P1.1 STATISTICAL GUIDANCE FOR TERMINAL AERODROME FORECASTS FROM THE LOCALIZED AVIATION MOS PROGRAM

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1. INTRODUCTION

Recently, the meteorological and aviation communities have been working closely together to improve ceiling height and visibility forecasts. These forecasts are not only valuable in a societal context (e.g., flight delays and guarding against the loss of life) but are also important in making economic decisions that routinely impact airline operations.

Ceiling height and visibility have traditionally been two of the more difficult weather elements to predict. Conditions leading to poor visibility such as fog and air pollution are complex and often locally driven. Forecasting the local effects of terrain, water bodies, and soil moisture on visibility requires a reasonable depiction of these features as they relate to visibility through physical parameterization schemes (Smirnova et al. 2000). Predicting ceiling height, much like visibility, is also quite challenging. Ceiling height, like visibility, is not a state variable, and is modeled by physical parameterizations that incorporate complex microphysics. Dynamical models have insufficient horizontal and vertical resolutions to resolve the mechanisms and variables (e.g., moisture) that lead to the conditions that affect these elements.

Terminal Aerodrome Forecasts (TAFs) are official aviation forecasts produced regularly four times daily, with amendments as necessary. TAFs consist of forecasts of significant weather expected to impact an airport over a specific time period. This time period is usually 24 hours with the first 6 hours being recognized as the Critical TAF Period (NWS 2007). Aviation forecasters use model guidance to assist with the forecasting of sensible weather in the TAFs. Two weather elements included in the TAF that are critical to aviation operations are ceiling height and visibility.

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The NWS's Meteorological Development Laboratory (MDL) has been producing objective statistical guidance in the form of Model Output Statistics (MOS) since the 1970's (Glahn and Lowry 1972). To provide guidance to the aviation forecaster preparing TAFs, MDL produces a short-term statistically-based forecast guidance product called the Localized Aviation MOS Program (LAMP). LAMP is designed to update the Global Forecast System (GFS) MOS forecast guidance on an hourly basis with hourly forecasts extending out to 25 hours in advance (Ghirardelli 2005). (A note on terminology: the LAMP guidance that updates the GFS MOS is sometimes referred to as "GFS LAMP" to distinguish it from the NGM LAMP, which was the previous LAMP product and updated the NGM MOS. The NGM LAMP was discontinued as of January 2008. In this paper the acronym LAMP refers to the GFS LAMP system, and never to the NGM LAMP system.) LAMP generates both categorical and probabilistic guidance for a variety of weather elements with special emphasis on those affecting the aviation community. The guidance includes, but is not limited to, probabilistic and categorical forecasts of ceiling height and horizontal visibility.

Verification of the current LAMP forecast guidance has shown improvements in LAMP over the GFS MOS forecasts of visibility (Rudack 2005) and ceiling height (Weiss and Ghirardelli 2005) during the 1- though 9-h projections (the reader is referred to these references for more details on the comparison between LAMP and GFS MOS forecasts of visibility and ceiling height). Moreover, LAMP displays better accuracy than persistence during the LAMP forecast period, even in the short-term 1-6 hour period. This is a time-frame in which persistence forecasts are regarded to be highly competitive (Dallavalle and Dagostaro 1995).

Recently, the Global Systems Division's (GSD) Rapid Update Cycle model (RUC) (Benjamin et al. 1999), and the National Centers for Environmental Prediction's (NCEP) Weather Research and Forecasting (WRF) Nonhydrostatic Mesoscale model (NMM) (hereafter referred to as the WRF-NMM) model, and the Short-Range Ensemble Forecasting (SREF) system (Zhou et al. 2004) have begun producing ceiling height and visibility forecasts. Since very little has been published concerning the seasonal verification of these elements, we have investigated the quality of these forecasts as compared to LAMP.

This paper compares and contrasts statistically-based LAMP ceiling height and visibility forecasts with forecasts produced by the RUC, WRF-NMM, and SREF. Section 2 briefly discusses the models and type of data used in this verification study as well as how the dynamical model data were interpolated to stations for verification purposes. Verification results are presented in Sections 3 and 4. Section 5 outlines the current available LAMP products, and Section 6 addresses the current status of LAMP as well as future plans. A summary can be found in Section 7.

2. MODEL DATA AND METHODOLOGY

LAMP is a multiple linear regression forecasting model that updates the GFS MOS guidance and provides forecasts at an hourly resolution out to 25 hours in advance. Most forecast weather elements are available for 1591 stations located in the contiguous United States, Alaska, Hawaii, Puerto Rico, and the Virgin Islands. The predictor pool for the regression portion of the LAMP system consists of observations, GFS MOS forecasts, climatic variables (e.g., cosine of the day of the year), and forecasts generated by simple models. Forecast equations can be developed regionally, that is, a regression equation is developed with data obtained from several stations in a region. In this instance, guidance for all stations in that region is generated by use of that same regression equation. An alternative approach, which is more commonly used in forecasting temperature, dew point, wind speed, and wind direction, involves developing a regression equation that exclusively applies to a unique station. The regional approach is typically used in situations where the forecasted events are rare and require a larger sample to stabilize the regression analysis. This is the approach used in developing LAMP ceiling height and visibility forecast equations.

The RUC (hereafter referred to as the RUC20) and WRF-NMM are dynamical models that generate continuous ceiling height and visibility forecasts through post-processing algorithms. The models produce forecasts on 20-km and 12-km horizontal resolution Lambert Conformal grids, respectively. The SREF system is ensemble-based and produces probabilistic forecasts which are interpolated to a 40-km horizontal resolution, Lambert Conformal grid. The SREF is comprised of 10 perturbations from the Eta, five perturbations from the Regional Spectral model, three perturbations from the WRF-NMM, and three perturbations from the National Center for Atmospheric Research Weather Research & Forecasting model (NCAR-WRF), totaling 21 members. (J. Du 2007, personal communication.) All three systems use 3-dimensional prognostic hydrometeor values, which are generated at each time step, to calculate ceiling height and visibility forecasts. Ceiling height and visibility forecasts are not direct model output. If the reader is interested in a discussion outlining the RUC20 and SREF visibility algorithms, please refer to Smirnova et al. (2000) and Zhou et al. (2004), respectively.

In this study, we intended to compare the LAMP probabilities of ceiling height and visibility to those from the SREF. However, due to time constraints and a complication involving the understanding of the exact definition of the SREF visibility probabilities, the authors are unable to present the SREF visibility results in this paper. Verification results for probabilities of visibility for LAMP alone are presented here, and it is our intent to present a comparison of LAMP and SREF probabilistic verification of visibility in a future publication.

2.1 *Verification Data*

LAMP station-based ceiling height and visibility probabilistic and categorical forecasts were generated from 0000 UTC initial conditions. These weather forecasts are at an hourly resolution from 1 to 25 hours in advance for the period of October 2006 through September 2007. Although data from the RUC20 and WRF-NMM were available prior to this period for comparison, an independent LAMP verification was not possible because the dependent sample used in developing the LAMP equations spanned the dates of September 2000 through September 2006. Consequently, the verification was limited to the October 2006 through September 2007 period.

To evaluate the quality of categorical ceiling height and visibility forecasts, the operational model data from the 0000 UTC runs of the RUC20 and WRF-NMM were retrieved for the

October 2006 through September 2007 period. Specifically, the model analysis and forecasts of continuous ceiling height and visibility at an hourly resolution extending out to 12 hours for the RUC20 and 25 hours for the WRF-NMM were collected. Ideally, we would have liked to use the higher 13-km resolution RUC model, however, an archive of that RUC data was not available. Although the coarser 20-km horizontal resolution RUC model does degrade the quality of visibility and ceiling height forecasts, the forecasts are still considered skillful (S.G. Benjamin 2007, personal communication).

Evaluating the LAMP and SREF probability forecast systems required the retrieval of the 0900 UTC post-processed SREF ceiling height probability forecasts for the period of October 2006 through September 2007. The 0900 UTC LAMP probabilities for both ceiling height and visibility were also generated for this period. The collected SREF probabilities are at 3-h intervals extending out to 24 hours. Table 1 shows the category definitions for the LAMP ceiling height and visibility forecasts. For a specific element and category, the SREF probability forecasts of ceiling height represent a consensus frequency based on all 21 members. For example, if 10 of the 21 members predict a ceiling height of < 3000 feet, the probability forecast for ceiling height of < 3000 feet would be 48%.

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 or unlimited ceiling
Category	**Visibility (Miles)**
1	< ½
2	½ - < 1
3	1 - < 2
4	2 - < 3
5	3 – 5
6	6
7	> 6

Table 1. LAMP category definitions of ceiling height and visibility.

2.2 *Model Data Conversion*

The verification in this study is intended to assess the quality of guidance available for TAFs, which are valid at stations. This is the rationale for verifying the ceiling height and visibility forecasts at stations and not at grid points. Therefore, the model forecasts had to be interpolated to stations. Due to the discontinuous nature of ceiling height and visibility, a nearest neighbor interpolation was performed; that is, the ceiling height or visibility value at the grid point closest to a station was assigned to that station. Generally, a more realistic representation of the interpolated field at stations is preserved when applying this interpolation type, rather than, for instance, bilinear interpolation. To correctly represent the RUC20 ceiling height values which are given relative to sea level, the ceiling height forecast was calculated by subtracting the station elevation from the ceiling height forecast. This conversion was not necessary for the WRF-NMM because the WRF-NMM ceiling height forecasts are already defined relative to the model surface.

Once the model-based ceiling height and visibility forecasts were properly interpolated to stations, the continuous forecast values were binned into the LAMP categories (Table 1) which are in terms of hundreds of feet and miles, respectively. Note that the RUC20 and WRF-NMM ceiling height data were converted and rounded to the nearest hundreds of feet. Consequently, all model-based continuous ceiling height forecasts were populated across all eight LAMP categories. Note that the LAMP ceiling height and visibility categories are consistent with the significant levels of the aviation flight categories (NWS 2007).

The 0900 UTC SREF ceiling height probability forecasts were interpolated to stations from forecast grids with a bilinear interpolation. Finally, each station value was converted from a percent to a probability ranging between 0 and 1, inclusively.

2.3 *Verification Methodology*

The verification periods for both categorical and probabilistic forecasts were stratified into two seasons. The cool season spans October 2006 through March 2007, while the warm season goes from April to September 2007. This is consistent with the seasonal stratification used in the development and verification of MDL's LAMP and MOS statistical products. Although low ceiling heights and poor visibility are more common in the cool season, warm season verification was performed for the sake of completeness. Note that all cross model comparison verification scores are derived from matched samples. Table 2 shows the forecast events which are verified in this paper.

The domain of the LAMP forecasting system covers the contiguous United States (CONUS) and the non-contiguous United States. In contrast, the domains of the RUC20, WRF-NMM, and SREF are primarily restricted to the CONUS. Given these circumstances, the verification domain was limited to the CONUS. A total number of 1462 Meteorological Aviation Report (METAR) stations in the CONUS are used in this verification study. Fig. 1 depicts the system domains and the 1462 LAMP stations in the CONUS which were used for verification.

Ceiling Height
< 500 feet
< 1000 feet
< 3000 feet
Visibility
< ½
< 1
< 3

Table 2. Events verified in this paper.

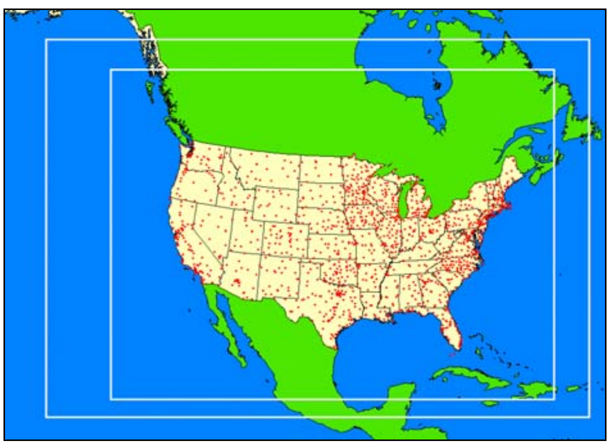

Figure 1. The domains of the systems investigated. The outer rectangle indicates the area of the WRF-NMM and SREF domains. The inner rectangle indicates the area of the RUC20 domain. The red dots indicate the 1462 LAMP stations in the CONUS, which coincide with the verification points.

3. VERIFICATION RESULTS OF CATEGORICAL FORECASTS

Categorical and probabilistic forecasts require different metrics to evaluate their utility. The threat score or critical success index (CSI) is often used to determine the accuracy of categorical forecasts (e.g. forecasts of ceiling height < 1000 feet) (Wilks 2006). A perfect forecasting system has a CSI of one while a value of zero represents the worst possible CSI score. This metric allows one to quickly judge the accuracy of forecasts of the threat event. The accuracy of all categorical ceiling height and visibility forecasts shown in this section is demonstrated through the CSI.

After sharing our verification results with the RUC20 developers, they identified a problem with both the operational ceiling height and visibility RUC20 analyses and forecasts (S.G. Benjamin 2007, personal communication). The error was corrected at NCEP in January 2008. As such, the RUC20 data are suspect but the verification scores are shown nonetheless. It is likely that a verification of RUC20 forecasts produced after the correction was implemented operationally would yield improved results for the RUC20 over what is shown here.

3.1 *Categorical Ceiling Height Forecasts*

Fig. 2 displays the CSI values of 0000 UTC categorical ceiling height forecasts at an hourly resolution for the 2006-2007 cool season. (Recall, that the RUC20 model forecasts beyond the 12-h projection were not available.) All three figures display the same general type of behavior. At every projection, LAMP forecasts exhibit equal or better forecast accuracy as compared to persistence, the RUC20 and the WRF-NMM. Prior to the 7-h projection, LAMP demonstrates marked improvement over the RUC20 and WRF-NMM. Improving over persistence and other models in the very-short term (1-6 hours) is what distinguishes LAMP from other forecasting systems. Although LAMP CSI scores tend to level-off beginning at the 8-h projection (~0.49 < 3000 feet, ~0.34 < 1000 feet, and 0.25 < 500 feet), the CSI scores still remain at or above all three other forecasting systems throughout the 12-h forecasting period. However, the RUC20 and WRF-NMM do show accuracy comparable to LAMP during the 9-12 hour projections for ceiling heights < 3000 feet.

The accuracy of persistence forecasts is close to that of LAMP in the 1- through 5-h projections but declines sharply shortly thereafter. A slower trend in the degradation of persistence forecast accuracy is noted for ceiling height < 3000 feet and < 500 feet. This is reasonable because lower ceiling heights are usually associated with weather conditions that do not rapidly change. Another common feature is the overall consistent CSI scores the RUC20 and WRF-NMM share. The

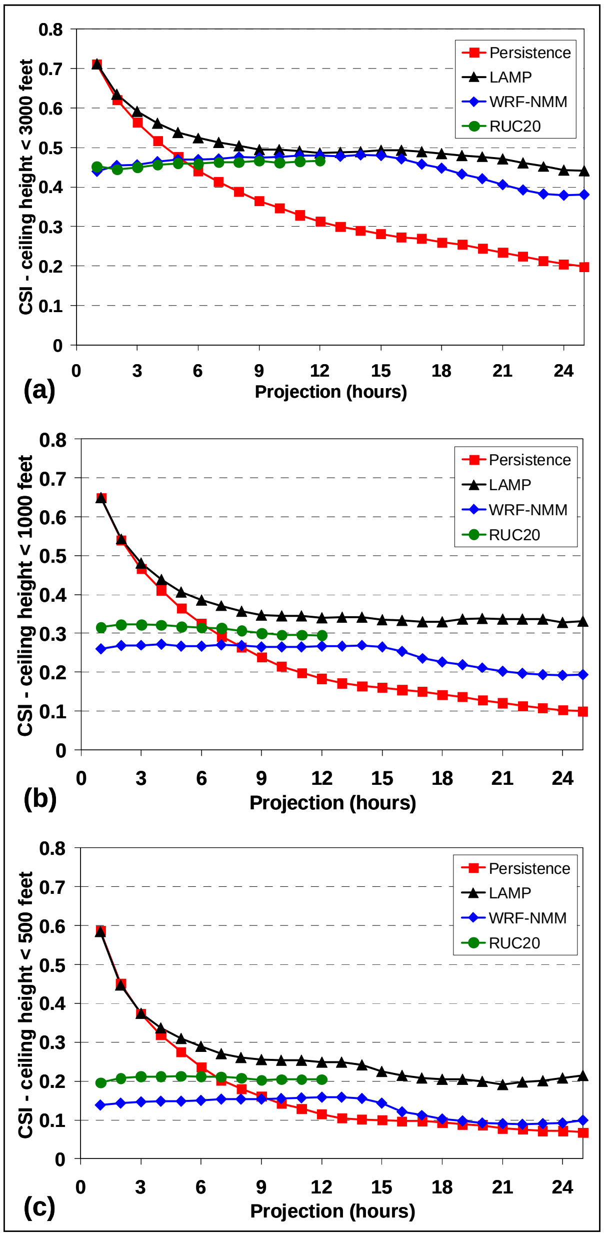

Figure 2. CSI for ceiling height (a) < 3000 feet, (b) < 1000 feet, and (c) < 500 feet for the 0000 UTC cool season. Shown are persistence (red squares), LAMP (black triangles), WRF-NMM (blue diamonds), and RUC20 (green circles).

CSI scores for both models remain fairly constant for all projections. The WRF-NMM performs marginally better for ceiling height forecasts of < 3000 feet (~0.47 vs. ~0.46) while the RUC20 shows a more pronounced improvement in ceiling height categorical forecasts of < 1000 feet (~0.30 vs. ~0.27) and < 500 feet (~0. 21 vs. ~0.15.).

For projections beyond 12 hours, CSI scores for WRF-NMM categorical ceiling height forecasts for all three categories remain noticeably lower than LAMP, with the exception of ceiling height forecasts of < 3000 feet for projections 12 through 15 hours, when LAMP and WRF-NMM scores are very close.

3.2 Categorical Visibility Forecasts

The overall behavior of the verification scores for categorical visibility forecasts (Fig. 3) is similar to the ceiling height categorical forecasts. One difference, however, is a sharper rate of decline in the LAMP CSI scores for visibility forecasts of < 3 miles in the first 6 hours. A second difference can be found in the visibility forecasts of < 3 miles where the RUC20 performed better for all projections (albeit negligibly) as compared to the WRF-NMM. A third distinction is that the LAMP CSI scores become almost constant from the 6-h projection onward. This leveling-off period begins approximately 2 hours earlier than those found in the ceiling height plots.

The LAMP and persistence CSI scores for forecasts of visibilities < 3 miles are similar to each other for the first four projections and diverge quickly thereafter. After the 4-h projection, LAMP CSI scores remain in the 0.24 range while persistence drops below the value of 0.20 after the 6-h projection. From the first projection and onward, the RUC20 and WRF-NMM CSI scores straddle the value of 0.20. LAMP and persistence CSI values for visibility forecasts of < 1 mile and < ½ mile diverge less quickly in the first 6 hours as opposed to forecasts of < 3 miles. In fact, persistence narrowly improves over LAMP in the first two projections for visibility forecasts of < ½ mile. The RUC20 and WRF-NMM CSI scores for all three categories and projections demonstrate little accuracy with values hovering around 0.20 and below. The overall lower visibility CSI scores for all three categories exhibited by all four systems are indicative of the inherent complexity in predicting visibility.

During the 13- through 25-h projections, LAMP visibility CSI scores generally remain higher than those of the WRF-NMM. However, CSI scores for visibilities of < 1 mile and < ½ mile during these later periods remain below 0.20.

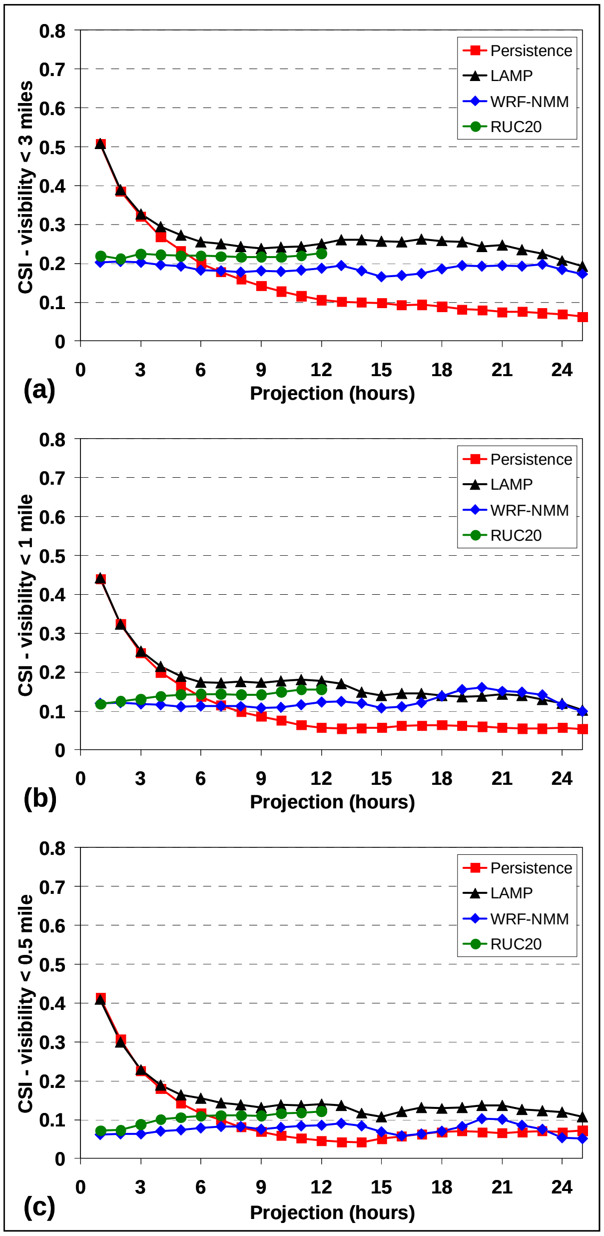

Figure 3. CSI for visibility (a) < 3 miles, (b) < 1 mile, and (c) < 1/2 mile for the 0000 UTC cool season. Persistence is indicated by red squares, LAMP by black triangles, WRF-NMM by blue diamonds, and RUC20 by green circles.

3.3 *IFR or Worse Forecasts*

Since correctly forecasting Instrument Flight Rule (IFR) conditions or worse is extremely important in aviation forecasting, the subsequent verification results will primarily focus on these conditions. IFR or worse conditions occur when either the lowest ceiling height is < 1000 feet and/or the visibility is < 3 miles (NWS 2005).

Fig. 4a shows the CSI values for IFR conditions or worse for the 2006-2007 cool season, and compares persistence, LAMP, RUC20, and the WRF-NMM at an hourly resolution with forecasts extending out to 25 hours. As expected, the same overall behavior exhibited in the categorical ceiling height and visibility verifications is also displayed here. LAMP improves over all other systems at every projection. For the first three or four projections, persistence is a strong competitor to LAMP with CSI scores ranging from 0.64 at the 1-h projection to 0.40 at the 4-h projection. However, by the 7-h projection, the forecast accuracy of persistence begins to quickly fall below the accuracy of the LAMP, RUC20 and WRF-NMM. The performance of the RUC20 and WRF-NMM is generally constant through all 12 projections with CSI values of ~0.34 and ~0.30, respectively.

During the 12- through 15-h projections, LAMP and WRF-NMM CSI scores are somewhat comparable. However after this period, the scores begin to drop for the WRF-NMM (0.23 by hour 25) while the LAMP scores remain fairly constant (0.34 by hour 25).

Fig. 4b displays the warm season (April – September 2007) verification results for IFR conditions or worse. The same type of relational behavior between all four systems is noted with a couple exceptions. As expected, the CSI scores for IFR or worse conditions for all systems are lower when compared to the cool season. This result is consistent with the infrequent occurrence of this phenomenon in the warm season. For the 1- through 3-h projections LAMP shows more of an improvement over persistence in the warm season compared to the cool season. Although this improvement is modest, adding any skill over persistence in the very short-range is noteworthy. The warm season RUC20 and WRF-NMM CSI score values shadow each other much more closely throughout the 12 hour forecast period compared to the cool season CSI scores. The CSI scores for the LAMP and WRF-NMM beyond the 12-h projection are comparable with a slow and steady decline. Values approach 0.20 in these later projections.

4. VERIFICATION RESULTS OF PROBABILITY FORECASTS

Recently, end-users of aviation products have expressed interest in using probability forecasts of ceiling height and visibility for specific conditions. These probabilities can be incorporated into cost-loss models which are then used by airlines to make critical economic decisions (Keith and Leyton 2007).

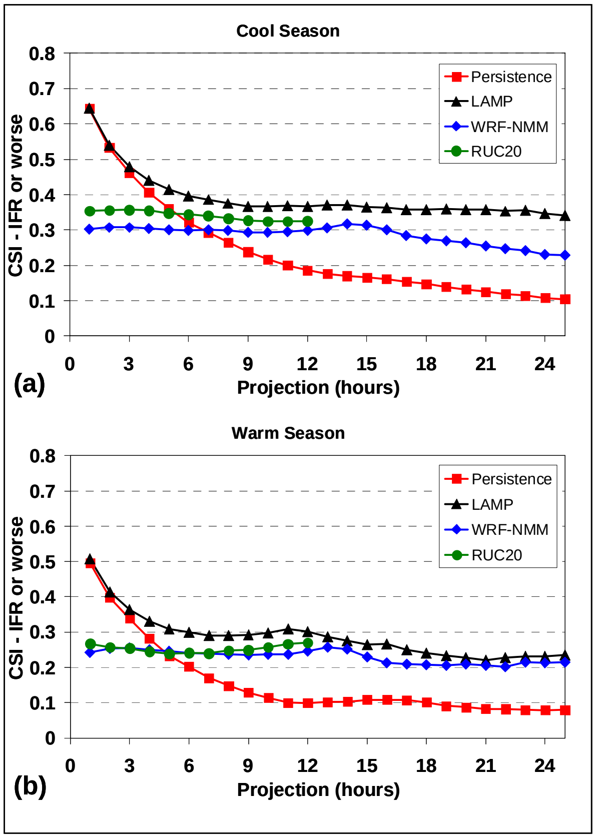

Figure 4. CSI for IFR or worse conditions for 0000 UTC for the (a) cool season and (b) warm season. Shown are persistence (red squares), LAMP (black triangles), WRF-NMM (blue diamonds), and RUC20 (green circles).

In 2006 the National Research Council (NRC 2006) released a report on characterizing and communicating uncertainty information. This report discusses the problems with deterministic forecasts and how they can be misleading without understanding the underlying uncertainties. It further charges that the NWS has a responsibility to provide products that communicate the underlying forecast uncertainty. LAMP provides probabilistic forecast guidance, and as such does provide information relating to forecast uncertainty.

The reliability diagram is one method to visually assess the behavioral characteristics of a set of probabilistic forecasts. Probabilistic forecasts are deemed reliable when the average probability forecast and the average frequency of the event being approximated are about the same. This is a desirable characteristic and may be interpreted that the forecasting system is accurate. However, this is not always the case. For example, if a forecaster routinely issues the current day's climatology as the official forecast, his/her forecasts will demonstrate perfect reliability. Despite this caveat, reliability diagrams are typically accepted as one component of forecast accuracy (Wilks 2006).

4.1 *Probabilistic Ceiling Height Forecasts*

For the comparison of the LAMP and SREF probabilities, reliability diagrams were generated for each of the categories discussed in sections 3.1 and 3.2 for the 3-, 6-, 9-, 12-, 18-, and 24-h projections for the stations and periods noted above (not all diagrams are shown here). Fig. 5 displays the cool season reliability diagrams for ceiling height probability forecasts of < 3000 feet for the 3-, 6-, and 12-h projections. LAMP demonstrates better reliability for all projections (even those projections not shown) as shown by its close proximity to the perfect reliability diagonal. The SREF shows a strong bias of underforecasting probabilities of less than 50%. For example, at the 3-h projection when the SREF probability forecasts range between 15% and 25%, the actual observed frequency is approximately 46%. Although, the SREF reliability line shows improvement above the 50% level, one would like to observe consistent reliabilities across all probability bins. Interestingly, the SREF at the 12-h projection demonstrates noticeably better reliability for forecast probabilities of 40% and above compared to what is seen in the earlier projections. The 18- and 24-h projections (not shown) indicate an improvement in reliability across all bins for the SREF compared to the earlier projections. For these later projections, the LAMP and SREF reliabilities are similar for probabilities of 50% and above, with the SREF slightly overforecasting and LAMP slightly underforecasting the event. As with earlier projections, LAMP is more reliable than the SREF for probabilities below 50%. Perhaps this improvement in the SREF at later projections can be attributed to model spin-up and/or the ability of the ensemble forecasts to sufficiently capture the destabilization of the planetary boundary layer during the late morning and afternoon hours (projections 12 though 24). The same overall behavior is noted in the warm season verification plots (not shown).

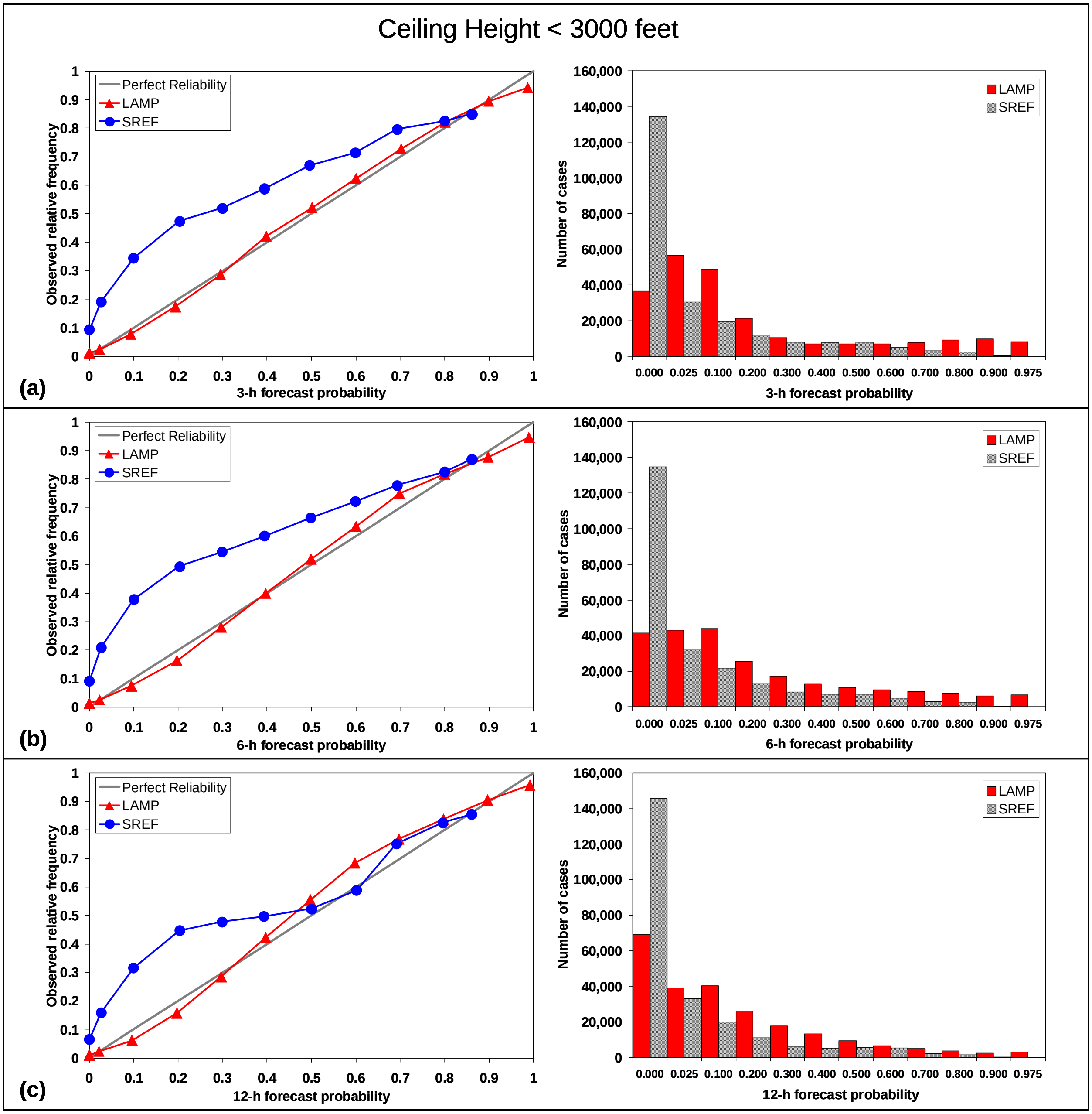

Figure 5. Reliability diagrams (left side) and histograms (right side) for probabilities of ceiling height < 3000 feet for the (a) 3-h projection, (b) 6-h projection, and (c) 12-h projection for the 0900 UTC cycle cool season for LAMP (red diamonds and solid red bars) and SREF (blue circles and hatched bars).

Unlike the SREF's tendency to underforecast probability forecasts of < 3000 feet in the cool season in the earlier projections, the SREF's ceiling height forecasts of < 1000 feet (Fig. 6) demonstrate good reliability for probabilities at and below 30%. This behavior is generally seen for projections of 3, 6, and 9 hours (9-h projection not shown), and to a lesser extent at the 12-h projection. The reliability of LAMP forecasts closely straddles the reliability diagonal for projections of 3 and 6 hours but begins to noticeably overshoot the diagonal (under forecasting ceiling heights < 1000 feet) for all subsequent projections for the probability bins between 40% and 80%. In contrast to the underforecasting behavior exhibited by LAMP in these bins, the SREF displays a distinct overforecasting bias over all projections.

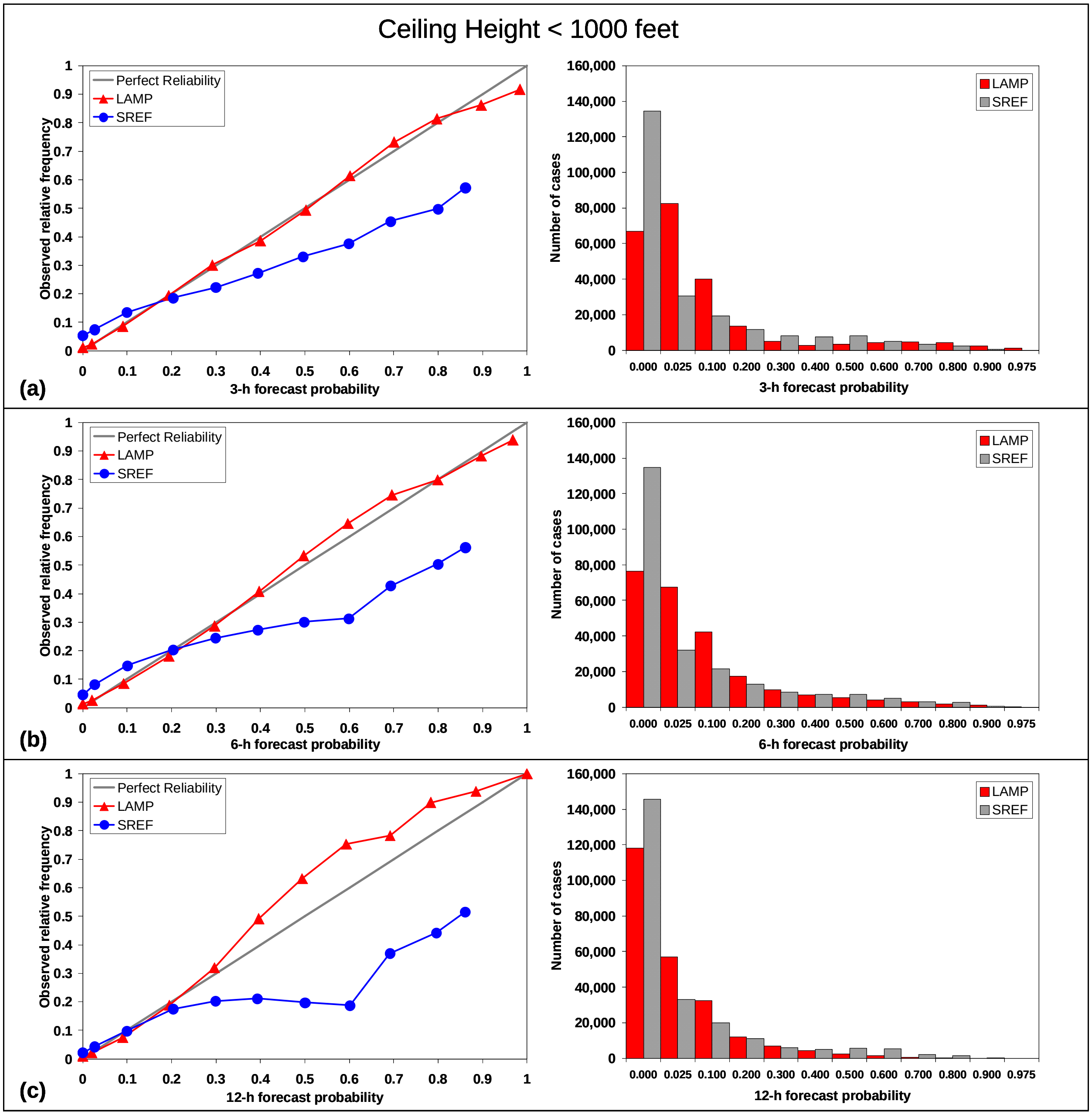

Figure 6. Reliability diagrams (left side) and histograms (right side) for probabilities of ceiling height < 1000 feet for the (a) 3-h projection, (b) 6-h projection, and (c) 12-h projection for the 0900 UTC cycle cool season for LAMP (red diamonds and solid red bars) and SREF (blue circles and hatched bars).

As a word of caution, the SREF reliability scores in the upper bins (60% and greater) must be interpreted judiciously. The significant drop in the number of forecasts in these bins can create the misconception of an unreliable system when in fact a portion of the degradation is due to chance, that is, the small number of forecasts in those bins. While the small number of forecasts with higher probabilities is a deficiency in the system, generating high probability forecasts of rare events is extremely difficult.

4.2 *Probabilistic Visibility Forecasts*

The LAMP cool season probability forecasts of visibility < 3 miles demonstrate good reliability

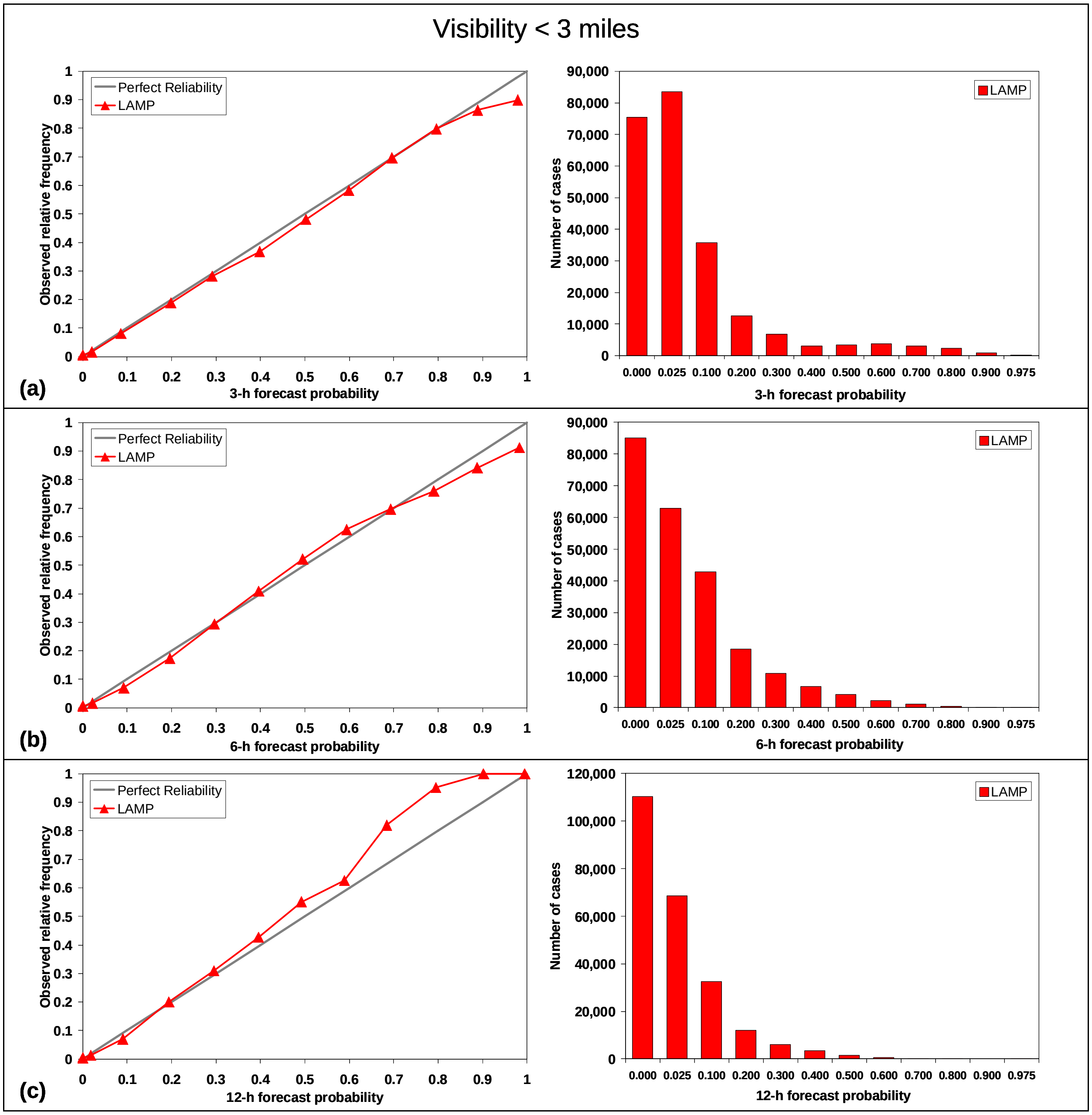

Figure 7. Reliability diagrams (left side) and histograms (right side) for probabilities of visibility < 3 miles for the (a) 3-h projection, (b) 6-h projection, and (c) 12-h projection for the 0900 UTC cycle cool season for LAMP.

across all bins for all projections examined. Fig. 7 displays the reliability diagrams and histograms for LAMP for the warm season 0900 UTC cycle. The forecasts display good projection-to-projection consistency, and LAMP produces probability forecasts greater than 90% for most projections. LAMP forecasts of visibilities < 3 miles for the 3- and 6-h projections do not exhibit a discernable forecast bias, while the forecasts for 12 and 18 hours (not shown) display a tendency to underforecast visibilities < 3 miles in the upper bins.

The warm season reliability plots for LAMP (not shown) indicate that LAMP has the tendency to underforecast visibilities of < 3 miles, especially at the later projections and in the upper bins, and for more bins and projections in the warm season than in the cool season. In addition, LAMP produces fewer forecasts in the uppermost bins in the warm season compared to the cool season, which is not surprising. Despite this behavior, LAMP still demonstrates overall good reliability and produces probability forecasts in the upper bins in the early projections.

5. LAMP PRODUCTS

LAMP provides station based guidance for ceiling height and visibility that can be used to prepare TAFs. This section outlines the available LAMP products and how the reader can access them.

The LAMP guidance for ceiling and visibility is produced operationally at NCEP for the cycles of 0000, 0300, 0400, 0500, 0600, 0900, 1000, 1100, 1200, 1500, 1800, and 2100 UTC. The data are disseminated from NCEP across the Satellite Broadcast Network and NOAAPort, and are also available on the NWS File Transfer Protocol (FTP) site tgftp.nws.noaa.gov. The categorical ceiling height and visibility data are available in text format while both the categorical and probabilistic guidance is contained in BUFR format. The text bulletin is disseminated via the World Meteorological Organization (WMO) header of FOUS11 KWNO. The interested reader can refer to the LAMP documentation found on the web site http://www.nws.noaa.gov/mdl/gfslamp/docs/gfslamp_info.shtml for a list of the WMO headers for the BUFR LAMP products.

The NWS forecaster can view these data in the Advanced Weather Interactive Processing System at the NWS Weather Forecast Offices. The text bulletin is stored in the text database with the AWIPS identifier of LAV. The ceiling and visibility data are plotted in AWIPS as a graphic in the Display 2-Dimensional (D2D). In addition, time series plots of the LAMP guidance can be displayed via the Volume Browser in AWIPS.

The LAMP guidance and graphics for all elements, including ceiling height and visibility, can be found on the MDL LAMP web page http://www.nws.noaa.gov/mdl/lamp. Ceiling height and visibility guidance are available in the LAMP text bulletins found on the web site. The text bulletins are available for as many as 1591 stations across the CONUS, Alaska, Hawaii, Puerto Rico, and Virgin Islands.

The web site displays graphics of ceiling height and visibility guidance. Guidance of ceiling height, visibility, and the combination of the two into Aviation Flight Categories are available in a station plot format which color codes the LAMP guidance by category at the stations on a plan view map. Fig. 8 is an example of the LAMP Flight Categories station plot map. This map can be clicked on to “zoom” to a regional map showing the guidance over a smaller area. The color coded boxes represent the LAMP forecast for that valid time for the stations shown. If the user clicks on the station, a meteogram of the LAMP guidance for that cycle is displayed.

By default, this resulting meteogram displays the guidance for all elements contained in the text bulletin, however the user can configure the meteogram via check boxes to limit the LAMP guidance to only those elements he/she is interested in. The meteogram data is updated once an hour to represent the current observation to allow the user to assess how LAMP is performing relative to the verifying observation. Guidance from previous LAMP cycles, along with the verifying observations, is also available from this web site to allow the user to determine the recent performance of LAMP. Fig. 9 is an example of a previous LAMP cycle and shows the verifying observations for the period up until the current time. This is intended to allow a user to become familiar with LAMP’s behavior at specific stations for differing synoptic situations and weather events.

6. CURRENT STATUS AND FUTURE WORK

While LAMP produces probabilistic forecasts of ceiling height and visibility, these probabilities are not readily available to the user. They are contained in the BUFR messages, but in the authors’ experience, not many users are familiar with decoding the BUFR to extract this information. Moreover, many users are unaware that LAMP even provides probabilistic guidance for ceiling height and visibility.

In an effort to provide probabilistic aviation guidance to the user in a more accessible format, a new probabilistic product is being considered for the LAMP web site. The product would graphically depict ceiling height and visibility probabilities for various significant aviation breakpoints by cycle and station for all the available LAMP stations. This work is currently in the prototype stage, but an example of what the graphic might look like can be found in Fig. 10. This graphic is similar to a product being displayed by the NWS Weather Forecast Office in Charleston, WV, and is being prototyped in collaboration with them.

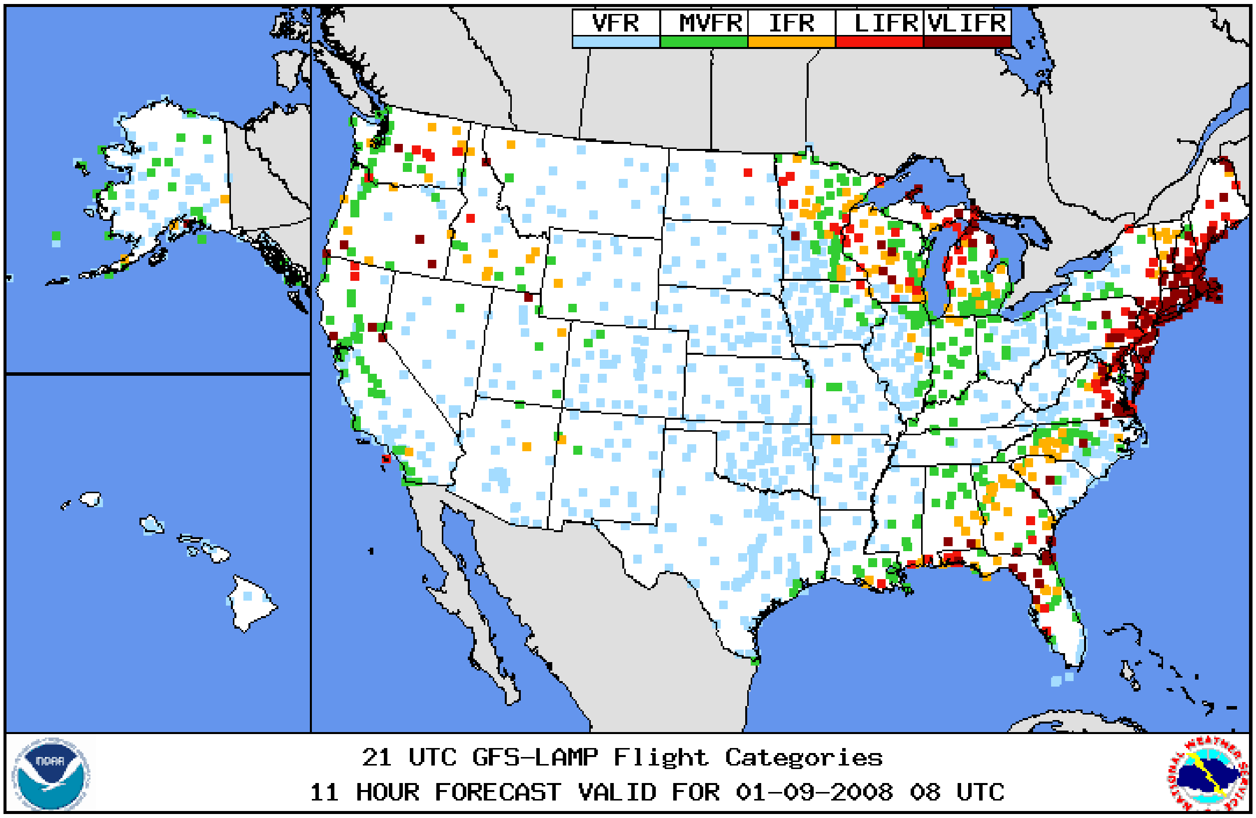

Figure 8. LAMP web-site graphic depicting Aviation Flight Categories. Squares represent the flight category forecast from LAMP at that station for valid time indicated. This graphic is also available for other categorical guidance from LAMP.

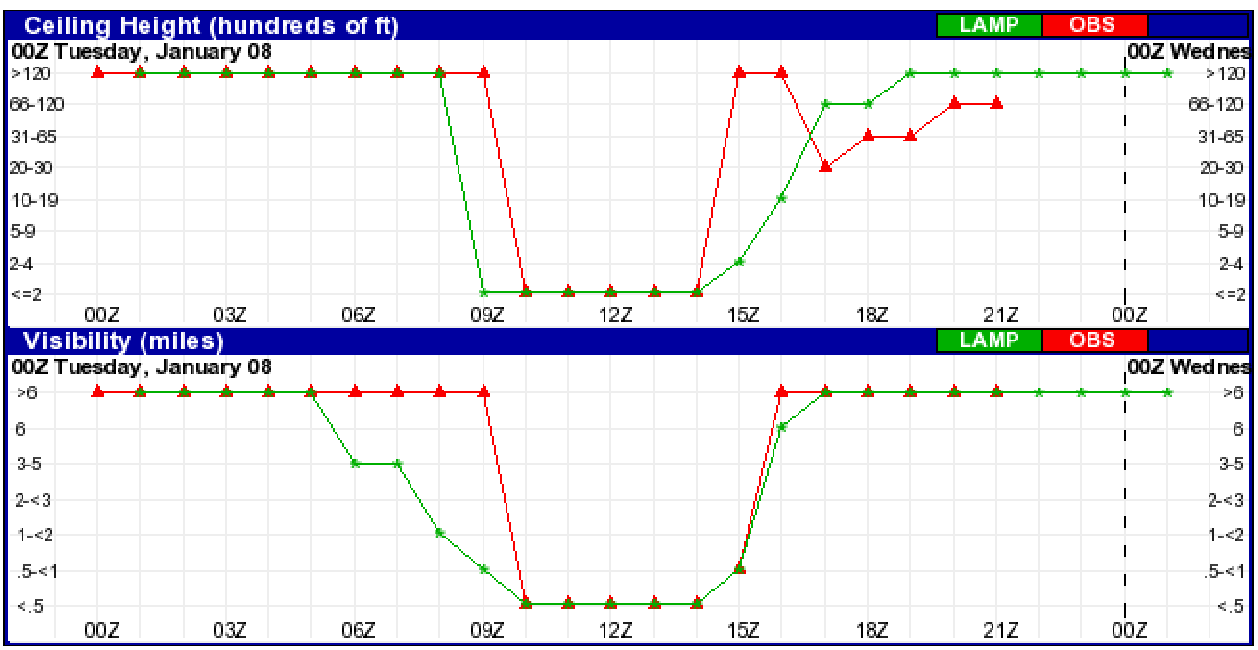

Figure 9. LAMP web-site graphic displaying a past cycle's LAMP guidance (in green) and the verifying observations (in red) for ceiling height (upper time series) and visibility (lower time series).

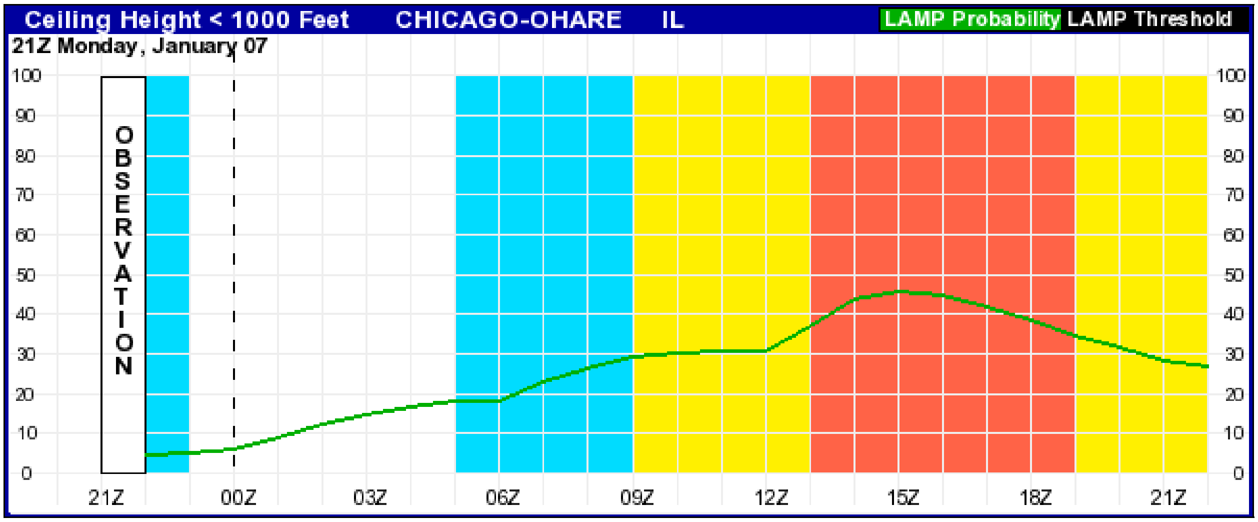

Figure 10. Prototype LAMP probability graphic. The green line is the LAMP probability of ceiling height < 1000 feet for Chicago-Ohare. The colored bars represent the times LAMP guidance of ceiling height and visibility combined indicates the conditions of the various Flight Categories (white is greater than Marginal Visual Flight Rules (MVFR), blue is MVFR, yellow is Low Instrument Flight Rules, and orange is Very Low Instrument Flight Rules).

The next cycles planned are 0100, 0700, 1300, and 1900 UTC and are scheduled to be operational in spring of 2008. Four more LAMP cycles will be released in the summer of 2008, with the final four cycles available early in 2009. This will result in producing guidance hourly for a total of 24 LAMP cycles. We expect this frequent release and rapid updating of the guidance to add a very useful tool to the suite of available objective statistical guidance of sensible weather, and we expect this will be of great value to aviation forecasters.

7. SUMMARY

LAMP offers guidance that can be valuable to aviation forecasters interested in ceiling height, visibility, and aviation flight category forecasting at stations. This study shows that station-based 0000 UTC LAMP categorical forecasts of ceiling height and visibility are more accurate than RUC20 and WRF-NMM post-processed, categorized forecasts of ceiling height and visibility interpolated to stations. These results are true for both the warm and cool seasons. Warm season verification scores for LAMP categorical forecasts of the more rare events (e.g., visibility < 1 mile or ceiling < 500 feet) display less skill than the cool season for all systems. The lower scores which are observed in the LAMP system in the warm season can be attributed to its inability to resolve and accurately model rare events. Statistical regression requires a sufficient number of events to properly forecast a future occurrence of that event. A "sufficient" number is usually experimentally determined and may vary between elements. Another reason for the observed degradation in the warm season scores observed in all four systems is the inability to accurately model the factors forcing these events at the scales at which they occur. Modeling the onset of mesoscale events and their evolution will undoubtedly continue to present challenges in the years to come.

For the cycle and periods studied here, LAMP ceiling height probabilities exhibit better reliability than ceiling height probabilities from the SREF system. However, preliminary investigations (not presented here) indicate that the SREF probabilities of both ceiling height and visibility do contain predictive information, and might well benefit from statistical post-processing. LAMP visibility probabilities, while not compared here with any other system, display good reliability.

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