feet, < 1000 feet, < 2000 feet, < 3100 feet, < 6600 feet, and ≤ 12000 feet. For aviation interests, a CIG of < 500 feet matches the definition for Limited Instrument Flight Rules (LIFR) conditions, < 1000 ceiling heights represent Instrument Flight Rules (IFR) conditions, and < 3000 feet ceiling heights represent Marginal Visual Flight Rules (MVFR) conditions (NWS 2005). Ceiling heights above 12000 feet are not measured due to the limits of the Automatic Surface Observing System (ASOS) reports.

The estimated total sky cover is divided into five binary exclusive predictands. Clear indicates zero cloud coverage followed by few, 1/8 through 2/8; scattered, 3/8 through 4/8; broken, 5/8 through 7/8; and overcast, complete cloud coverage. Since ASOS reports are limited to 12000 feet, CLD estimates are complemented with a derived satellite cloud product (SCP) (Kluepfel et al. 1994) to obtain cloud cover estimates above 12000 feet.

Three primary data sources make up the list of predictors used to develop the CIG and CLD equations. GFS MOS 3-h predictors from the 0000 UTC cycle run consist of probability forecasts for CIG, CLD, visibility (VIS), obstruction to vision (OBV), surface temperature, dew point and wind speed. These probability forecasts were linearly interpolated to a one-hour resolution. Another source of predictors is current surface observations, which include ceiling height, non-SCP complemented total sky cover (SCP data are not available in real time), temperature, dew point, and dew point depression. The third set of predictors includes advected ceiling height, total sky cover, surface temperature, and dew point which were generated by the advective model (Glahn and Unger 1986).

3. EQUATION DEVELOPMENT

Equations are developed for two seasons: warm (April-September) and cool (October-March). In this paper, only warm season results are shown. When available, data from an additional 15 days prior and subsequent to the defined season are included to increase sample size, and smooth the transition between seasons. The developmental data period ranges from 1999 to 2003, with the 2004 warm season used as an independent sample.

The regression equations for the seven CIG and five CLD predictands contain the same predictors for a specified projection hour. The coefficients and constants are different for each predictand. This method was used to enhance consistency among the forecasts generated by the equations (Weiss 2001). In addition, the regression equations also contain the same predictors for all 25-hour projections. The values of GFS MOS 3-h and advective model predictors vary with the projection hour. This procedure reduces undesirable fluctuations in the hourly resolution forecasts of a particular predictand (Rudack 2005).

The CIG/CLD regression equations are developed regionally to enhance our ability to predict the occurrence of relatively infrequent events (e.g. a CIG of less than 500 feet), and develop more stable forecast relationships (Weiss 2001). For the warm and cool season development, a total of 31 and 30 regions are used respectively. The same regional boundaries are used for both CIG/CLD GFS MOS and LAMP development.

During equation development, we allowed the variable selection process to continue until a maximum of 15 predictors was chosen, or until none of the remaining predictors contributed an additional 0.1% reduction of variance to any of the 12 predictands. For the resultant regression equations, the 0900 UTC CIG and CLD observations and the GFS MOS probability forecasts of CIG and CLD were found to be the most dominant predictors, and contributed most of the explained variance for all predictands over all projections. The GFS MOS probability forecasts for VIS and OBV along with advected CIG and CLD were found to be less useful.

4. POST PROCESSING

The process used to generate the best category forecasts entails a number of steps. First, the raw probability forecasts generated from the CIG and CLD regression equations are post processed. Development of the CIG and CLD predictands using the same predictors ensures that the set of resulting CIG and CLD probabilities for a given case (station at a given projection hour) add up to one, respectively. However, some values may be slightly greater than one or less than zero. Therefore, the probabilities are post processed to ensure the values range between zero and one.

The next step involves transforming the normalized probability forecasts to a best category forecast. However, before this step can proceed, threshold values (probability thresholds) for each category must be derived. Probability thresholds are generated from the developmental sample of data. For CLD, the probability thresholds are obtained through an iterative process based on a user specified bias of one (number forecasts and observations are approximately equal). For CIG, the probability thresholds are obtained through an iterative process that maximizes the Threat Score within a targeted bias range. Maximizing the Threat Score yields more accurate forecasts of rarer events (e.g., low ceiling heights) and so is used for CIG, while the bias approach works better for CLD.

Once the thresholds are determined, best category forecasts can be generated for a given case. The CIG and CLD LAMP categories are listed in Tables 1 and 2, respectively. These categories are identical to those used in the GFS MOS. For CIG, the best category is determined in a cumulative manner. This procedure commences with the probability forecast for the lowest CIG (< 200 feet). If the probability forecast does not exceed the probability threshold of the lowest CIG category, the probability forecast for < 500 feet CIG is compared to the next highest CIG probability threshold. If this process continues until all probability thresholds are exhausted, the default category (category eight) is chosen as the best category. Best category forecasts for

CLD are determined similarly, but in an exclusive manner, processing from clear to overcast.

Table 1. Category definitions of LAMP Ceiling Height forecasts

Category	Ceiling Height (Feet)
1	< 200
2	200 – 400
3	500 – 900
4	1000 – 1900
5	2000 – 3000
6	3100 – 6500
7	6600 – 12000
8	> 12000

Table 2. Category definitions of LAMP Total Sky Cover forecasts.

Category	Ceiling Height (Feet)
Clear	zero cloud coverage
Few	1/8 – 2/8
Scattered	3/8 – 4/8
Broken	5/8 – 7/8
Overcast	8/8 cloud coverage

5. RESULTS

The LAMP and GFS MOS best category forecasts for CIG and CLD are now compared along with persistence. Since the LAMP and MOS CIG and CLD category definitions are the same, we can compare verification scores between the LAMP and MOS systems.

The Threat Score is used to evaluate the accuracy of the CIG forecasts. A higher threat score indicates a more accurate forecast. Since ceiling heights for categories two, three, and five are crucial for aviation interests, only verification scores pertaining to these threat events are shown.

Figs. 1, 2, and 3 show the Threat Scores for CIG categories two, three, and five respectively. These results are for the 2004 warm season, where the 1523 stations pooled from the CONUS, Alaska, Hawaii, and Puerto Rico regions are used. Each figure shows the CIG forecasts generated by the 0900 UTC LAMP, 0000 UTC GFS MOS, and persistence. Two similar patterns are observed for these threat events. First, LAMP in the very short range demonstrates either similar or better accuracy than persistence. This result is not unexpected since low ceiling height is a rare event and is therefore more difficult to forecast. Second, LAMP gives better scores than the GFS MOS guidance through the 25-h projection (or 36-h GFS MOS projection). For forecasts beyond the 9-h projection, the improvement of LAMP over the GFS MOS remains relatively stable for all Threat Scores. A possible reason for the improvement during this period may be the diminished but lasting correlation of the observed CIG predictor in the regression equations.

It is interesting to note that the Threat Scores of LAMP and persistence increase slightly in the later projections beyond 20-h. This phenomenon is most likely attributed to the influence of cases where a diurnal signal combined with persistent conditions out through the 25-h projection may generate a similar ceiling height forecast.

The Heidke Skill Score (HSS) is used to verify CLD for the same period and 1523 stations noted earlier in this section. The HSS is a positively oriented skill score, measured over all categories of CLD and not any one specific sky cover category. Fig. 4 shows the HSS for CLD. Persistence in this plot is the non-SCP complemented CLD estimate (see Section 2). Since SCP data is not available in real time, we base our comparison on the available observation at the forecast time. This figure shows that the LAMP forecasts have better skill than both persistence and the GFS MOS out through the 7-h projection. LAMP CLD forecasts beyond the 7-h projection generally demonstrate the same or slightly better skill than the GFS MOS CLD forecasts.

6. SUMMARY AND CONCLUSIONS

The Meteorological Development Laboratory is currently redeveloping the LAMP system focusing on aviation related meteorological variables. In this paper, we have shown that for the 0900 UTC cycle, warm season, LAMP 1-h through 25-h categorical forecasts for CIG are more accurate than those generated by the 0000 UTC GFS MOS valid at the same time. LAMP CIG forecasts have equal or better accuracy than persistence in the first 4 hours. There is improvement of LAMP CLD forecasts over the GFS MOS forecasts for the 1-h through 7-h projections. For both CIG and CLD, this improvement is compatible with the LAMP goal of serving as an update to the GFS MOS system. We believe the redeveloped LAMP system will be a valuable new tool in making timely and skillful forecasts for the aviation weather community.

7. FUTURE WORK

Development of the cool season 0900 UTC LAMP CIG and CLD guidance will occur later this summer. The LAMP guidance will run experimentally starting in September 2005. During 2006, the 0900 UTC LAMP guidance will become operational and the 1500 UTC cycle cool and warm season LAMP guidance will be developed. Special emphasis will be placed on improving forecasts for IFR conditions or worse. LAMP will also be providing categorical forecasts of conditional ceiling height (i.e., ceiling height forecasts conditional on precipitation occurring) that will be used in producing Terminal Aerodrome Forecasts. The release times of the experimental and operational conditional ceiling height guidance are expected to follow the release times of the ceiling height forecasts.

8. REFERENCES

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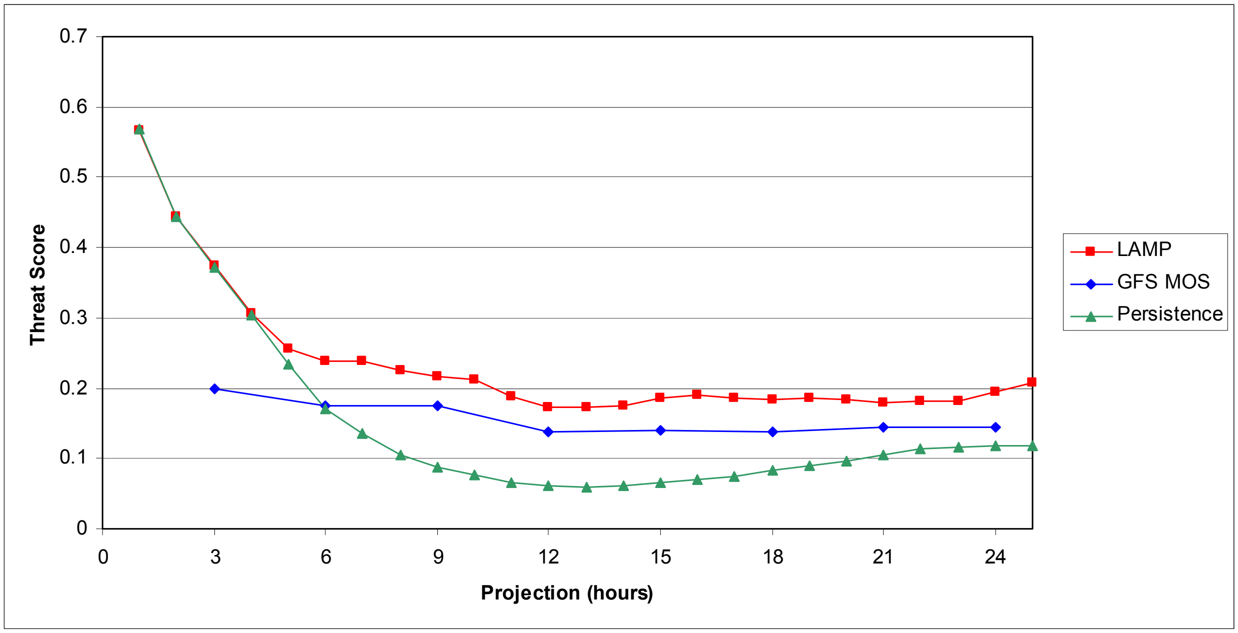

Figure 1. Threat Scores for categorical ceiling height forecasts of < 500 feet from the 2004 warm season. Forecasts were generated from the 0900 UTC LAMP and 0000 UTC GFS MOS.

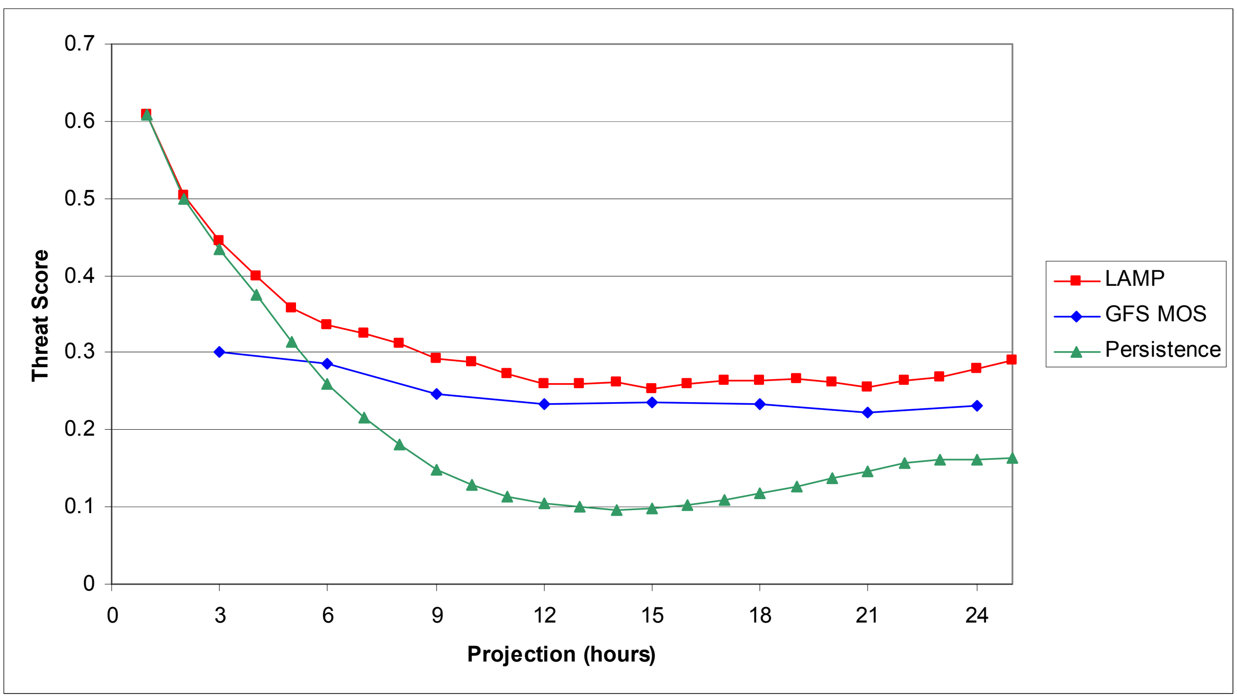

Figure 2. Same as Fig. 1 except for ceiling height < 1000 feet.

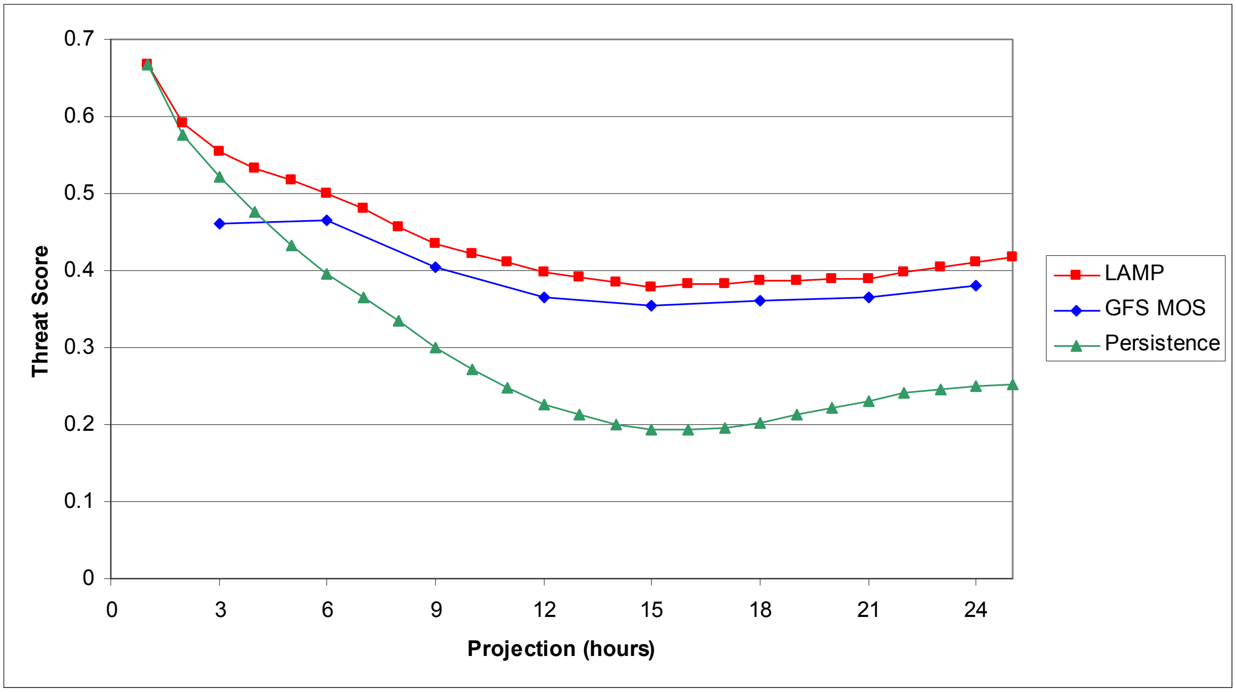

Figure 3. Same as Fig. 1 except for ceiling height < 3000 feet.

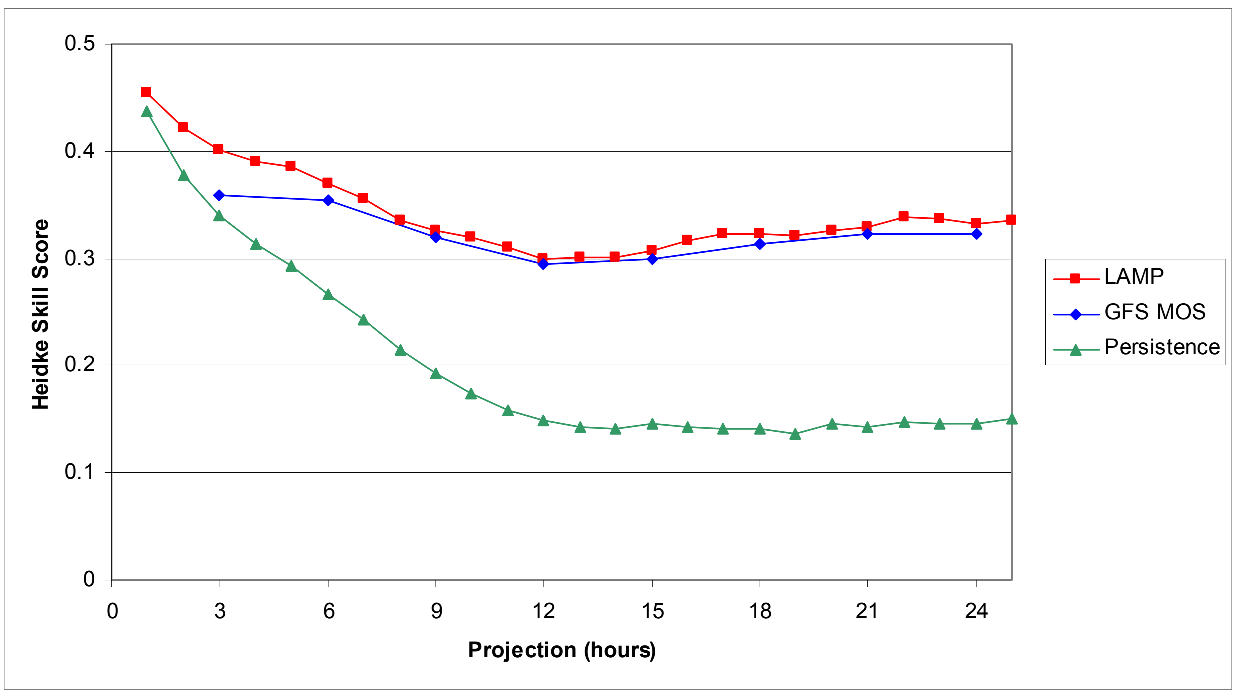

Figure 4. Heidke Skill Scores for categorical total sky cover forecasts for the 2004 warm season. Forecasts were generated from the 0900 UTC LAMP and 0000 UTC GFS MOS.