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IMPROVEMENTS IN THE LOCALIZED AVIATION MOS PROGRAM (LAMP) CATEGORICAL VISIBILITY AND OBSTRUCTION TO VISION STATISTICAL GUIDANCE

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1. INTRODUCTION

The National Weather Service's Meteorological Development Laboratory is redeveloping the current LAMP system with special emphasis on aviation weather (Ghirardelli 2005). LAMP is an update system to the Model Output Statistics (MOS) and provides statistically derived guidance for the forecasting of sensible weather elements. The new LAMP system will run hourly producing one hour forecasts spanning 25 projections. LAMP utilizes (1) the most recent observations, (2) statistical MOS guidance, and (3) simple models. The output of the simple models consist of forecasts that predict 1000-mb heights (Reed 1963, Unger 1982), moisture fields (Younkin et al. 1965, Unger 1985), and advect analysis fields such as ceiling height, visibility, sky cover, and present weather (Glahn and Unger 1986) to improve its short-range forecasting skill. LAMP will produce forecast guidance for approximately 1500 sites covering the contiguous United States, Alaska, Hawaii, and Puerto Rico.

This paper describes the methodology employed in developing hourly LAMP forecasts for visibility (VIS) and obstruction to vision (OBV) following the MOS approach (Glahn and Lowry 1972). This includes equation development, the post processing of probability forecasts that are used in generating thresholds for best category forecasts, and the process itself used in making best category forecasts. Warm and cool season verification results will be discussed and compared to persistence and the Global Forecasting System (GFS) 0000 UTC MOS.

2. EQUATION DEVELOPMENT

Equations for VIS and OBV were developed by using multiple linear regression. The data used in this development were stratified into two seasons, warm (April-September) and cool (October-March). During the equation testing phase of the development, 6 years (98-03) of historical data were used for the cool season while five years (99-03) of historical data were used for the warm season. The last year of data for each season was withheld and used for independent verification. In order to smooth the transition between seasonal developments, the data samples included 15 days prior and subsequent to the defined season.

To establish better consistency between VIS and OBV LAMP probability forecasts, the regression development was done simultaneously. That is to say, the VIS and OBV probability equations share identical predictors but differ in projection and coefficient values. This method minimizes the number of cases of inconsistency between forecasts of low visibility and no obstruction to vision, and conversely.

The regression program screens all predictors over all predictands for all forecast projections. Once a predictor is chosen for a particular equation at some projection, it is then forced into all other equations for that particular predictand over all remaining projections. This procedure minimizes undesirable fluctuations in the hourly resolution forecasts of that particular predictand. The regression process for a particular equation terminates when either 15 terms are chosen in the equation or the remaining predictors do not contribute at least an additional 0.1% reduction of variance to the predictand equation.

Regression equations for VIS and OBV are developed regionally. Pooling stations into a region provides the regression program a sufficient number of rare events (e.g., visibility less than a mile) so that stable equations for these events can be generated. For the warm and cool season development, 27 and 23 regions were used, respectively. Regions used in the LAMP

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development were identical to those used in developing GFS MOS equations.

3. PREDICTAND DEFINITION

Observed continuous visibility is divided into six binary predictands so that the regression program generates six individual equations of forecast probabilities of < 1/2 mile, < 1 mile, < 2 miles, < 3 miles, $\leq$ 5 miles, and $\leq$ 6 miles. Generating forecast probabilities in this fashion is the first step in creating best category forecasts for VIS.

OBV is categorized into five distinct groups prior to being processed by the regression program. These groups are: No obstruction to vision; haze, smoke, or dust; mist (i.e., fog with visibility $\geq$ 5/8 mile); fog or ground fog (i.e., visibility < 5/8 mile); and blowing dust, sand, or snow. Upon input to the regression program, each of the five categories is converted to a binary predictand so that the regression program yields five individual probabilistic equations, one for each category. It is important to note that precipitation obstructions (e.g., snow) are not included in the predictand definition.

4. EQUATION PREDICTORS AND SELECTION

Three primary data sources were pooled for use as predictors in developing VIS and OBV equations. These included hourly observations, GFS MOS 3-h VIS and OBV forecast probabilities that were linearly interpolated to an hourly resolution, and forecasts generated by the advective model.

Results from the regression program demonstrate that the VIS and OBV observations and the GFS MOS probability forecasts of OBV and VIS were the most useful predictors. That is to say, these predictors were vital in explaining a majority of the explained variance for all predictands over all projections. The advection of OBV and VIS were found to be minimally useful. This is consistent with the fact that visibility and most obstruction to vision phenomenon are localized in nature and not advected events. These results were consistent for both the warm and cool season developments.

5. POST PROCESSING

Since the raw probability forecasts for VIS and OBV were derived from simple linear regression equations, some of the generated probabilities were slightly negative or greater than one. To resolve this issue, all forecast probabilities were post processed to ensure that they were constrained between values of zero and one, inclusive. The VIS forecast probabilities were then reprocessed to ensure a consistent increasing and never decreasing behavior. OBV probabilities were normalized (i.e., the sum of the forecast probabilities for all OBV predictand categories equaled one). Following this procedure, the probabilities were used in determining the appropriate thresholds for best category forecasts.

Thresholds for categories of VIS and OBV were obtained through an iterative procedure that maximizes the threat score within a targeted bias range. This iterative procedure was performed at each projection for each region. The regions used in this process were identical to those regions used in the development of the regression equations. Consequently, not only does each station in a region share an identical regression equation, it also shares an identical threshold value for each projection and category. Although threshold values could have been generated by targeting unit bias, it was thought that the approach of maximizing the threat score would yield better results in forecasting the rarer events (e.g., low visibilities or dense fog).

Generating forecasts in the very short range that are more skillful than persistence has always been a challenge. This is especially true when the forecast event is rare as in the case of reduced visibilities. It was found that the thresholds used in making categorical forecasts which were derived from maximizing the threat score yielded better forecast results than those generated from targeting unit bias, especially in the very short range of 1-4 hours.

Once the thresholds were determined, the next step was to generate a best category forecast of VIS and OBV for each station for each of the 25 hour projections. This involved comparing forecast probability values to their respective threshold value. If the forecast probability exceeded the threshold value for that particular category, it was selected as the best category forecast. Otherwise, this procedure continued until a forecast probability exceeded its respective threshold value. If none of the probability forecasts exceeded its respective threshold value, the most common event was chosen as the best category forecast.

The breakdown of LAMP categories for which VIS and OBV forecasts are made can be seen in Tables 1 and 2, respectively. These categories are identical to those used in the GFS MOS. This allows for the comparison of verification scores between the LAMP and MOS systems which will be discussed below.

Table 1. Categories of LAMP VIS forecasts.

Category	Visibility (Statue Miles)
1	< ½
2	½ - < 1
3	1 - < 2
4	2 - < 3
5	3 – 5
6	6
7	> 6

Table 2. Categories of LAMP OBV forecasts.

Category	Obstruction to Vision
1	none of the following
2	haze, smoke or dust
3	mist (fog with VIS ≥ 5/8 mile
4	fog or ground fog (VIS <5/8 mile)
5	blowing dust, sand, or snow

6. RESULTS

The threat score was used to evaluate the accuracy of the visibility forecasts for both the warm and cool seasons. A higher threat score indicates a more accurate forecast. Since visibilities less than 3 miles are most important to aviation, only verification scores pertaining to threat events below 3 miles will be addressed.

Figs. 1, 2, and 3 show the verification of visibility in terms of threat score for the cool (October-March) 2003-2004 season using 1523 stations pooled from the contiguous United States, Alaska, Hawii, and Puerto Rico regions. Each figure shows the visibility forecasts generated by the 0900 UTC LAMP, 0000 UTC GFS MOS, and persistence. Fig. 1 pertains to events less than ½ mile, Fig. 2 pertains to events less than 1 mile, and Fig. 3 pertains to events less than 3 miles. Two common score patterns are noted for all threat events: (1) LAMP in the very short range demonstrates comparable or better skill than persistence, and (2) LAMP displays better skill than the GFS MOS guidance through the 9-h projection (or 18-h GFS MOS projection). LAMP visibility forecasts beyond the 9-h projection generally demonstrate the same skill as the GFS MOS visibility forecasts. However, LAMP shows better skill through the 15-h projection for threat events less than 3 miles.

Figs. 4, 5, and 6 show the 2004 warm season (April-September) visibility threat scores using the same set of 1523 stations noted above. The same general temporal shape of the skill pattern seen in the cool season is also evident in the warm season with one noted exception: LAMP warm season visibility threat score forecasts for less than 3 miles in the 1-6 hour projection range (Fig. 6) deteriorate quicker than those in the cool season (Fig 3). This difference can be attributed to the lower frequency of low visibility events during the warm season. A second reason may be the lasting effect of the observed visibility as a predictor in the regression. This can be seen in the very short range where the temporal skill pattern of LAMP forecasts follows the same temporal skill pattern as persistence. It is interesting to note that the threat scores of persistence begin to improve (albeit negligibly) around the 20-h projection. In a general forecasting sense, this can be interpreted such that in the instance where low visibility was observed (in this case during the nighttime hours) say at 0500 UTC, there is some skill in saying that 24 hours later low visibility conditions may be present once again.

The Heidke Skill Score (HSS) (Wilks 1995) was used to verify warm and cool season forecasts of obstruction to vision over the same periods and 1523 stations noted earlier in this section. A higher HSS indicates a more accurate forecast; it is a skill measure over all categories of obstruction to vision and not any one specific threat category such as fog, for example. Figs. 7 and 8 show the HSS for the cool and warm seasons, respectively. These figures show that for both seasons, the LAMP forecasts have comparable skill to persistence in the 1-4 hour forecast range (Fig. 7). In addition, LAMP demonstrates considerable skill over the GFS MOS forecasts during the 1-9 hour projection range. During the cool and warm seasons, the LAMP forecasts maintain a slight edge in skill level over the GFS MOS between the 9-25 hour projections. Fig. 8 shows the LAMP and GFS MOS HSS rising in concert with persistence beyond the 15-h projection. Moreover, the skill difference between LAMP and the GFS MOS increases during this period as well. This demonstrates the positive impact an observation can have at specific forecast hours where it shares a noticeable correlation with the predictand.

7. SUMMARY AND CONCLUSIONS

The Meteorological Development Laboratory has recently launched a project to redevelop the LAMP system with special emphasis on aviation weather. In this paper, it has been shown that for the 0900 UTC cycle, cool season, LAMP 1-9 hour categorical forecasts for VIS are significantly more skillful than those generated by the 0000 UTC GFS MOS valid at the same time. The LAMP forecasts beyond the 9-h projection exhibit similar skill as those produced by the GFS MOS system. LAMP forecasts also exhibit comparable or better skill than persistence in the first 4 hours, which is often difficult to improve upon. The verification of LAMP categorical OBV forecasts also demonstrates a significant improvement over the GFS MOS forecasts in the 1-9 hour projection range. Moreover, LAMP forecasts between the 9-25 hour projections show a small improvement in skill over the GFS MOS system. With these improvements, it is believed that LAMP VIS and OBV forecasts will be a valuable data source in generating aviation weather forecasts.

8. FUTURE WORK

A portion of the LAMP effort will continue to focus on developing VIS and OBV 25-hour forecast guidance that will be issued at each hour of the day. 0900 UTC LAMP VIS and OBV forecasts are expected to be run experimentally in September 2005, and become operational during 2006, with the 1500 UTC cycle cool and warm season forecasts following shortly thereafter. Special emphasis will be placed on improving forecasts for IFR conditions or worse. In addition, LAMP will also be providing categorical forecasts of conditional visibility (i.e., visibility forecasts conditional on precipitation occurring) that will be utilized in making Terminal Aerodrome Forecasts. The experimental and operational release times of conditional visibility forecasts will follow the same time table as noted for the visibility forecasts. It is believed that with the incorporation of higher resolution observational data sets, continued improvements in the MOS system, and hourly LAMP forecast updates, LAMP will be a vital tool in making timely and skillful forecasts for the aviation community.

8. REFERENCES

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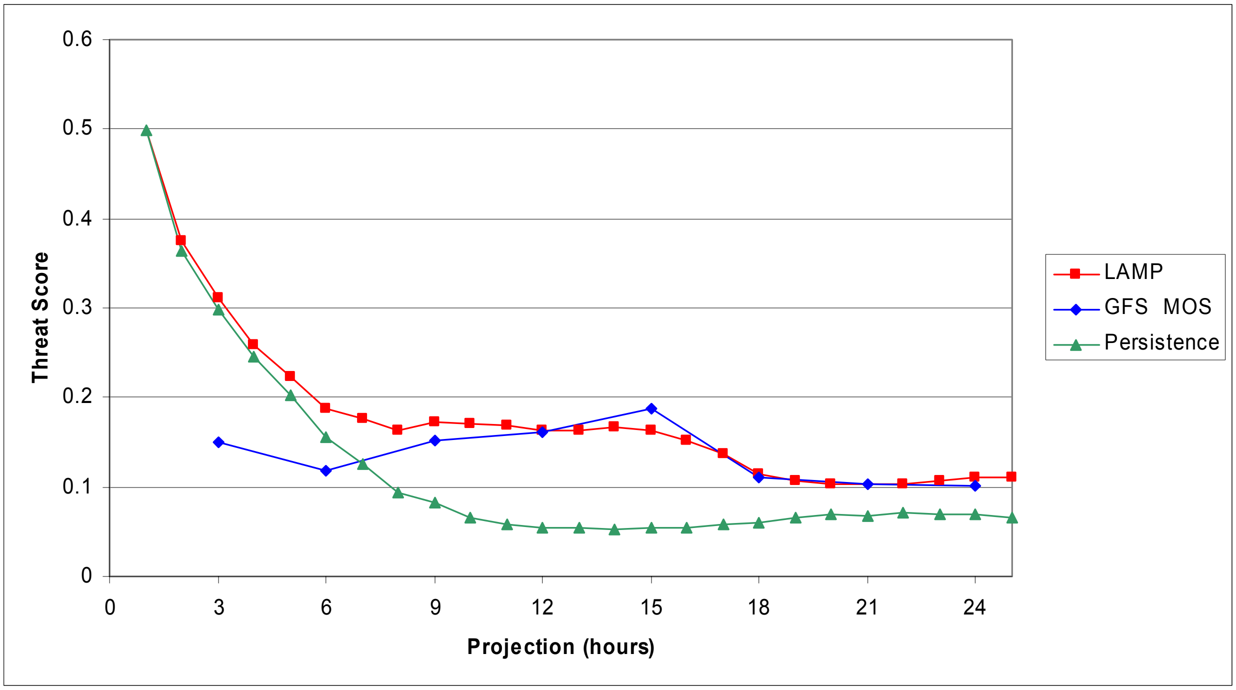

Figure 1. Threat Scores for categorical visibility forecasts of < 1/2 mile from the 2003-2004 cool season. Forecasts were generated from the 0900 UTC LAMP and 0000 UTC GFS MOS.

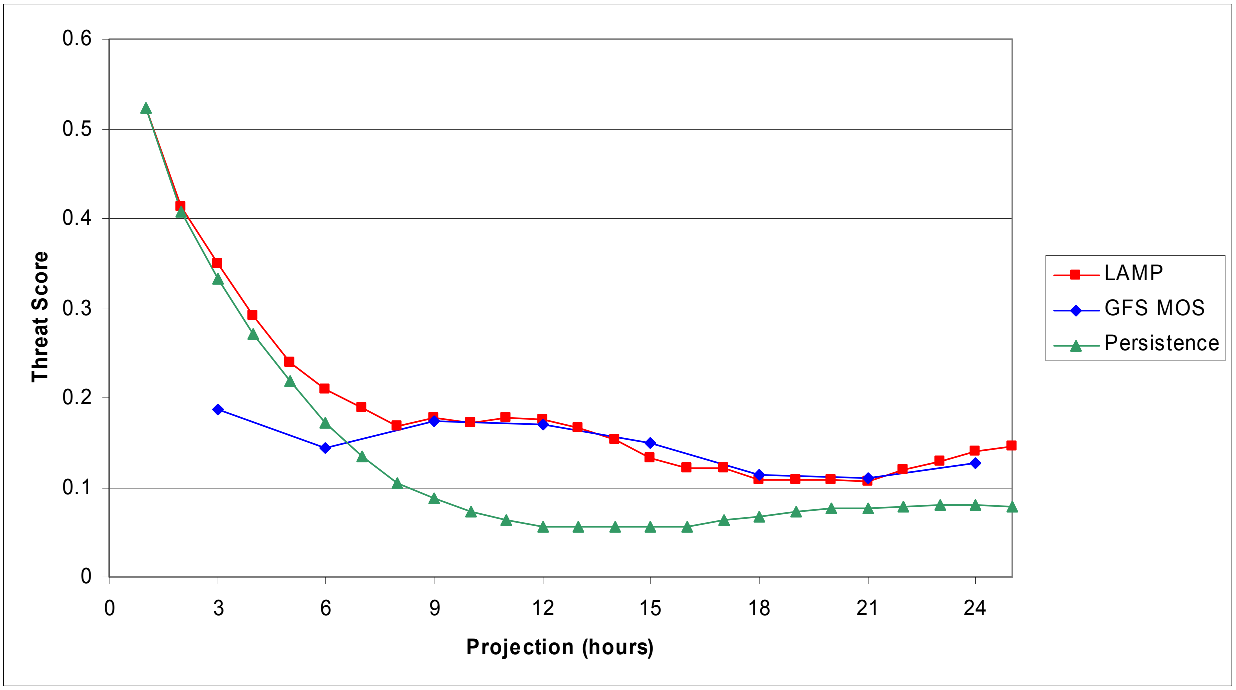

Figure 2. Same as Fig. 1 except for visibility < 1 mile.

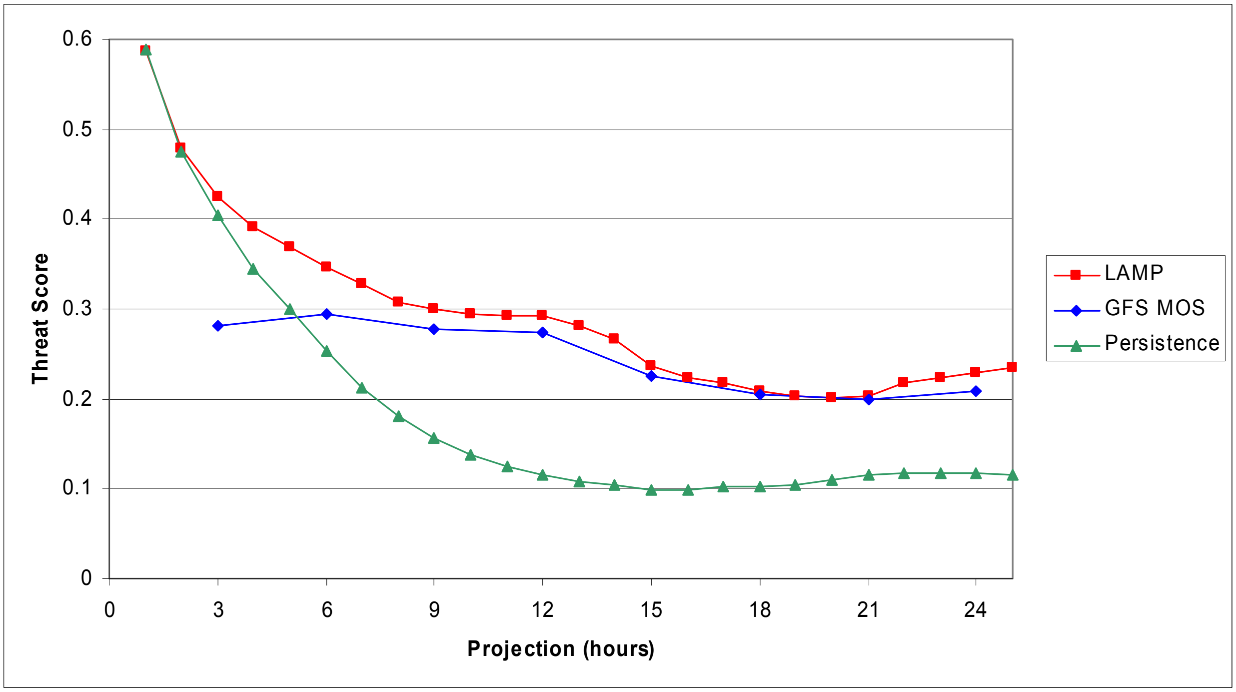

Figure 3. Same as Fig. 1 except for visibility < 3 miles.

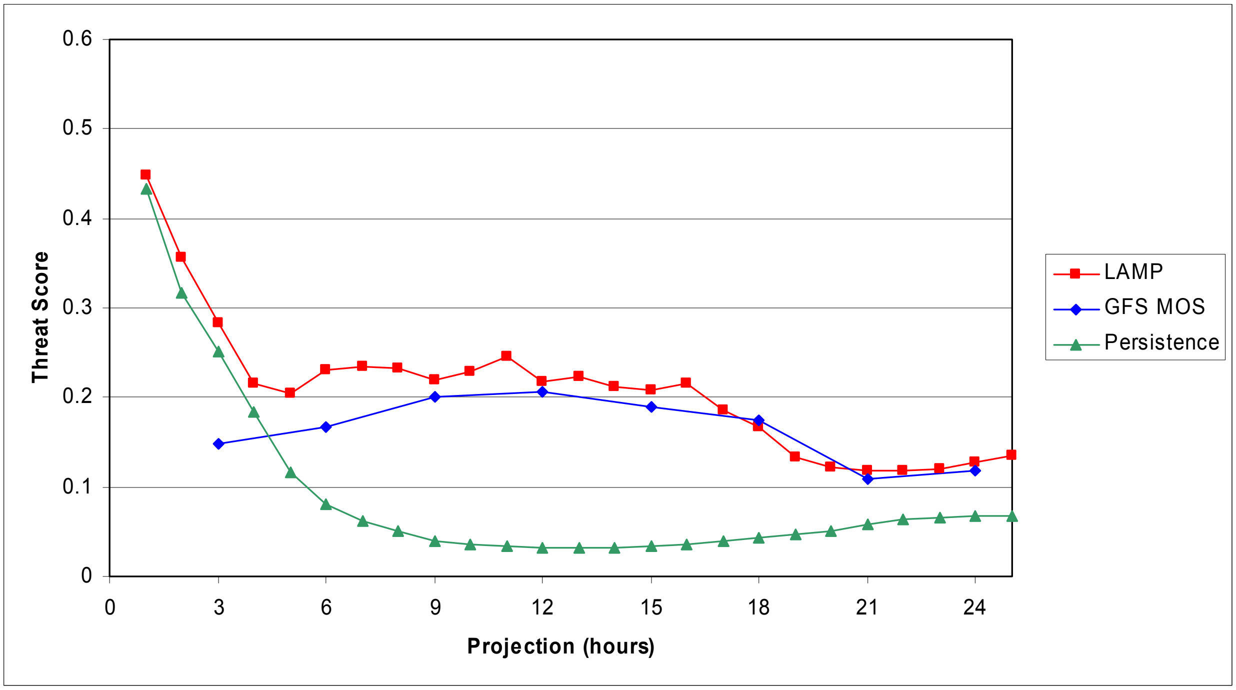

Figure 4. Threat Scores for categorical visibility forecasts of < 1/2 mile from the 2004 warm season.

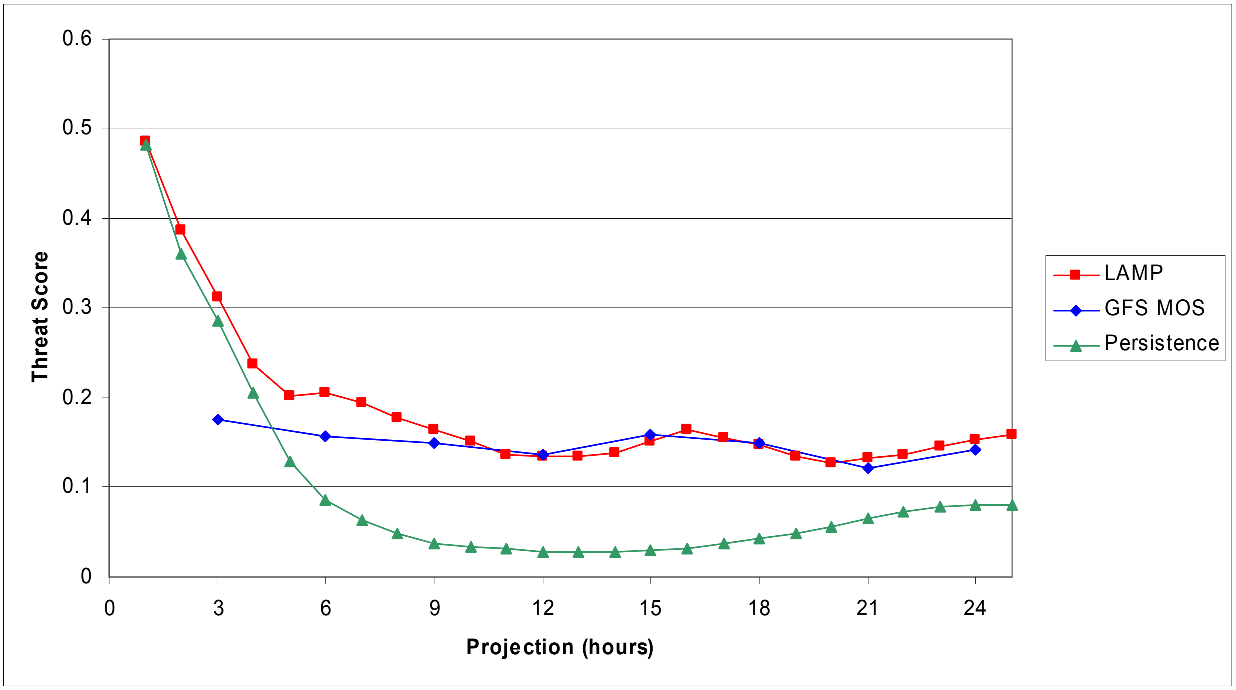

Figure 5. Same as Fig. 4 except for visibility < 1 mile.

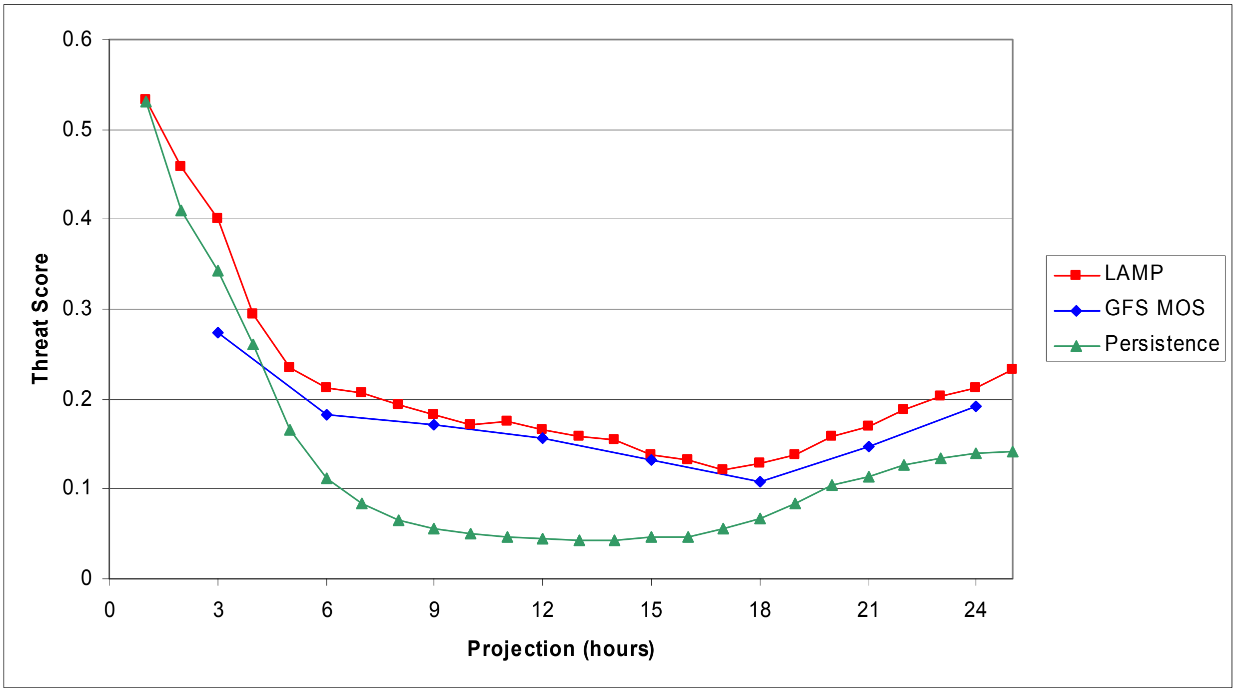

Figure 6. Same as Fig. 4 except for visibility < 3 miles.

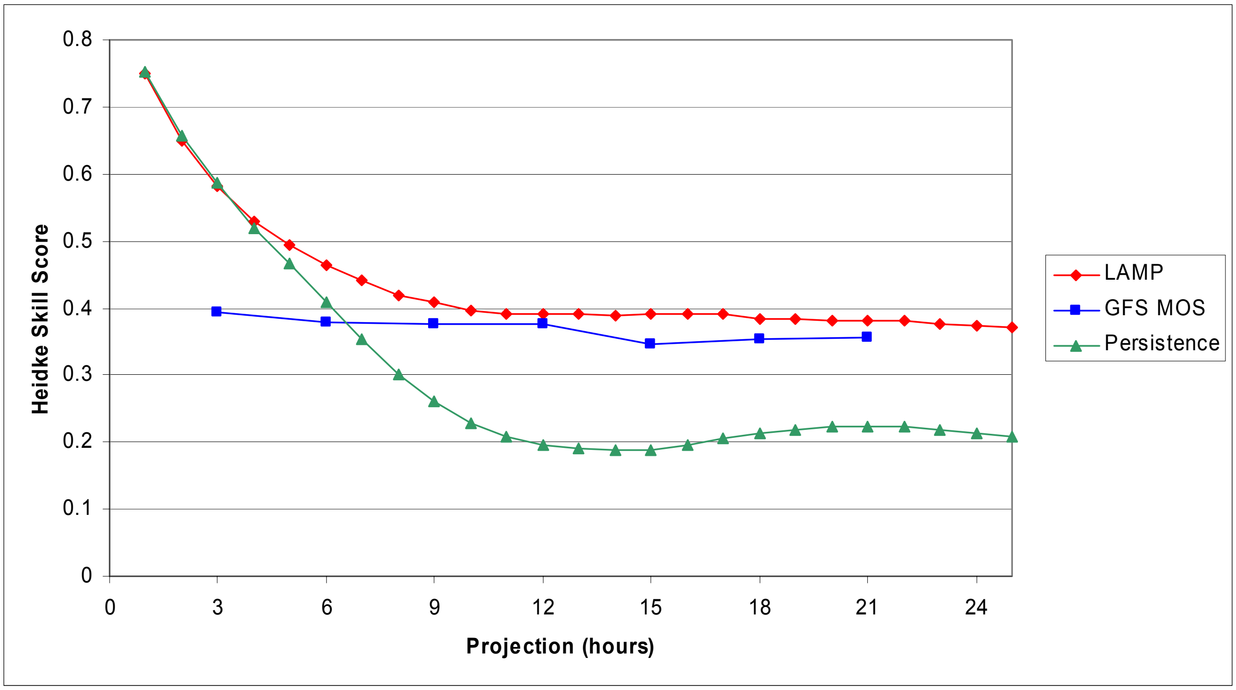

Figure 7. Heidke Skill Scores for categorical obstruction to vision forecasts for the 2003-2004 cool season. Forecasts were generated from the 0900 UTC LAMP and 0000 UTC GFS MOS.

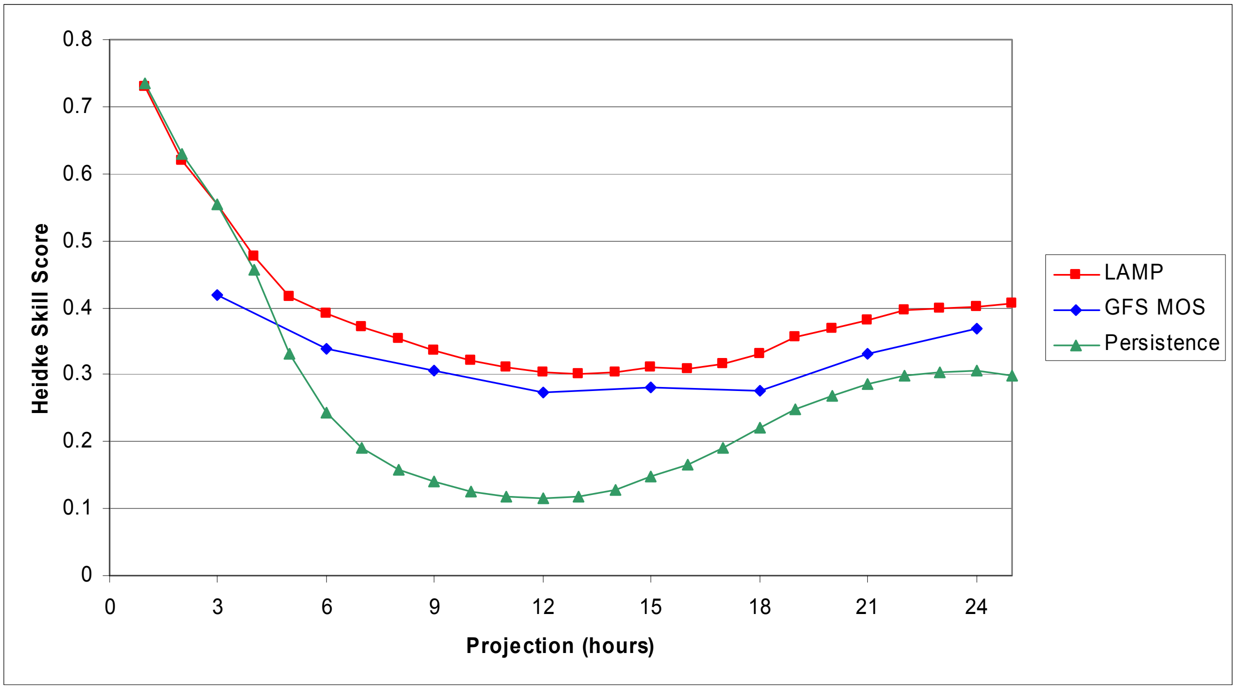

Figure 8. Same as Fig. 7 except for the 2004 warm season.