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Applied Meteorology Unit (AMU) Quarterly Report

Third Quarter FY 2010 Contract NNK06MA70C 31 July 2010

Executive Summary

This report summarizes the Applied Meteorology Unit (AMU) activities for the third quarter of Fiscal Year 2010 (April - June 2010). A detailed project schedule is included in the Appendix.

Task Peak Wind Tool for User Launch Commit Criteria (LCC)

Goal Update the Phase I cool season climatologies and distributions of 5-minute average and peak wind speeds. The peak winds are an important forecast element for the Expendable Launch Vehicle and Space Shuttle programs. The 45th Weather Squadron (45 WS) and the Spaceflight Meteorology Group (SMG) indicate that peak winds are a challenging parameter to forecast. The Phase I climatologies and distributions helped alleviate this forecast difficulty. Updating the statistics with more data and new time stratifications will make them more robust and useful to operations.

Milestones The final report was completed, distributed, and uploaded to the AMU website.

Discussion The final report was completed after making modifications suggested in the internal AMU and external customer reviews. It was distributed and posted on the AMU website after receiving approval from NASA.

Task Objective Lightning Probability Tool, Phase III

Goal Update the lightning probability forecast equations used in 45 WS operations with new data and new stratification based on the progression of the lightning season. Update the Microsoft Excel and Meteorological Interactive Data Display System (MIDDS) graphical user interfaces (GUIs) with the new equations. The new data and stratifications are likely to improve the performance of the equations used to make the daily lightning probability forecasts for operations on Kennedy Space Center (KSC) and Cape Canaveral Air Force Station (CCAFS).

Milestones Determined the start dates for each of the lightning sub-seasons during the months May–October.

Discussion Three methods were used to determine the start dates for the ramp-up and lightning sub-seasons in each year. One method was able to identify the beginning of ramp-up season, but none of the methods could identify the beginning of the lightning sub-season with accuracy. Therefore, the beginning of each sub-season was determined by the 20-year daily lightning climatology.

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Executive Summary, *continued*

Task: Peak Wind Tool for General Forecasting, Phase II

Goal Update the tool used by the 45 WS to forecast the peak wind speed for the day on KSC/CCAFS during the cool season months October-April. The tool forecasts the peak wind speed for the day, the associated average speed, and provides the probability of issuing wind warnings in the KSC/CCAFS area using observational data available for the 45 WS morning weather briefing. The period of record will be expanded to increase the size of the data set used to create the forecast equations, new predictors will be evaluated, and the performance of the Phase I and Phase II tools will be compared to determine if the updates improved the forecast.

Milestones Completed the development and testing of the MIDDS Peak Wind Tool.

Discussion Feedback from the 45 WS resulted in improvements to the MIDDS Peak Wind Tool. The tool was updated again when the 45 WS gained access to higher resolution point model data, then it was delivered to the 45 WS for operational use.

Task: Upgrade Summer Severe Weather Tool in MIDDS

Goal Upgrade the Severe Weather Tool by adding weather observations from the years 2004-2009, re-analyzing the data to determine the important parameters, and update the tool with the new information. The likelihood of severe weather occurrence for the day is included in the morning weather briefing. 45 WS forecasters use the Severe Weather Tool, developed by the AMU, to assist in making this forecast. Updating the database and MIDDS GUI will likely improve the performance of the tool and will increase forecaster confidence in the output.

Milestones Completed and distributed the final report.

Discussion The final report was modified based on comments from internal AMU and external customer reviews, then distributed to customers. The report is now available on the AMU website.

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Task — ADAS Update and Maintainability

Goal Acquire the latest version of the Advanced Regional Prediction System (ARPS) Data Analysis System (ADAS) for the local data integration system (LDIS) at the National Weather Service in Melbourne, FL and SMG, and update the AMU-developed shell scripts that were written to govern the LDIS so that it can be easily maintained. In addition, the AMU will update the previously developed ADAS GUI.

Milestones Finished updating the existing ADAS GUI. Split Meteorological Assimilation Data Ingest System (MADIS) mesonet data into individual data source files and rewrote them into a format ingestible by ADAS. Began optimizing error variances.

Discussion The GUI update was completed with the creation of a Perl script that extracts information about the observations analyzed by ADAS for the ADAS GUI. To improve the ADAS analyses, error statistics are being optimized to fit the new datasets being assimilated by ADAS.

Task — Verify MesoNAM Performance

Goal Verify the performance of the 12-km North American Mesoscale model (MesoNAM) forecasts for CCAFS and KSC. Verification will be accomplished by an objective statistical analysis consisting of comparing the MesoNAM forecast winds, temperature and moisture, as well as the changes in these parameters over time, to the observed values at customer selected KSC/CCAFS mesonet wind towers. The objective analysis will give the forecasters knowledge of the model's strength and weaknesses, resulting in improved forecasts for operations.

Milestones The 45 WS started using the tool operationally. Added 10 months of new MesoNAM forecasts and tower observations to the data set and recalculated statistics. Added observations from additional sensor heights on Towers 2, 6, 108 and 110.

Discussion Recalculated all statistics from the dataset including the additional 10 months of model forecasts and tower observations as well as the additional sensor heights on three towers. The additional data did not improve the "noisy" statistics in situations when the number of events, such as in warm season offshore flow, was low.

Special Notice to Readers

Applied Meteorology Unit (AMU) Quarterly Reports are now available on the Wide World Web (www) at http://science.ksc.nasa.gov/amu/.

The AMU Quarterly Reports are also available in electronic format via email. If you would like to be added to the email distribution list, please contact Ms. Winifred Crawford (321-853-8130, crawford.winnie@ensco.com). If your mailing information changes or if you would like to be removed from the distribution list, please notify Ms. Crawford or Dr. Francis Merceret (321-867-0818, Francis.J.Merceret@nasa.gov).

Background

The AMU has been in operation since September 1991. Tasking is determined annually with reviews at least semi-annually. The progress being made in each task is discussed in this report with the primary AMU point of contact reflected at the end of each task summary.

AMU ACCOMPLISHMENTS DURING THE PAST QUARTER

SHORT-TERM FORECAST IMPROVEMENT

Peak Wind Tool for User LCC (Ms. Crawford)

The peak winds are an important forecast element for the Expendable Launch Vehicle and Space Shuttle programs. As defined in the Launch Commit Criteria (LCC) and Shuttle Flight Rules (FR), each vehicle has peak wind thresholds that cannot be exceeded in order to ensure safe launch and landing operations. The 45th Weather Squadron (45 WS) and the Spaceflight Meteorology Group (SMG) indicate that peak winds are a challenging parameter to forecast, particularly in the cool season. To alleviate some of the difficulty in making this forecast, the AMU calculated cool season climatologies and distributions of 5-minute average and peak winds in Phase I (Lambert 2002). The 45 WS requested that the AMU update these statistics with more data collected over the last five years, using new time-period stratifications, and a new parametric distribution. These modifications will likely make the statistics more robust and useful to operations. They also requested a graphical user interface (GUI) similar to that developed in Phase II (Lambert 2003) to display the wind speed climatologies and probabilities of meeting or exceeding certain peak speeds based on the average speed.

Final Report

Ms. Crawford modified the report based on recommendations received from the internal AMU and external customer reviews. She distributed the report to customers and, after receiving NASA approval, posted the report on the AMU website.

Contact Ms Crawford at 321-853-8130 or crawford.winnie@ensco.com for more information.

Objective Lightning Probability Tool, Phase III (Ms. Crawford)

The 45 WS includes the probability of lightning occurrence in their daily morning briefings. This information is used by forecasters when evaluating LCC and FR, and planning for daily ground operations on Kennedy Space Center (KSC) and Cape Canaveral Air Force Station (CCAFS). In Phase I, the AMU developed a set of equations that calculate the probability of lightning occurrence for the day (Lambert and Wheeler 2005) and a GUI to display the output. These equations outperformed several forecast methods used in operations. The GUI allowed forecasters to interface with the equations by entering predictor values to output a probability of lightning occurrence. In Phase II (Lambert 2007), two warm seasons were added to the period of record (POR), the equations redeveloped with the new data, and the GUI transitioned to the Meteorological Interactive Data Display System (MIDDS). The MIDDS GUI retrieves the required predictor values automatically, reducing the possibility of human error. In this phase, three warm seasons (May–September) will be added to the POR, increasing it to 20 years (1989–2008), and data for October will be included. The goal of this phase is to create equations based on the progression of the lightning season instead of creating an equation for each month. These equations will capture the physical attributes that contribute to thunderstorm formation more so than a date on a calendar.

Determine Lightning Season Dates

The goal of this portion of the task was to create an objective method to determine the beginning of each lightning sub-season in each year in order to stratify the data properly for equation development. Ms. Crawford imported the stability parameter files from S-PLUS to Excel and created Pivot Charts to assist in determining which parameters could be used to determine the lightning season dates in each year. She began by analyzing the 20-year means of the parameters, and found that the Lifted Index (LI), K-Index (KI), Thompson Index (TI), precipitable water (PW), and average relative humidity (RH) showed the most promise as sub-season discriminators. Figure 1 shows the daily 20-year mean values for these parameters. All but LI begin at relatively low values, increase (ramp-up) through days 45–50 (14–19 June), plateau through days 145–150 (22–27 September), and then decrease (ramp-down) through day 184 (31 October). The LI had opposite and less pronounced trends. The increase in KI, TI, PW and RH as well as the decrease in LI are consistent with an increase in lightning probability. The trends at the beginning of the warm season closely match the KSC/CCAFS daily lightning climatology, but the decrease for all parameters is approximately a month later than for the daily lightning climatology (Figure 2).

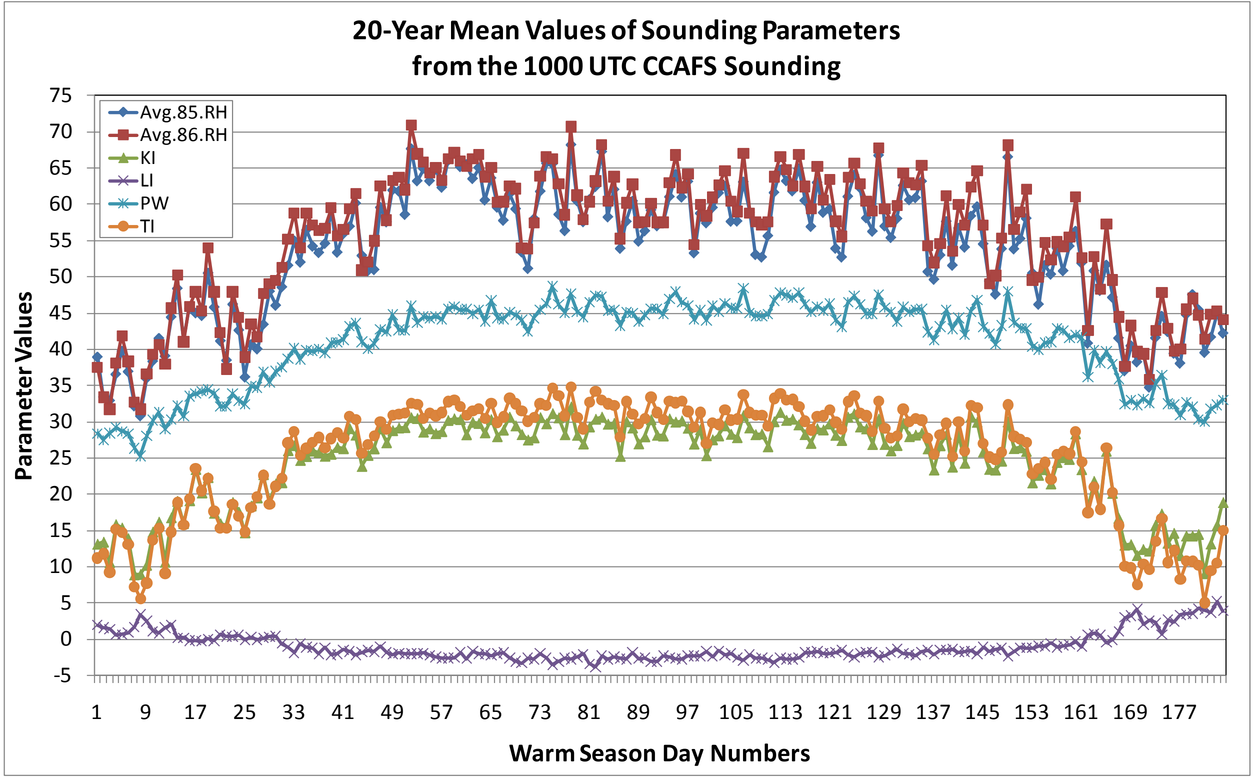

Figure 1. The 20-year daily mean values of the average RH in the 825–525 mb layer (Avg.85.RH), average RH in the 800–600 mb layer (Avg.86.RH), KI, LI, PW, and TI. The magnitude of the values is on the vertical axis, and the warm season day numbers, beginning with 1=1 May and ending with 184=31 October, are along the horizontal axis. RH values are in percent and PW values are in mm.

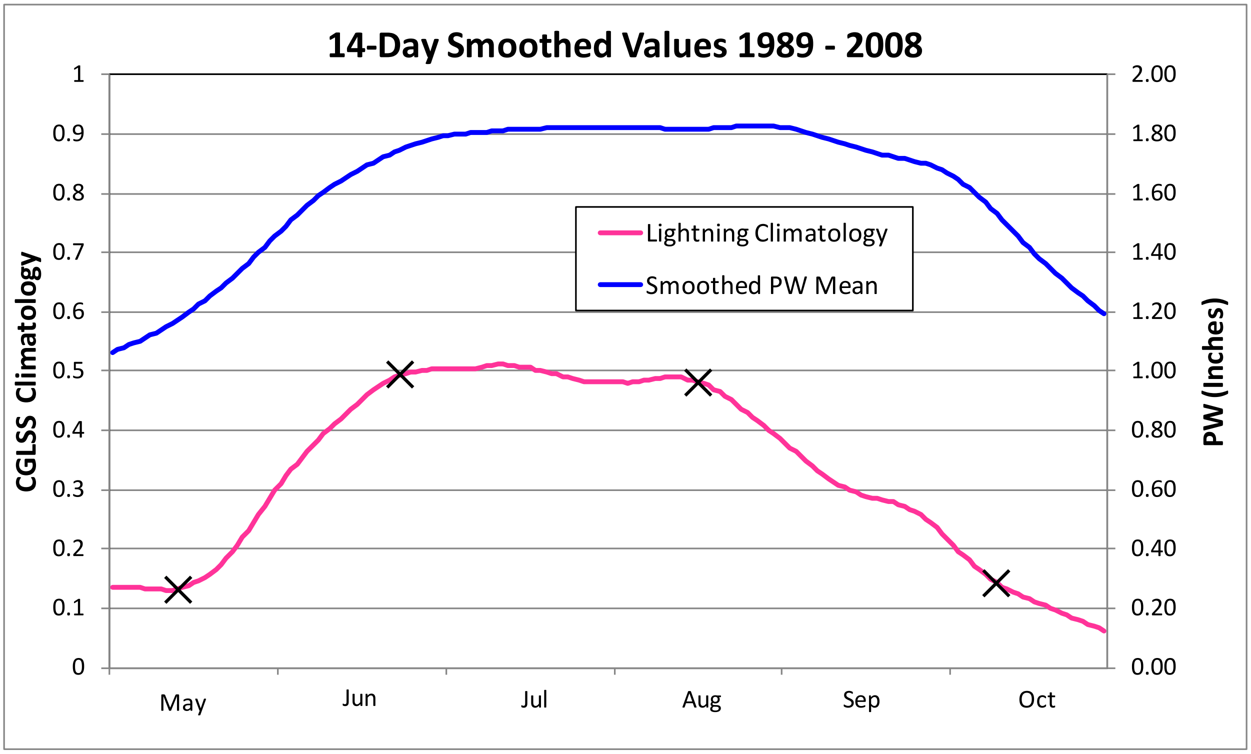

Figure 2. The smoothed daily lighting climatology (magenta) and mean PW (blue). The daily climatology values are on the left vertical axis and the PW values are on the right vertical axis. The black X's indicate the start dates of the sub-seasons.

Ms. Crawford then analyzed the standard deviations of the mean values in Figure 1. During the ramp-up at the beginning of the warm season, the standard deviations of most parameters were only slightly less than, if not equal to, their associated mean. This indicated too much variance in the parameters to make good indicators of lightning sub-season dates. However, the PW standard deviations were 1/3 to 1/4 of their mean values. This makes PW a better candidate for indicating lightning sub-season start dates.

Ms. Crawford tested three statistical methods to determine which could choose lightning sub-season start dates similar to the wet season dates found by the National Weather Service in Melbourne, FL (NWS MLB):

- Number of occurrences above a PW threshold value from the beginning of the warm season,
- One-Sample t Test on the running PW mean, and
- Multiple discriminant analysis.

The NWS MLB wet season start dates and the study describing how they were determined are at http://www.srh.noaa.gov/mlb/?n=wetdryseason. These dates were used as ground truth in determining the ability of the three techniques to identify the start of the lightning sub-season. To be successful, the technique had to choose a date within one week (seven days) before or after the NWS MLB date in each year.

Chronological Check

The first method was a simple chronological check of the number of occurrences of a threshold PW value. Since the daily PW values in any individual year can be highly variable from day to day, especially early in the season, the first occurrence of a threshold value is not likely a good indicator of the start of a sub-season. At the beginning of the ramp-up sub-season in the daily lightning climatology, the average PW value is 1.2 in (30.5 mm). At the beginning of the lightning sub-season, it is 1.75 in (44.5 mm). Ms. Crawford created an algorithm that began at Day 1 (1 May) and checked the daily PW values in chronological order. She found that the ramp-up sub-season was defined reasonably well after the third occurrence of PW ≥ 1.2 in. There is no equivalent ground truth for this date, only the daily lightning climatology (Figure 2). The average start-day for the ramp-up sub-season using this technique was 10 May, only three days earlier than the apparent start-day of 13 May from the daily climatology (left-most black X in Figure 2). The same algorithm, beginning from the ramp-up start date instead of 1 May and using a threshold of 1.75 in, was able to choose a lightning sub-season start date within one week of the NWS MLB start dates in only 8 of the 20 years. Ms. Crawford varied the required number of occurrences of PW ≥ 1.75 in from two to five and the threshold value from 1.7–1.8 in, but no combination was successful.

One-Sample t Test

The one-sample t test is used to determine if an observed sample mean was drawn from a population with a predetermined mean. The t value is given by the equation

$$t = \frac{\bar{x} - \mu_0}{[V\hat{a}r(\bar{x})]^{\frac{1}{2}}},$$

where $\bar{x}$ is the running PW mean, μ_0 is the predetermined PW mean threshold defining the start of the lightning sub-season, and $V\hat{a}r(\bar{x})$ is the sample estimate of the variance of the sample mean defined as

$$V\hat{a}r(\bar{x}) = s^2/n,$$

where s^2 is the sample variance and n is the sample size (Wilks 2006). The null hypothesis is that the mean of the population from which $\bar{x}$ is drawn is μ_0, and the alternative hypothesis is that the mean is not μ_0.

Since the chronological check established the beginning of the ramp-up sub-season well, Ms. Crawford used this technique to choose the beginning dates of the lightning sub-season. She began testing the technique with μ_0=1.75 in and n = 4 (days). The first day checked in each year was the day after the ramp-up start. The PW from this day plus the three days previous were used to calculate the running mean. If the t value indicated that the running mean was likely ≥ μ_0, the fourth day in the running mean was considered the start of the lightning sub-season. The results in comparison with the NWS MLB start dates were worse than the chronological check. Only 6 dates out of 20 were within one week of the NWS MLB dates. Ms. Crawford varied the number of days in the running mean (n) from 3 to 8, and μ_0 from 1.7 to 1.8 in, with little success.

Multiple Discriminant Analysis

Multiple discriminant analysis (MDA) is a statistical method used to discern between groups in a dataset. In this case, it would be tuned to discern between the ramp-up and lightning sub-seasons. The steps in developing an MDA equation are given in Wilks (2006). Ms. Crawford used an equivalent function in the S-PLUS® software package (Insightful Corporation 2007) to develop and test the MDA.

Ms. Crawford began by creating a dataset to be used in developing the MDA function. This dataset contained the year, month, day, PW, KI, LI, and TI for all dates in the POR, and a new parameter that identified whether the day was in the ramp-up or lightning sub-season. Ms. Crawford used the NWS MLB wet-season start dates as the beginning point for the lightning sub-season in each year. Ms. Crawford began by using data from the odd years as a test. She developed the MDA with the odd-year data, then tested it on the same data. It is a good test of a predictive function to use the data from which it was developed. If it does not perform well with the development data, it will not perform well with other data.

Ms. Crawford first used PW alone as the discriminating variable to develop the MDA, then added TI when the results with only PW were not acceptable. She chose TI since it is the difference between KI and LI and, therefore, has attributes of both. The results improved by adding TI, but the procedure still picked dates within one week of the NWS MLB dates in 5 of the 10 years. In the other years, the dates chosen were two to three weeks before or after the NWS MLB dates. Figure 3 shows the PW and TI values for the ramp-up (blue X) and lightning (red box) sub-seasons. Note the large overlap of sub-seasons between PW=20–35 and TI=0–35.

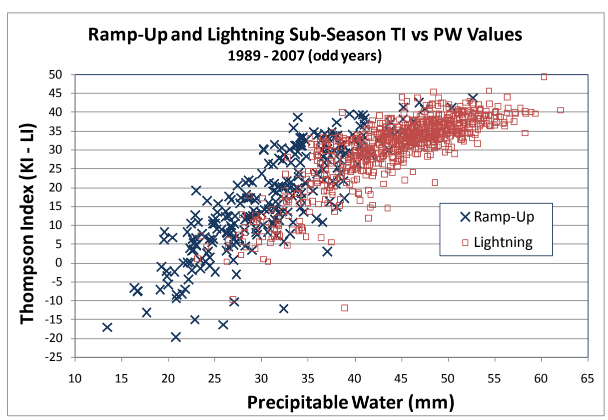

Figure 3. Scatter diagram of TI vs PW values for the ramp-up (blue Xs) and lightning (red boxes) sub-seasons for the odd years in 1989–2007.

Daily Climatology

While not successful, the MDA method showed promise as a sub-season discriminator and should be explored further. However, due to time constraints on the task, Ms. Crawford and Mr. Roeder agreed to define the sub-season dates using the daily lightning climatology. The black Xs in Figure 2 show the beginning of each sub-season:

- Ramp-up begins 13 May when the climatological lightning frequency starts to increase,
- Lightning begins 23 June when the PW climatology reaches 1.75 in,
- Ramp-down begins 17 August when the large decrease in climatological lightning frequency begins, and
- Post begins 12 October when the rate of decrease lessens and becomes steady.

Ms. Crawford stratified the data in each year by these dates and created flow regime lightning climatologies for each sub-season. She entered the values in tables and delivered them to Mr. Roeder for review.

Contact Ms Crawford at 321-853-8130 or crawford.winnie@ensco.com for more information.

Peak Wind Tool for General Forecasting, Phase II (Mr. Barrett)

The expected peak wind speed for the day is an important element in the daily morning forecast for ground and space launch operations at KSC and CCAFS. The 45 WS must issue forecast advisories for KSC/CCAFS when they expect peak gusts to exceed 25, 35, and 50 kt thresholds at any level from the surface to 300 ft. In Phase I of this task (Barrett and Short 2008), the AMU developed a tool to help forecast the highest peak non-convective wind speed, the timing of the peak speed, and the average wind speed at the time of the peak wind from the surface to 300 ft on KSC/CCAFS for the cool season (October – April). For Phase II, the 45 WS requested that additional observations be used in the creation of the forecast equations by expanding the POR. In Phase I, the data set included observations from October 2002 to February 2007. In Phase II, observations from March and April 2007 and October 2007 to April 2008 will be added. To increase the size of the data set even further, the AMU will consider adding data prior to October 2002. Additional predictors will be evaluated, including wind speeds between 500 ft and 3000 ft, static stability classification, Bulk Richardson Number, mixing depth, vertical wind shear, inversion strength and depth, wind direction, synoptic weather pattern and precipitation. Using an independent data set, the AMU will compare the performance of the Phase I and II tools for peak wind speed forecasts. The final tool will be a user-friendly GUI to output the forecast values.

As in Phase I, the tool will be delivered as a Microsoft Excel GUI. In addition, at the request of the 45 WS, the AMU will make the tool available in MIDDS, their main weather display system. This will allow the tool to ingest observational and model data automatically and produce 5-day forecasts quickly.

Development of the MIDDS Tool

The previous AMU Quarterly Report (Q2 FY10) described the initial development of the MIDDS tool. After Mr. Barrett completed writing the source code using the Tool Command Language/Tool Kit (Tcl/Tk) programming language, forecasters from the 45 WS evaluated the tool. Based on the forecasters' feedback, Mr. Barrett made four modifications:

- Added a function to print out the tool's forecasts,
- Modified the GUI to automatically scroll down to the displayed forecasts,
- Extended the forecasts from five days to seven days, and
- Added forecasts for the daily average wind speed, which is the 24-hour average wind speed from 30 ft to 60 ft above ground level.

Model point data are not available on the 45 WS MIDDS. Therefore, they were given access to these data from a MIDDS server at Johnson Space Center. The MIDDS point model data have a higher vertical resolution compared to MIDDS gridded model data. For example, the vertical levels in the gridded model data are primarily confined to the NWS mandatory sounding levels (surface, 1000 mb, 925 mb, 850 mb, etc.). On the other hand, the point model data include all of the model's vertical levels. The North American Mesoscale (NAM) model contains 60 vertical levels from the surface to 14.5 mb, while the Global Forecast System (GFS) model contains 64 vertical levels from the surface to 0.29 mb. The point model data also have a higher temporal resolution. Gridded model data forecasts from the GFS and NAM are available every six hours, while point model data forecasts are available every three hours from the GFS and every hour from the NAM. In order to increase the accuracy of the tool, Mr. Barrett updated the tool to use the higher resolution point model data. The tool's source code and installation instructions were then delivered to the 45 WS for operational use.

Using the MIDDS Tool

To use the tool, the forecaster first opens it from the MIDDS Weather Menu. The tool reads in NAM and GFS data from the latest 0000 UTC and 1200 UTC model runs. After the tool has finished reading the model data, it displays the message "Initialization Complete". The user selects a model name (GFS or NAM) and model run (00 UTC or 12 UTC) and then selects the "Calculate Peak Wind" button. The tool calculates and displays the forecasts for the peak wind speed, 5-minute wind speed at the time of the peak wind, daily average wind speed, and the probability the peak wind will meet or exceed 25 kt, 35 kt and 50 kt. Except for the daily average wind speed, separate forecasts are made for days with and without precipitation across KSC and CCAFS. The NAM forecasts go from Day-1 to Day-3, while the GFS forecasts go from Day-1 to Day-7. Figure 4 shows the tool's forecasts from the model runs on 7 July 2010. The forecaster has the option of printing out the displayed forecasts by selecting the "Print Display" button. The user closes the tool by selecting the "Exit Tool" button.

Contact Mr. Barrett at 321-853-8205 or barrett.joe@ensco.com for more information.

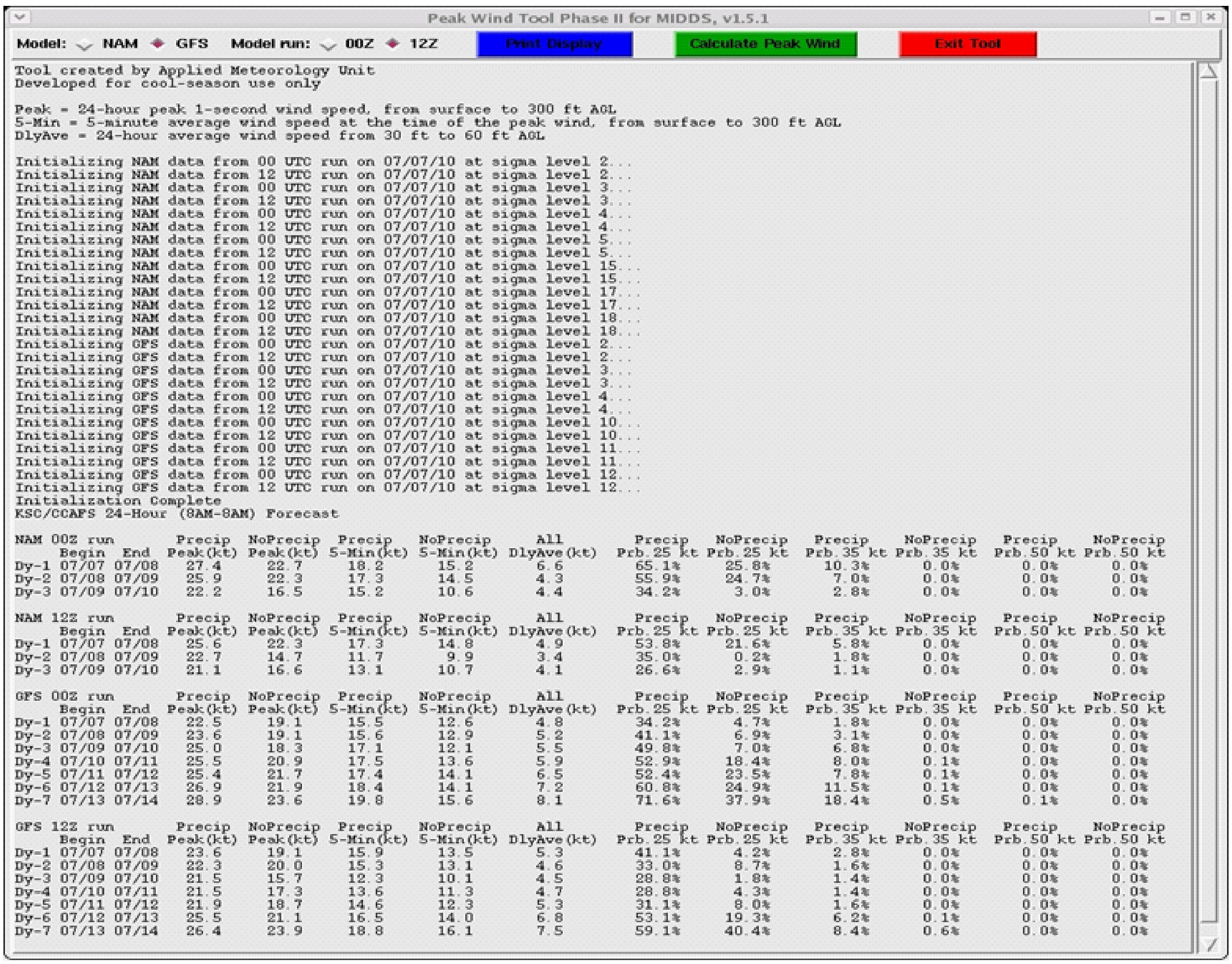

Figure 4. MIDDS Peak Wind Tool showing forecasts from the 7 July 2010 model runs. Forecasts for days with precipitation have the header "Precip", while days without precipitation have the header "NoPrecip". The header "All" includes days with and without precipitation.

INSTRUMENTATION AND MEASUREMENT

Upgrade Summer Severe Weather Tool in MIDDS (Mr. Wheeler)

The 45 WS Commander's morning weather briefing includes an assessment of the likelihood of local convective severe weather for the day in order to enhance protection of personnel and material assets of the 45th Space Wing, CCAFS, and KSC. Forecasting the occurrence and timing of severe weather is challenging for 45 WS operational personnel. In Phase I, the AMU analyzed stability parameters and synoptic patterns from Central-Florida severe weather days in the years 1989-2003 to determine which were important to severe weather development. The AMU then created an objective Hyper-Text Markup Language (HTML) tool using the important predictors to assist forecasters in determining the probability of issuing severe weather watches and warnings for the day. Work in a follow-on task resulted in a MIDDS-based GUI to replace the HTML tool. This new tool retrieved stability parameters and other information from MIDDS automatically, minimizing the forecaster's interaction with the tool. The result was a reduction in the possibility of human error and increased efficiency, giving forecasters more confidence in the tool output and allowing them more time to do other duties. For this task, the 45 WS requested the AMU upgrade the severe weather database by adding weather observations from the years 2004-2009, re-analyzing the data to determine the important parameters, make adjustments to the index weights depending on the analysis results, and update the MIDDS GUI. Updating the database and MIDDS GUI will likely improve the tool's performance and increase forecaster confidence in the output.

Final Report

Mr. Wheeler wrote the final report and submitted it for internal AMU and external customer reviews. He modified the report based on recommendations from those reviews. Mr. Wheeler then distributed the report to the AMU customers. The report was uploaded to the AMU website after receiving approval from NASA.

For more information contact Mr. Wheeler at wheeler.mark@ensco.com or 321-853-8105.

MESOSCALE MODELING

ADAS Update and Maintainability (Dr. Watson)

Both NWS MLB and SMG have used a local data integration system (LDIS) since 2000 and routinely benefit from the frequent analyses. The LDIS uses the Advanced Regional Prediction System (ARPS) Data Analysis System (ADAS) package as its core, which integrates a wide variety of national and local-scale observational data. The LDIS provides accurate depictions of the current local environment that help with short-term hazardous weather applications and aid in initializing the local Weather Research and Forecasting (WRF) model. However, over the years the LDIS has become problematic to maintain since it depends on AMU-developed shell scripts that were written for an earlier version of the ADAS software. The goal of this task is to update the NWS MLB/SMG LDIS with the latest version of ADAS and upgrade and modify the AMU-developed shell scripts written to govern the system. In addition, the previously developed ADAS GUI will be updated.

Modification of ADAS GUI

One of the goals of this task is to update the previously developed ADAS GUI. The original GUI was developed by the AMU in 2004 to allow forecasters to quickly and easily interact with ADAS to maintain or improve the integrity of each 15-minute analysis cycle. The intent was to offer forecasters the means to monitor and manage the observational data streams ingested by ADAS without having prior ADAS expertise. The GUI was created using the Tcl/Tk programming language.

Dr. Watson finished updating the ADAS GUI software. The GUI is passed information about the data ingested by ADAS from the output of the ADAS analysis. She finished re-writing the Perl script that extracts the numbers of each observation type analyzed by ADAS from the ADAS output file. This script takes into account the new Meteorological Assimilation Data Ingest System (MADIS) data now assimilated by ADAS.

Optimize Error Statistics

The quality of the ADAS analyses is affected in part by user-configurable error parameters. Large (small) errors assigned to a data source result in a smaller (larger) influence of that data on the nearby grid points. The previously written shell scripts used a small number of error statistics optimized specifically for the previously assimilated mesonet data. The new Perl scripts assimilate a much larger set of MADIS mesonet data that come from multiple data sources. To improve the ADAS analyses, Dr. Watson began modifying the old error statistics to fit the new datasets.

She first split the MADIS mesonet data available in NetCDF format into individual data source files and rewrote them into a format ingestible by ADAS. After to speaking with Mr. Peter Blottman at NWS MLB, Dr. Watson learned that NWS MLB already receives MADIS mesonet data separated by data source in comma-separated value (CSV) format. NWS MLB prefers to use the data available in CSV format over NetCDF since it arrives in a more timely fashion. Therefore, Dr. Watson wrote a Perl script to process the mesonet data in CSV format and rewrite it into a format ingestible by ADAS.

The next step is to optimize the error statistics for the MADIS mesonet data to improve the ADAS analyses. To do this, Dr. Watson began examining a set of control error variances assigned to the observations while varying the error parameters. She did this to determine how much the background field is modified by the observations with a different set of error parameters.

For more information contact Dr. Watson at watson.leela@ensco.com or 321-853-8264.

Verify MesoNAM Performance (Dr. Bauman)

The 45 WS Launch Weather Officers (LWOs) use the 12-km NAM (MesoNAM) text and graphical product forecasts extensively to support launch weather operations. However, the actual performance of the model has not been measured objectively. In order to have tangible evidence of model performance, the 45 WS tasked the AMU to conduct a detailed statistical analysis of model output compared to observed values. The model products are provided to the 45 WS by ACTA, Inc. and include hourly forecasts from 0 to 84 hours based on model initialization times of 00, 06, 12 and 18 UTC. The objective analysis will compare the MesoNAM forecast winds, temperature and dew point, as well as the changes in these parameters over time, to the observed values from the sensors in the KSC/CCAFS wind tower network shown in Table 1. Objective statistics will give the forecasters knowledge of the model's strength and weaknesses, which will result in improved forecasts for operations.

Table 1. Towers, launch activities and sensor heights at KSC and CCAFS that will be used in the objective analysis to verify the MesoNAM forecasts. Additional sensor heights were added to the data set this quarter as shown in the right hand column.

Tower Number	***Supported Activity and Facility***	***Original Sensor Heights***	***Additional Sensor Heights***
0002	Delta II (LC-17)	6 ft, 54 ft, 90 ft	145 ft, 204 ft
0006	Delta IV (LC-37)/ Falcon 9 (LC-40)	54 ft	6 ft, 12 ft, 162 ft, 204 ft
0108	Delta IV (LC-40)/Falcon 9 (LC-40)	54 ft	6 ft, 12 ft
0110	Atlas V (LC-41)/Falcon 9 (LC-40)	54 ft, 162 ft, 204 ft	6 ft, 12 ft
0041	Atlas V (LC-41)	230 ft	
393 / 394	Shuttle/Constellation (LC-39A)	60 ft	
397 / 398	Shuttle/Constellation (LC-39B)	60 ft	
511 / 512 / 513	Shuttle Landing Facility	6 ft, 30 ft	

Operational Use of the Tool

The LWO's evaluated the tool after Dr. Bauman delivered it to the 45 WS on 22 March. They did not request any changes or updates and began using the tool operationally at the end of April. It was used to support launch operations for Atlas 5 (22 April), STS-132 (14 May), Delta 4 (21, 24 and 27 May) and Falcon 9 (4 June). The tool will be updated with additional data and delivered to the 45 WS in Q4 FY10.

Noisy Statistics

As discussed in the previous AMU Quarterly Report (Q2 FY10), two years worth of warm season data stratified by onshore and offshore flow produced "noisy statistics" due to the lack of observations, especially with the offshore stratification during the summer months. Therefore, additional observations from September 2006 and May 2009-January 2010 were added to the data set and the statistics were recalculated. Dr. Bauman added the MesoNAM forecasts for these time periods that he acquired from ACTA, Inc.

Dr. Bauman assessed random samples of objective analysis charts and determined the additional data did not make a significant difference in the statistics – especially in situations when the number of events was low to begin with, such as offshore flow during the warm season months. A comparison from Towers 393 and 394 at LC-39A is shown in Figures 5 and 6. Figure 5, published in the previous AMU Quarterly Report (Q2 FY10), shows an example of the noisiness in the T bias for Towers 393 and 394 at 60 ft prior to adding the new data. Figure 6 shows an example of the noisiness in T bias for Towers 393 and 394 at 60 ft after adding the new data. There were 444 observations added to the original data set which increased the number of observations by 12.4%. A comparison of these figures shows little difference in the T bias before and after the additional data was added.

Dr For more information contact Dr. Bauman at bauman.bill@ensco.com or 321-853-8202.

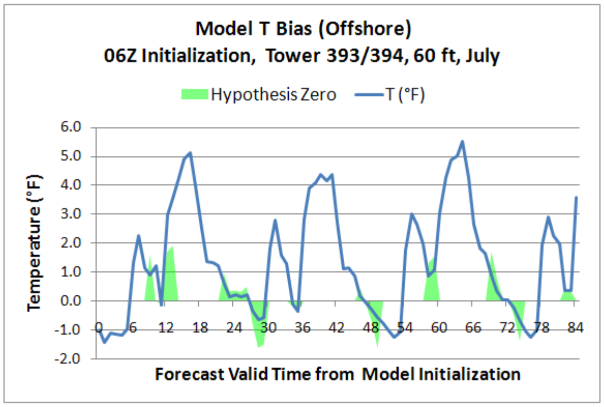

Figure 5. The verification chart showing model bias of T from a 0600 UTC model initialization using observations from Towers 393 and 394 at LC-39A at 60 ft for July before adding the new data.

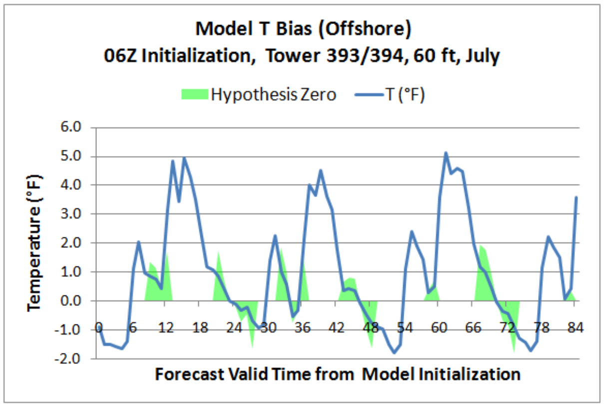

Figure 6. As in Figure 5, except after adding the new data.

AMU CHIEF'S TECHNICAL ACTIVITIES (Dr. Merceret)

Dr. Merceret completed the Lightning Launch Commit Criteria and Lightning Advisory Panel (LAP) History. He submitted it to a technical editor to be formatted for formal publication as a NASA Special Paper. This document will be cited as "Merceret, F.J. and J.C. Willett, Editors, 2010: A History of the Lightning Launch Commit Criteria and the Lightning Advisory Panel for America's Space Program, NASA/SP-2010-216283". Dr. Merceret also began work on his contributions to the companion Rationale document being edited by Dr. John Willett of the LAP, including an appendix on radar measurement error sources.

Dr. Merceret prepared and presented numerous briefings containing recommendations for the future of the KSC/CCAFS weather infrastructure, including the AMU, in the post-Shuttle era. These briefings were submitted to a variety of panels and boards that prepared integrated KSC decision packages for submission against probable or possible post-Shuttle budget line items. These briefings are now being presented to KSC senior management.

Dr. Merceret participated in a three day workshop titled "Resilience and Adaption to Climate Change Risks Workshop: Kennedy Space Center and the Space Coast" held in Cocoa Beach and sponsored by NASA Headquarters.

AMU OPERATIONS

Conferences, Meetings, and Training

Ms. Crawford attended the 21st International Lightning Detection and 3rd International Lightning Meteorology conferences in Orlando, FL from 19 to 22 April.

Launch Support

- Dr. Bauman and Ms. Wilson supported the successful launch of STS-131 on 5 April.
- Mr. Wheeler and Dr. Merceret supported the successful launch of the Atlas 5 on 22 April.
- Mr. Barrett and Dr. Merceret supported the successful launch of STS-132 on 14 May.
- Mr. Barrett and Dr. Watson supported the launch attempts of Delta IV with Dr. Merceret on 21 May and 24 May, respectively, and Dr. Bauman and Ms. Wilson supported the successful launch on 27 May.
- Ms. Crawford and Dr. Merceret supported the inaugural launch of Falcon 9 on 4 June.

AMU Visitors

For the sixth consecutive summer, Dr. James Koermer and students from the Meteorology Program at Plymouth State University (PSU) have come to work at CCAFS on convective storm research supported through the NASA Space Grant Program. Most of their effort has focused on studying summertime convective winds, for which 45 WS forecasters issue the second highest number of warnings, only exceeded by those for lightning. In the process, the PSU team has developed a comprehensive climatology of these events using the KSC/CCAFS tower network, NWS MLB WSR-88D, CCAFS soundings, and other meteorological data for the region.

Ms. Katie Laro, an undergraduate meteorology major from PSU, and Dr. Koermer are updating and expanding the climatology through 2009, so that it now covers the period of 1995-2009. Many graphics have been updated to reflect the additional year. The AMU has provided some data and assistance to the PSU contingent over the years including daily flow regime determinations. As an example, Figure 7 shows a climatological summary of convective events stratified by flow regime and month.

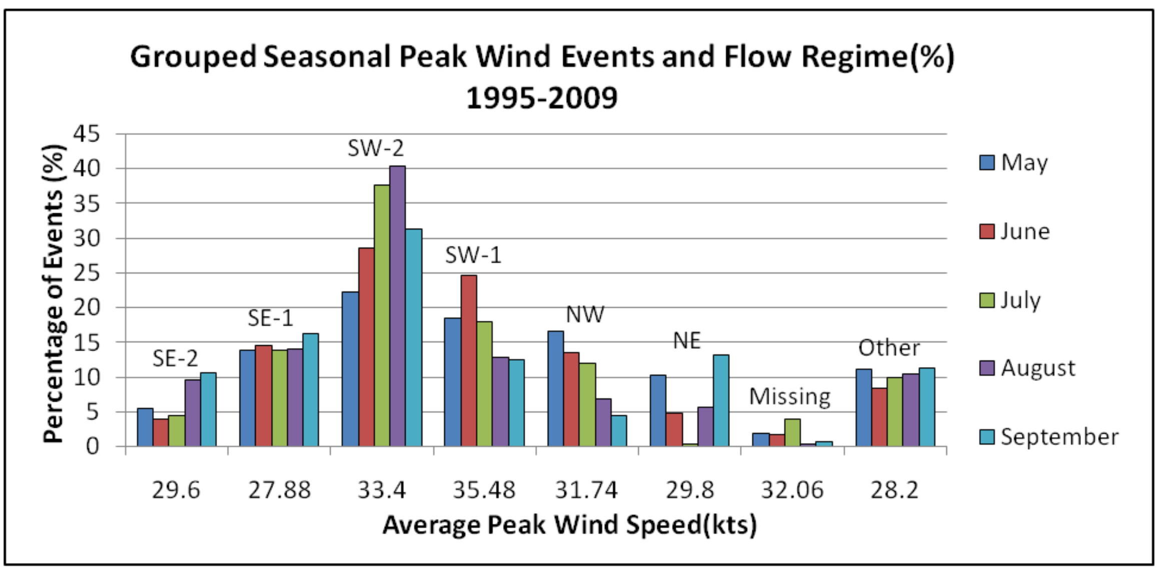

Figure 7. This bar chart shows the percentage of convective wind events per flow regime in each month, with the bars grouped by flow regime. The average peak convective wind speed for each flow regime group is given along the horizontal axis.

They have also started building a database for 2010, which can act as an independent dataset for verification of the Classification And Regression Tree (CART) prediction model techniques developed last summer. An extensive online summary of PSU convective wind research for KSC/CCAFS and results can be found at http://vortex.plymouth.edu/conv_winds.

Mr. Alexander Jacques, a PSU graduate student, and Dr. Koermer are also working on a lightning project involving the United States Precision Lightning Network™ (USPLN™), which is a large-scale lightning detection network co-owned by WSI Inc. and TOA Systems, Inc. Plymouth State University was asked by WSI to conduct a regional verification study of USPLN performance over an extended period of time. Past lightning verification methods included spotty fixed tower analyses/strike reports, and comparisons to other networks. The Cloud-to-Ground Lightning Surveillance System (CGLSS) is a local lightning detection network based at KSC/CCAFS and believed to be the most accurate system in the world. The present CGLSS-II (renamed from CGLSS in 2008 after upgrades) performance metrics include a 98% detection efficiency and 95% confidence location accuracy less than 600 m. These excellent performance metrics validate CGLSS-II as the primary verification tool used for this project. Its main weakness is that it can miss detecting some very strong current strokes because of the close proximity of the sensors, whereas the more widely spaced sensors of USPLN may better detection efficiency for these few very strong current events. Preliminary results have supported these observations. TOA will provide some additional data from a network of new sensors in Florida for evaluation, which they believe will provide more accurate data.

REFERENCES

Barrett, J. H. and D. A. Short, 2008: Peak Wind Tool for General Forecasting Final Report. NASA Contractor Report CR-2008-214743, Kennedy Space Center, FL, 59 pp. [Available from ENSCO, Inc., 1980 N. Atlantic Ave., Suite 830, Cocoa Beach, FL, 32931 and http://science.ksc.nasa.gov/amu/final-stfi.html] http://science.ksc.nasa.gov/amu/final-mm.html]

Insightful Corporation, 2007: *S-PLUS 8 Guide to Statistics, Volume 2*, Insightful Corp., Seattle, WA, 576 pp.

Lambert, W., 2002: Statistical Short-Range Guidance for Peak Wind Speed Forecasts on Kennedy Space Center/Cape Canaveral Air Force Station: Phase I Results. NASA Contractor Report CR-2002-211180, Kennedy Space Center, FL, 39 pp. [Available from ENSCO, Inc., 1980 N. Atlantic Ave., Suite 830, Cocoa Beach, FL 32931 and http://science.ksc.nasa.gov/amu/final-stfi.html]

Lambert, W., 2003: Extended Statistical Short-Range Guidance for Peak Wind Speed Analyses at the Shuttle Landing Facility: Phase II Results. NASA Contractor Report CR-2003-211188, Kennedy Space Center, FL, 27 pp. [Available from ENSCO, Inc., 1980 N. Atlantic Ave., Suite 830, Cocoa Beach, FL 32931 and http://science.ksc.nasa.gov/amu/final-stfi.html]

Lambert, W. and M. Wheeler, 2005: Objective lightning probability forecasting for Kennedy Space Center and Cape Canaveral Air Force Station. NASA Contractor Report CR-2005-212564, Kennedy Space Center, FL, 54 pp. [Available from ENSCO, Inc., 1980 N. Atlantic Ave., Suite 830, Cocoa Beach, FL, 32931, and http://science.ksc.nasa.gov/amu/final-stfi.html]

Lambert, W., 2007: Objective lightning probability forecasting for Kennedy Space Center and Cape Canaveral Air Force Station, Phase II. NASA Contractor Report CR-2007-214732, Kennedy Space Center, FL, 59 pp. [Available from ENSCO, Inc., 1980 N. Atlantic Ave., Suite 830, Cocoa Beach, FL, 32931, and http://science.ksc.nasa.gov/amu/final-stfi.html]

LIST OF ACRONYMS

14 WS	14th Weather Squadron
30 SW	30th Space Wing
30 WS	30th Weather Squadron
45 RMS	45th Range Management Squadron
45 OG	45th Operations Group
45 SW	45th Space Wing
45 SW/SE	45th Space Wing/Range Safety
45 WS	45th Weather Squadron
ADAS	ARPS Data Analysis System
AFSPC	Air Force Space Command
AFWA	Air Force Weather Agency
AMU	Applied Meteorology Unit
ARPS	Advanced Regional Prediction System
CCAFS	Cape Canaveral Air Force Station
CSR	Computer Sciences Raytheon
CSV	Comma Separated Value
FR	Flight Rules
FSU	Florida State University
FY	Fiscal Year
GFS	Global Forecast System
GSD	Global Systems Division
GUI	Graphical User Interface
HTML	Hyper-Text Markup Language
JSC	Johnson Space Center
KI	K Index
KSC	Kennedy Space Center
LAP	Lightning Advisory Panel
LCC	Launch Commit Criteria
LDIS	Local Data Integration System
LI	Lifted Index
LWO	Launch Weather Officer
MADIS	Meteorological Assimilation Data Ingest System
MDA	Multiple Discriminant Analysis
MesoNAM	12-km resolution NAM
MIDDS	Meteorological Interactive Data Display System
MSFC	Marshall Space Flight Center
NAM	North American Mesoscale Model
NOAA	National Oceanic and Atmospheric Administration
NWS MLB	National Weather Service in Melbourne, FL
POR	Period of Record
PW	Precipitable Water
SMC	Space and Missile Center
SMG	Spaceflight Meteorology Group
Tcl/Tk	Tool Command Language / Tool Kit
TI	Thompson Index
USAF	United States Air Force
UTC	Universal Coordinated Time
WRF	Weather Research and Forecasting Model

Appendix A

AMU Project Schedule 31 July 2010				
AMU Projects	Milestones	Scheduled Begin Date	Scheduled End Date	Notes/Status
Peak Wind Tool for User LCC Phase II	Collect and QC wind tower data for specified LCC towers, input to S-PLUS for analysis	Jul 07	Sep 07	Completed
	Stratify mean and peak winds by hour and direction, calculate statistics	Sep 07	Oct 07	Completed Nov 07
	Stratify peak speed by month and mean speed, determine parametric distribution for peak	Oct 07	Nov 07	Completed
	Create distributions for 2-hour prognostic peak probabilities, and develop GUI to show climatologies, diagnostic and 2-hour peak speed probabilities	Nov 07	Oct 08	Completed Feb 09
	Create distributions for 4-hour prognostic peak probabilities and incorporate into GUI	Oct 08	Jan 09	Completed Mar 09
	Create distributions for 8-hour prognostic peak probabilities and incorporate into GUI	Jan 09	Apr 09	Completed Jul 09
	Create distributions for 12-hour prognostic peak probabilities and incorporate into GUI	Apr 09	Jul 09	Completed Feb 10
	Final report	Jul 09	Sep 09	Completed May 10
Objective Lightning Probability Tool – Phase III	Collect CGLSS data for May–Sep 2006–2008 and Oct 1989–2008, analyze to determine if Oct data are needed	Mar 09	May 09	Completed
	Determine dates for lightning season stratifications	Jun 09	Sep 09	Completed Jun 10
	Collect sounding data for May–Sep 2006–2008, and Oct 1989–2008 if needed, create candidate predictors for each stratification.	Jul 09	Nov 09	Completed Feb 10
	Create and test new equations; compare performance with previous equations	Dec 09	Mar 10	Delayed
	Incorporate equations in Excel GUI	Apr 10	Apr 10	Delayed
	Final Report	May 10	Jul 10	Delayed

AMU Project Schedule 31 July 2010				
AMU Projects	Milestones	Scheduled Begin Date	Scheduled End Date	Notes/Status
Peak Wind Tool for General Forecasting - Phase II	Collect wind tower data, CCAFS soundings, and SLF observations	Sep 08	Sep 08	Completed
	Interpolate 1000-ft sounding data to 100-ft increments for October 1996 to April 2008. Compare interpolated data to 100-ft sounding data for October 2002 to April 2008.	Sep 08	Oct 08	Completed Nov 08
	QC SLF observations	Oct 08	Nov 08	Completed
	QC wind tower data	Nov 08	Jan 09	Completed
	Create prediction equations for peak winds	Feb 09	Apr 09	Completed Jun 09
	Compare Phase I and II tools: • Using 2 cool-seasons of 45 WS-issued wind warnings/advisories; • To either MOS or model forecast winds; and • To wind tower climatology from the Peak Wind for User LCC task.	Jun 09	Nov 09	Completed
	Create and test Excel GUI application	Dec 09	Jan 10	Completed
	Transition tool to MIDDS to provide 5-day peak wind forecasts, using model data	Jan 10	Jun 10	Completed
	Final Report and training	Jul 10	Sep 10	On Schedule
Upgrade Summer Severe Weather Tool in MIDDS	Acquire and update the severe weather database and adjust weights	Nov 09	Feb10	Completed
	Update GUI software code	Feb 10	Mar 10	Completed
	Final Report and training	Apr 10	May 10	Completed

AMU Project Schedule
31 July 2010

AMU Projects	Milestones	Scheduled Begin Date	Scheduled End Date	Notes/Status
ADAS Update and Maintainability Task	Install and configure LDM on amu-cluster and retrieve real-time date	Jan 09	Feb 09	Completed
	Install and configure latest version of ADAS code	Feb 09	Mar 09	Completed
	Modify and upgrade AMU-developed scripts	Feb 09	Nov 09	Completed
	Update GUI software code	Dec 09	Feb 10	Completed Apr 10
	Split ADAS data sources into multiple files	May 10	May 10	Completed
	Optimize error statistics for MADIS data	Jun 10	Jul 10	On Schedule
	Update GUI with new source data	Aug 10	Aug 10	On Schedule
	Final Report and training	Aug 10	Sep 10	On Schedule
Verify MesoNAM Performance Task	Acquire ACTA MesoNAM forecasts and KSC/CCAFS wind tower observations	Jun 09	Jun 09	Completed
	QC wind tower observations, stratify by month, season and wind direction	Jun 09	Sep 09	Completed
	Objectively verify model forecasts against wind tower observations	Oct 09	Mar 10	Completed
	Add wind tower observations and MesoNAM forecasts from May 09-Feb 10 and process the data to prepare for updated verification	Mar 10	May 10	Completed
	Update objective model verification with additional May 09-Feb 10 data	May 10	Jun 10	Completed
	Update GUI	Jun 10	Jul 10	On Schedule
	Final report	Jul 10	Sep 10	On Schedule

NOTICE