P1.48 LOCALIZED AVIATION MOS PROGRAM (LAMP): STATISTICAL GUIDANCE OF WIND SPEED, DIRECTION, AND GUSTS FOR AVIATION WEATHER

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1. INTRODUCTION

The Meteorological Development Laboratory (MDL) is redeveloping the Localized Aviation MOS Program (LAMP), a system used to provide statistical guidance for sensible weather elements. The current LAMP system produces wind speed and direction guidance every 3 hours by utilizing Nested Grid Model (NGM) Model Output Statistics (MOS) (Kelly and Ghirardelli 1998). The new system will update the latest Global Forecast System (GFS) MOS to produce forecasts for wind speed, direction, and maximum wind gusts in an effort to improve the guidance for aviation purposes. LAMP guidance will be updated hourly producing forecasts every hour out to 25 hours for the conterminous United States, Alaska, Hawaii, and Puerto Rico.

This paper describes the steps necessary to produce forecast guidance for wind direction, wind speed, and maximum wind gusts. The objectives of redeveloping the LAMP wind direction and speed were to show improvement over persistence during the early projections and blend into the GFS MOS during the later projections. The objective of the wind gust development was to create a system that accurately forecasts the occurrence and speed of a wind gust.

2. PREDICTAND DEFINITIONS

The LAMP wind direction and speed forecasts were made from the u- and v- wind components (U and V) and wind speed (S) predictands. Equations for these three predictands were developed simultaneously to help ensure consistency in their forecasts. Since an hourly equation for each element contains the same predictors, only the coefficients will be different between each predictand (Glahn and Unger 1986).

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LAMP wind gust forecasts were made from two predictands. The first was the probability of a wind gust occurring. This predictand was based on the Automated Surface Observing System (ASOS) Users Guide's definition, which states that the minimum gust reported is 14 kts (NOAA 1998). The second predictand was the difference between the observed wind speed and the observed wind gust in the event of a wind gust occurring. Unlike the wind direction and speed development, these two predictands were developed independently.

3. EQUATION DEVELOPMENT

Warm and cool season equations have been developed for the 0900 UTC cycle for the U, V, S, and maximum wind gust. The warm season (April through September) equations were developed with five warm seasons (1999 through 2003). A sixth season (2004) was used for independent verification. When available, 15 days prior to April and after September were used. This was done to increase the data sample and help smooth the transition from the warm season to the cool season. Cool season (October through March) equations were developed with five cool seasons (1998 through 2003). A sixth season (2004) was saved for independent verification.

1523 stations were selected for developing equations for the wind elements. The U, V, and S equations used a single-station approach, while the wind gust development used a regional approach. In a regional development, each station in a region will use the same equation, whereas in a single station development, each station has a unique equation. A regional development is usually performed for rare predictands, such as wind gusts (Klein and Glahn 1974), allowing for a larger development sample. Ten regions, based on climatology and geographical factors, were found to best fit the wind gust development. Alaska was a separate region while Hawaii and Puerto Rico were grouped with Florida.

4. PREDICTORS

All wind elements used five types of predictors in their equations: hourly surface observations, LAMP Model analyses, LAMP Model forecasts, 0000 UTC GFS MOS, and geoclimatic variables. Analyses of U, V, and S from the Cresmann Technique (1959) were substituted for missing observations. The LAMP Models used were the Sea Level Pressure (SLP) Model (Unger 1982), a moisture model (SLYH) (Unger 1985), and the Cloud Layer Advection Model (CLAM) (Glahn and Unger 1986). The GFS MOS guidance was available in 3-hour increments. Since LAMP produces forecasts in hourly increments, a linear interpolation was required for the “off hours” of the GFS MOS. In addition to the previously mentioned systems, 0000 UTC GFS Model output and the 0900 UTC LAMP wind speed forecasts were also used as predictors for the wind gust equations.

LAMP software required that each predictor selected for an equation be present in every projection for all wind elements to minimize any large variations occurring between projections (Glahn and Unger 1986). It was also necessary to force the GFS MOS and the latest hourly observation as predictors into each equation. If this forcing were not performed, it would be possible to have some stations without the latest observation or GFS MOS. This would result in a system that does not update the GFS MOS with the latest observation.

4.1 U- and V- Wind Components and Speed

For the U, V, and S equations, the predictors that had the largest reduction of variance were the U, V, and S of the 0000 UTC GFS MOS and observations. The 1000 hPa geostrophic u- and v- wind components and speed were calculated from the SLP Model. These predictors added predictive value primarily during the middle projections. Saturation deficit, a measure of moisture, was computed from the moisture model. Binaries of this predictor helped to indicate the presence of precipitation during the forecast period and added minimal improvement to the forecast. Thickness advection calculated from the SLP Model, and Theta–E advection calculated from the CLAM Model, only reduced the variance by a few thousandths of a point, but could potentially help forecast wind shifts associated with frontal passages.

4.2 Wind Gust

For the wind gust equations, the predictors with the highest reduction of variance were the observed wind gust, the 0000 UTC GFS Model, and the 0900 UTC LAMP forecasted wind speed. In order to maintain a large number of cases, the observed wind gust was set to 0 kts when a wind speed observation was present and no wind gust was reported. The observed wind gust is extremely important when forecasting a gust, since typically a gust persists due to synoptic features. The LAMP U, V, and S forecasts were added to help ensure consistency between the wind gust forecasts and wind speed forecasts. 0000 UTC GFS Model output was necessary to use because no direct GFS MOS wind gust forecasts were available. The most important predictors from the GFS Model were the forecasted lapse rates, stability indices, and wind speeds at selected heights. The 0000 UTC GFS MOS wind speed was once again a powerful predictor, although overshadowed by the previously mentioned predictors.

5. POST-PROCESSING

5.1 U- and V- Wind Components and Speed

A few post processing steps were required before the final wind forecasts were made. All wind speed forecasts were inflated. This inflation increased the standard deviation of the distribution, which increased the frequency of higher wind speeds (Glahn and Unger 1986). As a result, wind speeds greater than the mean were increased and wind speeds lower than the mean were decreased. The inflation process did increase the overall Mean Absolute Error, however biases by category were improved. Due to the inflation process, a second check was needed to insure non-negative wind speed values. During the wind direction computation, if the u- and v- components were both 0 kts, the wind speed was set to 0 kts and the direction to 0 degrees. During events of wind speed less then .5 kts the wind direction was set to 0 degrees, which indicates calm winds.

5.2 Wind Gust

The first step taken to post process the wind gust forecasts was calculate thresholds for each region and projection. This was done by maximizing the Threat Score within a bias range. Once thresholds were determined, the forecast probabilities were categorized. If a forecasted probability exceeded the threshold, a gust was forecasted. If the threshold was not exceeded, no gust was forecasted.

The continuous wind gust forecasts represented the difference between the wind speed and wind gust. In order to create wind gust intensity forecasts, the inflated and post processed LAMP wind speeds were added to the wind gust difference forecast. This effectively created forecasted gust values at all 25 projection hours.

The next post processing step was to combine the categorical (yes/no) gust forecasts and the calculated wind gust forecasts. If the categorical gust forecast indicated "yes" for a gust, the calculated gust became the wind gust forecast. If the categorical gust forecast indicated "no" then no gust was forecast. A comparison between this two tiered approach and merely using a continuous forecast of the wind gust showed a dramatic decrease in the False Alarm Rate (FAR), while the Probability of Detection (POD) remained high.

Provided the above step resulted in a forecasted gust, some final post processing steps were required. These steps helped ensure sensibility and consistency in the wind gust forecasts. According to the ASOS User Guide, a sustained wind speed has to be at least 3 kts. Given this definition, the first check was to ensure that the LAMP speed was at least 3 kts. If this were not the case, no gust was forecasted. The second check was to ensure a minimum difference between the LAMP wind speed forecast and LAMP wind gust forecast. This was done by calculating the average difference between the observed wind gust and observed wind speed for the entire warm season sample. This was found to be 6.7 kts with a standard deviation of 2.5 kts. After a multitude of tests to maximize the POD and minimize the FAR, a value, one deviation from the mean, or 4.2 kts was chosen. If the difference was not at least 4.2 kts, no gust was forecasted. The final check maintained the ASOS definition of a minimum wind gust by only forecasting gusts of 14 kts or greater.

6. RESULTS

In this section, results for the 0900 UTC warm cycle are shown. The results for cool season forecasts were comparable to that of the warm season forecasts and will not be shown. Although many scores were computed for the individual elements, only select scores will be represented.

6.1 Wind Direction and Speed

For wind direction and speed, Mean Absolute Error (MAE) was used. MAE was calculated only for wind directions that had a verifying wind speed observation of at least 10 kts. Figs. 1 and 2 show that LAMP wind speed and direction are more accurate than persistence throughout the period. Fig. 1 demonstrates that LAMP wind speed is more accurate than the 0000 UTC GFS MOS speed during the first six projections. Fig. 2 shows that LAMP wind direction forecasts are able to improve on the 0000 UTC GFS during the first nine projections. After the sixth hour for speed and ninth hour for direction, LAMP produces nearly the same forecasts as the GFS MOS. Most of the improvement over the GFS MOS in hours 1 - 3 can be attributed to the observed wind predictors. Any errors that GFS MOS may contain should be removed with these predictors. During hours 4 – 9 the strongest predictors were the U, V, and S of the GFS MOS, and the U, V, and S geostrophic wind speed from the SLP Model. Any differences seen during hours 4 – 9 can be attributed to the SLP Model. After the ninth hour LAMP is mainly using the U, V, and S from the GFS MOS, so it should not show much variation in the forecast from the GFS MOS.

6.2 Wind gust

An 8 X 8 and a 2 X 2 contingency table were created to find the Heidke Skill Score (HSS) (Wilks 1995) and the Threat Score. A higher score for the HSS is more skillful. A higher Threat Score correlates with a high POD and a low FAR. The categories for the 8 X 8 contingency table are shown in Table 1. The categories for the 2 X 2 contingency table were gust events versus no gusts events.

Table 1. Wind Gust Categories used in Verification

1	No gusts or Gust < 18 kts
2	Gusts 18 to 23 kts
3	Gusts 23 to 28 kts
4	Gusts 28 to 33 kts
5	Gusts 33 to 38 kts
6	Gusts 38 to 43 kts
7	Gusts 43 to 48 kts
8	Gusts > 48 kts

For the wind gust verification, there was no GFS MOS with which to compare. As a substitute, a factor of 1.5 times the 0000 UTC GFS MOS wind speed was used. If the GFS MOS wind speed was less than 9 kts, the calculated GFS MOS gust was set to 0 kts. The LAMP forecasted wind gusts were then compared to the calculated GFS MOS gust and persistence.

Fig. 3 compares the three systems for the threat of a gust. Any gust forecast greater than 0 kts is considered a gust event. In this figure LAMP is consistently better than both persistence and the computed GFS MOS gust. Much of this improvement is attributed to the categorical gust forecast. The regression utilized the stability parameters from the GFS Model, which helped in forecasting the occurrence of a gust.

Figs. 4 and 5 show the Threat Score of a gust greater than or equal to 38 kts and 48 kts respectively. The objective is to show that LAMP forecasts the stronger wind events. In Fig. 4, with the exception of the first projection period, LAMP has a higher threat score than both persistence and the calculated GFS MOS gust. In Fig. 5, LAMP possesses more skill than the computed GFS MOS gusts throughout the period; however, persistence has more skill during the first three projections. These two figures prove that LAMP has the ability to forecast strong wind gust events, but persistence seems to be better during the early projections.

Fig. 6 shows the HSS for the three systems. In this figure, LAMP wind gust forecasts continue to demonstrate more skill than both persistence and the calculated GFS MOS wind gusts throughout the period. This is proof that LAMP does well with more typical gust events when speeds are between 14 kts and 38 kts.

7. SUMMARY AND CONCLUSIONS

The verification results for LAMP wind direction and speed support updating the GFS MOS with the latest observation. Including the latest observation had dramatic effect on forecasting these wind elements during the early periods. The utility of LAMP during the later projection hours, 9 – 25, can be mainly attributed to interpolating the 0000 UTC GFS MOS.

The addition of maximum wind gust forecasts to the LAMP system was worth the development efforts. LAMP has shown the ability to forecast wind gust events accurately throughout the period along with forecasting gust speeds accurately. This capability significantly improves guidance currently available to the aviation community.

8. FUTURE PLANS

MDL will continue redeveloping additional cycles for the LAMP wind elements. Eventually, LAMP will update the GFS MOS on an hourly basis. During the redevelopment process for upcoming cycles, special attention will be given to improving the ability of forecasting wind shifts associated with strong warm and cold fronts.

9. RESOURCES

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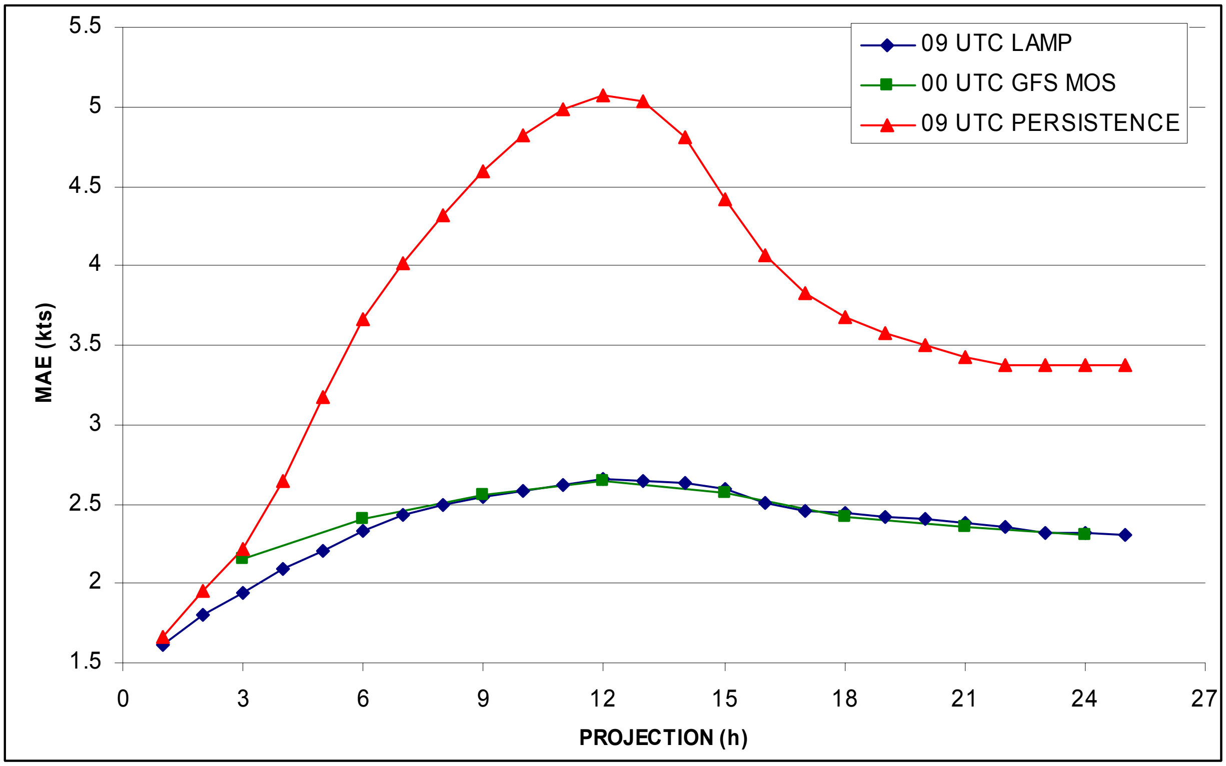

Figure 1. MAE Score for 2004 Warm Season Wind Speed

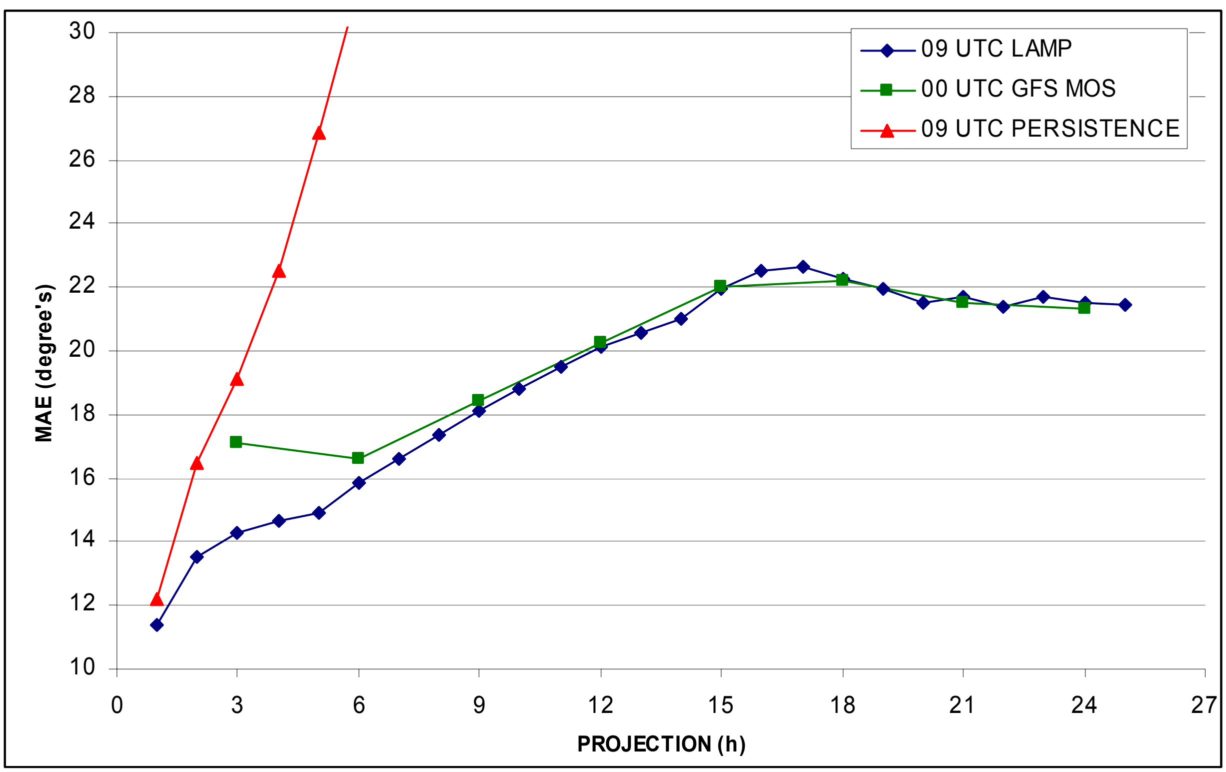

Figure 2. MAE Score for the 2004 Warm Season Wind Direction

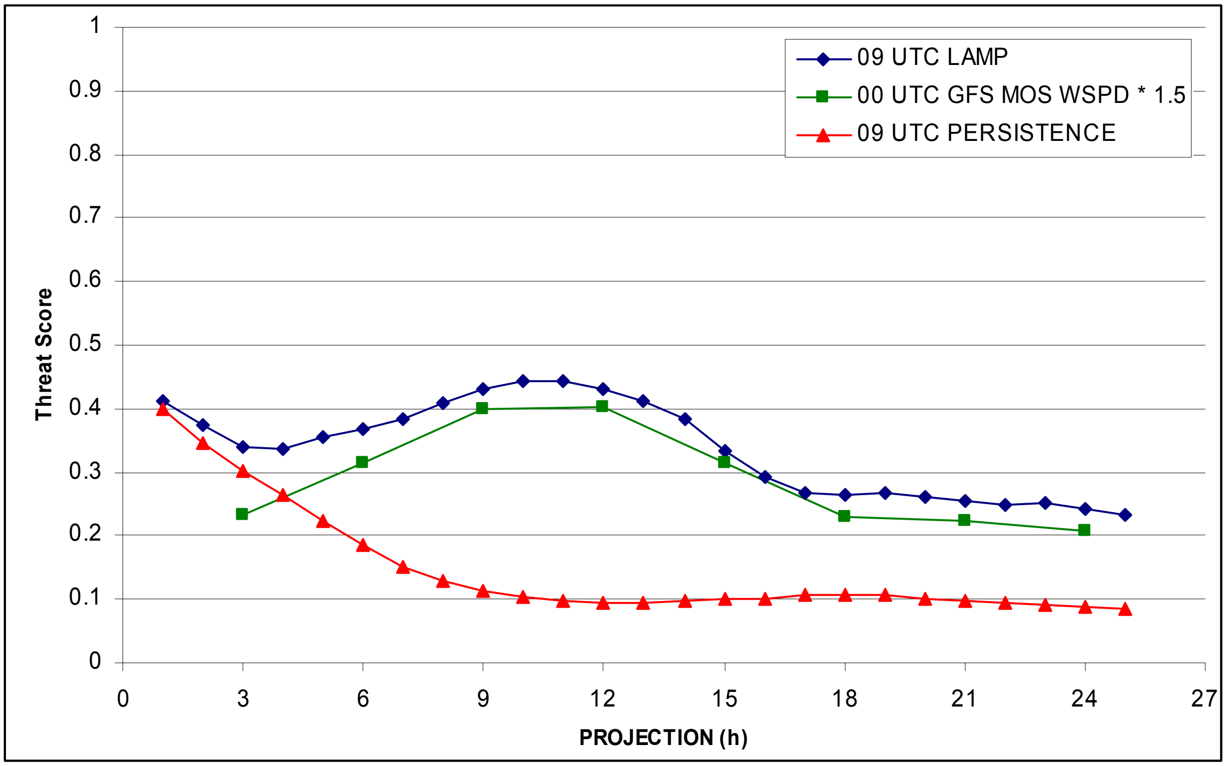

Figure 3. Threat Score for the occurrence of a Wind Gust for the 2004 Warm Season

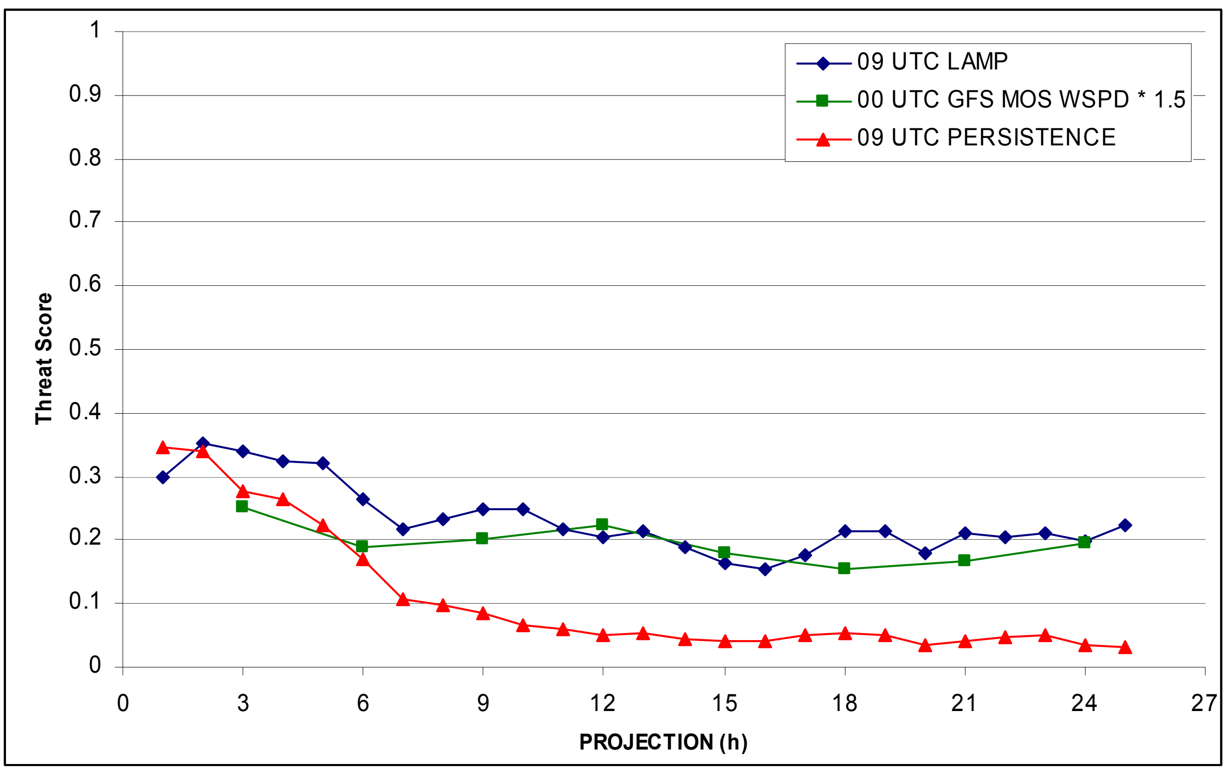

Figure 4. Threat Score of Wind Gusts greater than or equal to 38 kts for the 2004 Warm Season

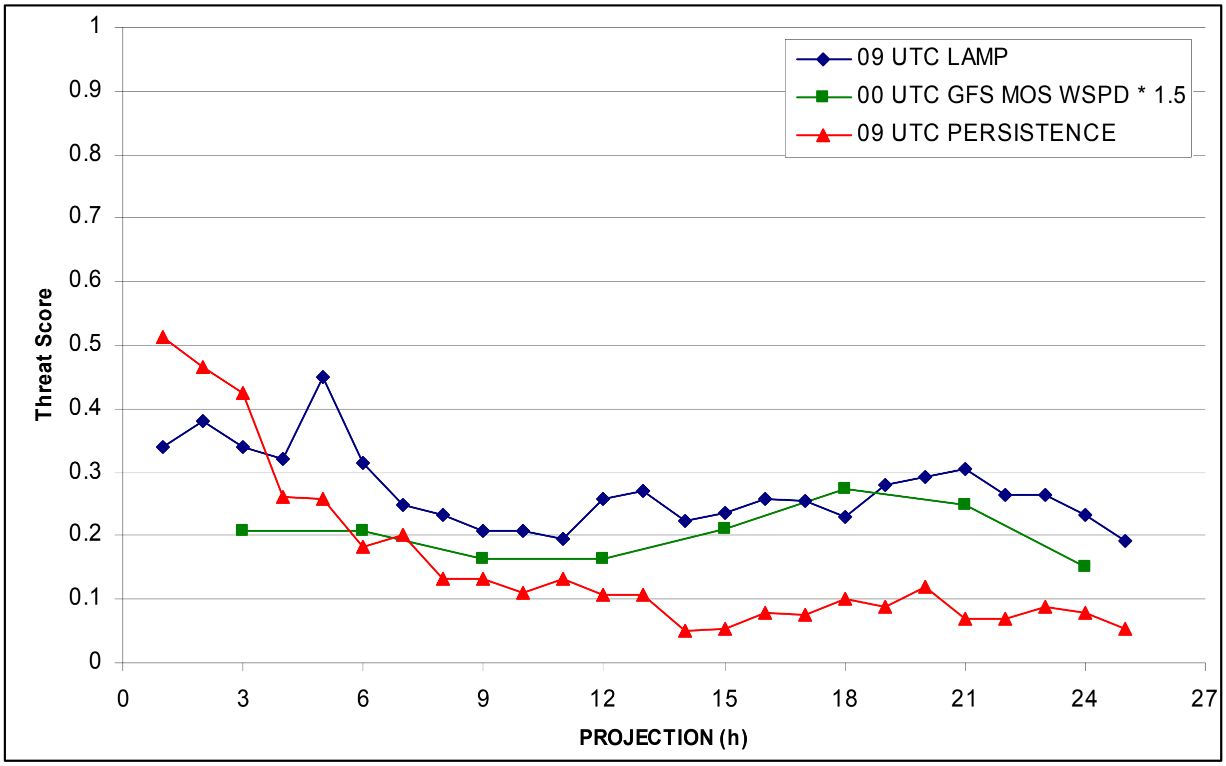

Figure 5. Threat Score of Wind Gusts greater than or equal to 48 kts for the 2004 Warm Season

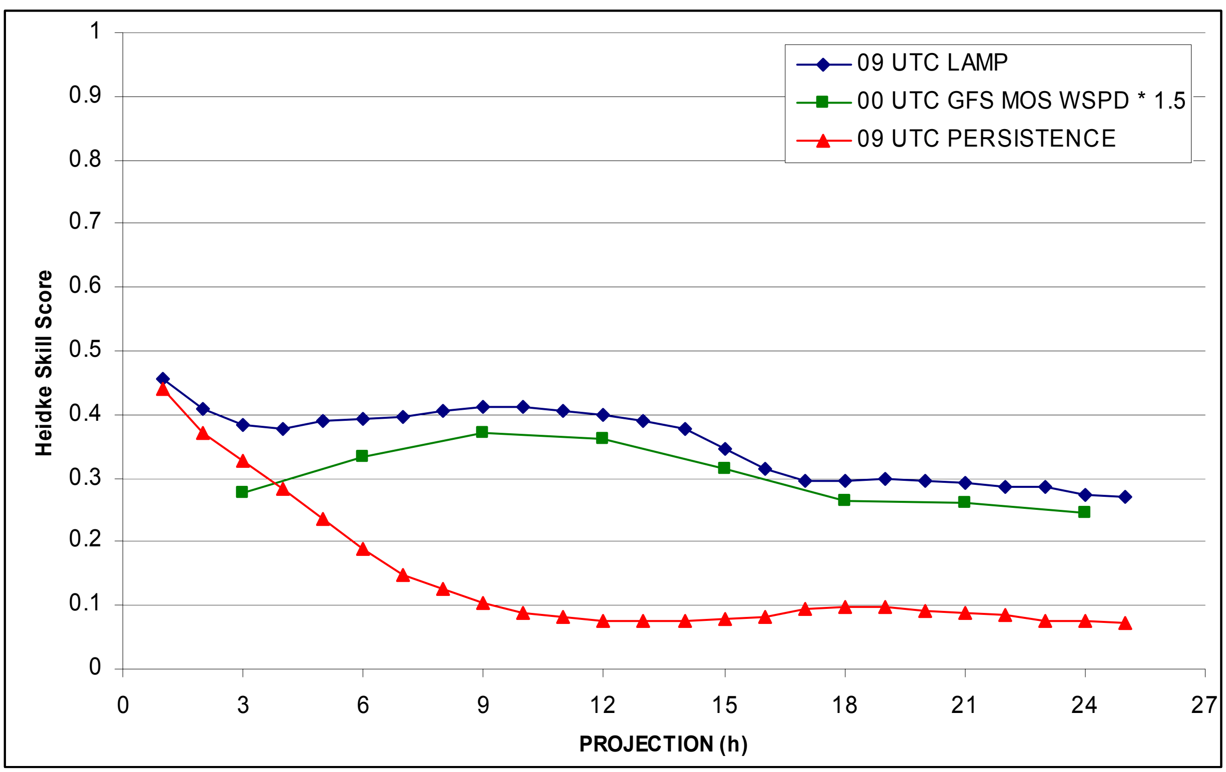

Figure 6. Heidke Skill Score for Wind Gusts for the 2004 Warm Season