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Applied Meteorology Unit (AMU) Quarterly Report

Fourth Quarter FY-09 Contract NNK06MA70C 31 October 2009

Executive Summary

This report summarizes the Applied Meteorology Unit (AMU) activities for the fourth quarter of Fiscal Year 2009 (July - September 2009). 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 Completed running the 8-hour scripts, and completed re-running the 2- and 4- hour scripts after removing tropical storm data from October. Modified the scripts to create the 12-hour data.

Discussion The new 2-, 4-, and 8-hour data will be processed to create the prognostic probabilities of meeting or exceeding a peak speed given a current mean wind speed.

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 (GUI) 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 Calculated median and 95th percentile of the wet season start and end date distributions as defined by the National Weather Service office in Melbourne, FL (NWS MLB).

Discussion The statistical values of the wet season start and end date distributions may be helpful in determining the start and end date of the lightning seasons for each year. They would be used in conjunction with other observed values such as precipitable water and lightning occurrence.

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Distribution:

NASA HQ/M/AA/W. Gerstenmaier
NASA KSC/AA/R. Cabana
NASA KSC/MK/L. Cain
NASA KSC/LX/P.Phillips
NASA KSC/PH/ R. Willcoxon
NASA KSC/PH-A2/D. Lyons
NASA KSC/PH/M. Leinbach
NASA KSC/PH/S. Minute
NASA KSC/VA/S. Francois
NASA KSC/VA-2/C. Dovale
NASA KSC/KT/D. Bartine
NASA KSC/KT-C/J. Perotti
NASA KSC/PH-3/J. Madura
NASA KSC/PH-3/F. Merceret
NASA KSC/PH-3/J. Wilson
NASA JSC/MA/W. Hale
NASA JSC/WS8/F. Brody
NASA JSC/WS8/B. Hoeth
NASA JSC/WS8/K. Van SpeyBroeck
NASA MSFC/EV44/D. Edwards
NASA MSFC/EV44/B. Roberts
NASA MSFC/EV44/R. Decker
NASA MSFC/EV44/H. Justh
NASA MSFC/MP71/G. Overbey
NASA MSFC/SPoRT/G. Jedlovec
NASA DFRC/RA/E. Teets
NASA LaRC/M. Kavaya
45 WS/CC/E. Borelli
45 WS/DO/L. Shoemaker
45 WS ADO/C. Lovett
45 WS/DOR/M. McAleenan
45 WS/DOR/M. Buchanan
45 WS/DOR/G. Strong
45 WS/DOR/R. Parker
45 WS/DOR/F. Flinn
45 WS/DOR/ T. McNamara
45 WS/DOR/J. Tumbiolo
45 WS/DOR/K. Winters
45 WS/SYA/B. Boyd
45 WS/SYR/W. Roeder
45 RMS/CC/W. Rittershaus
45 SW/CD/G. Kraver
45 SW/SESL/D. Berlinrut
45 SW/XPR/R. Hillyer
45 OG/CC/J. Ross
45 OG/TD/C. Olive
CSR 4500/J. Saul
CSR 7000/M. Maier
SMC/RNP/S. Exum
SMC/RNP/T. Knox
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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 timing of 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 compiling the verification data set that will be used to compare the Phase I and Phase II tools to climatology, model winds, and 45 WS wind warnings and advisories. In the verification data set, compared the Phase I and Phase II tools' forecasts of the timing of the peak wind to climatology and model winds.

Discussion The verification data set showed that, for the forecast timing of the peak wind, the Phase I, Phase II and 12-km resolution NAM model (MesoNAM) wind forecasts showed little skill compared to climatology. The model runs at 0000 UTC forecast the timing of the peak wind slightly better than the 0600 UTC model runs.

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 NWS MLB 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 Continued modifying and rewriting previously written shell scripts to run ARPS/ADAS using the Perl programming language. Modified the shell scripts that process soil data used in ADAS and that create the model initial and boundary conditions used in the Weather Research and Forecasting (WRF) model.

Discussion The scripts that were modified initialize the soil temperature and moisture variables used in the ARPS/ADAS model system, and create the initial and boundary conditions used in the Advanced Research WRF (ARW) model. Two new Perl scripts were written that create the initial and boundary conditions used in the Nonhydrostatic Mesoscale Model (*NMM*) and/or ARW cores and perform a temporal interpolation of the first-guess background model fields in the ADAS analyses.

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Task Verify MesoNAM Performance

Goal Verify the performance of the 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 Completed reformatting and stratifying the data with S-PLUS scripts. Completed combining the wind tower observations and model data in Microsoft Excel using Visual Basic code.

Discussion Completed reformatting, stratifying and then combining the wind tower observations and MesoNAM data files that will be used to verify the MesoNAM forecasts. After using S-PLUS software to reformat the model files and create the proper stratifications, the observation and model files were imported into Excel and combined to prepare them for the verification phase.

Task HYSPLIT Graphical User Interface

Goal Develop a GUI that allows forecasters to update selected parameters within the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model used at NWS MLB. The HYSPLIT model is used by NWS MLB for computing trajectories, dispersion, and deposition of atmospheric pollutants to assist local emergency managers. The GUI will allow easy adjustment of selected parameters on daily and emergency runs. This will help NWS MLB forecasters improve efficiency and reduce human error when running HYSPLIT in support of an incident involving toxic substances dispersed into the atmosphere.

Milestones Designed the HYSPLIT GUI layout, wrote scripts for user input fields and widget functionality, and tested the GUI functionality at the AMU and NWS MLB. Began writing the final report.

Discussion Finished development of the HYSPLIT GUI and background code to manage the different parameter files needed for the model runs. This allows forecasters to automatically provide trajectory and concentration forecasts on a scheduled and emergency basis using national and local model data and provide timely information on hazardous conditions to their customers.

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.

Prognostic Probability and GUI Status

Ms. Crawford completed running the 8-hour scripts that prepare the data for calculating peak speed probabilities based on the mean speed. She then ran the 2- and 4-hour scripts for October after removing data from four days on which the Kennedy Space Center (KSC) / Cape Canaveral Air Force Station (CCAFS) area was affected by tropical storm winds (AMU Quarterly Report Q3 FY09). After completing the 2-, 4-, and 8-hour scripts, Ms. Crawford began calculating the peak speed probabilities for each tower. She also modified the scripts to create the 12-hour data.

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 KSC and CCAFS. The AMU developed a set of logistic regression equations that calculate the probability of lightning occurrence for the day in Phase I (Lambert and Wheeler 2005). These equations outperformed several forecast methods used in operations. The Microsoft Excel GUI developed in Phase I 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 main goal of this phase is to create the 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. The Excel and MIDDS GUIs will be updated with the new equations.

Determining Stratifications

As described in the previous AMU Quarterly Report (Q3 FY09), five sub-seasons are evident in the daily lightning climatology (Figure 1):

1) Pre-lightning (~1–13 May),
2) Ramp-up (~14 May–22 June),
3) Lightning proper (~23 June–12 August),
4) Ramp-down (~13 August–12 October), and
5) Post-lightning (~13–31 October).

Ms. Crawford and Mr. Roeder discussed ways of developing an objective method to determine the start date of each season. The method must be appropriate for an operational setting such that the start date can be determined in real-time. The definition of the warm season dictates that the pre-lightning season begins on 1 May, and the post-lightning season ends on 31 October. The chosen method will determine the beginning dates for the ramp-up, lightning-proper, ramp-down, and post-lightning seasons in each year.

Ms. Crawford copied the wet season start and end dates for each year that were calculated by the National Weather Service in Melbourne, FL (NWS MLB) from their website (http://www.srh.noaa.gov/mlb/wetdry/WetDrySeason.html), to determine if they could be used in identifying the start dates of the sub-seasons. Mr. Roeder suggested using the 95th percentile date in the distribution as a no-later-than date to start a new season if other values do not indicate the season has started. To explore this option, Ms. Crawford calculated the median and 5% quantiles of the start and end date distributions. The start and end dates are plotted with the smoothed lightning and precipitable water (PW) climatologies in Figure 1. Ignoring the two outliers in the wet-season start dates (22 June 2000 and 6 July 1998), the median date is 31 May and the 95th percentile date is 11 June. Including the two outliers changes the dates to 2 and 23 June, respectively. There is one outlier in the end date distribution, 3 November 2007, not shown in Figure 1 because the last date on the chart is 31 October. Including this outlier makes no difference in the median and 95th percentile dates of 15 and 24 October, respectively.

The NWS MLB wet season start dates are clustered near the start of the ramp-up season, and the end dates are clustered near the start of the post-lightning season as shown by the lightning climatology curve in Figure 1. This suggests that these dates could be used in an algorithm to determine the start of the ramp-up and post lightning seasons, but not the lightning proper and ramp-down seasons.

Other data Ms. Crawford will analyze include the individual PW values and Cloud-to-Ground Lightning Surveillance System (CGLSS) observations for each day in each year. The observations are expected to be the main indicators of the beginning of each season, with the NWS MLB dates playing a secondary role.

Task Status

With approval from the 45 WS, work on this task will be delayed up to two months in order for Ms. Crawford to assist Dr. Merceret in gathering wind tower data and analyzing statistical results as part of his tropical storm peak wind tool task.

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

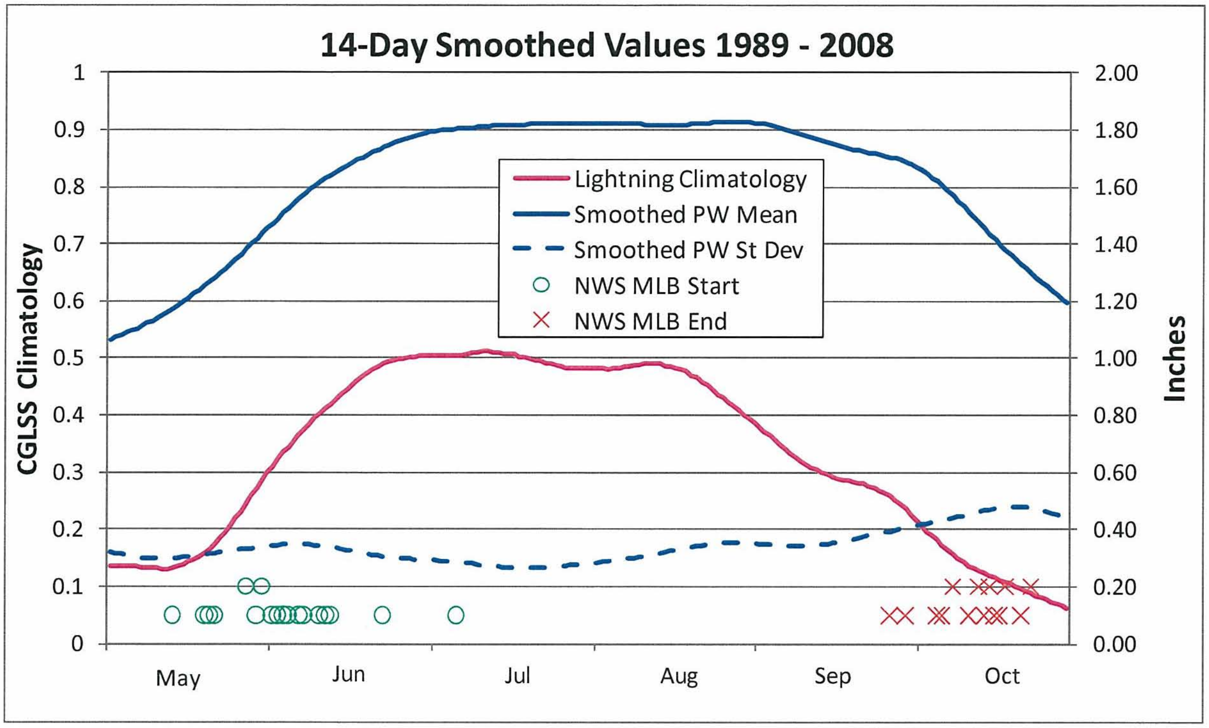

Figure 1. The 14-day Gaussian-smoothed lightning (left axis, magenta line) and PW (right axis, blue lines) values with the NWS MLB wet season start (green circles) and end (red Xs) dates in the POR. The values for the start and end dates are plotted with the PW values along the vertical axis on the right. A value of 0.1 means the wet season began/ended only once on that date in the POR, and 0.2 means it began/ended on that date twice in different years.

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 35 kt, 50 kt, and 60 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.

Verification Data Set

Mr. Barrett used the Phase I and Phase II forecast methods to calculate the peak wind, average wind, and timing of the peak wind speed using the verification data set. The verification data set includes observations for the cool season months from March 2007 to April 2009. He also added wind climatology, 12-km resolution North American Mesoscale (NAM) model (MesoNAM) winds, and 45 WS wind warnings and advisories to the verification data set.

Timing of Peak Wind Speed

Mr. Barrett completed the comparison of the Phase I and Phase II forecast methods to the climatology and model winds in the verification data set for the timing of the peak wind speed. The daily morning forecast by the 45 WS is valid for the 24-hour period of 8:00 AM to 8:00 AM, in local Eastern time. Since most of the cool season is in Standard time, the forecast period in this task is defined as 1300 to 1300 UTC. The timing is defined as the number of hours that have elapsed since the beginning of the forecast period. For example, if the peak wind speed of the day occurred at 0100 UTC, then the timing would be 12 hours since there is a difference of 12 hours from 1300 UTC to 0100 UTC.

The chart in Figure 2 compares the mean errors (ME) and mean absolute errors (MAE) of the timing of the peak wind by the Phase I and Phase II methods, as well as climatology and model winds. Fourteen forecast methods from Phase II were selected to be evaluated in the verification data set, as shown in Table 1 of the previous AMU Quarterly Report (Q3 FY09). Three of the six climatology values are based on the 54-, 90-, and 204-ft winds in the Peak Wind Tool for User LCC task. The other three values were calculated from the datasets used to develop and test the Phase I and II equations. The Phase I method and most of the Phase II methods have low biases in the timing, since their ME are near zero. The model winds have a positive bias of approximately 2 hours, meaning they tend to forecast the timing of the peak wind around 2 hours later than the average. Overall, the methods showed little skill compared to climatology, as indicated by the MAE values.

Model data was evaluated to determine if it was more accurate than the Phase I and II methods. The MAE of the model data increased with height. However, the model data in the lowest levels was generally slightly more accurate than the best methods from Phase I and II. Figure 3 compares the ME and MAE for the 0000 and 0600 UTC runs of the MesoNAM model. The first 17 points on the horizontal axis (from left to right) are the model winds at increasing heights, from approximately 70 - 2900 ft above the surface. The last three points (points 18-20) are the ME and MAE for the strongest winds in the lowest 1000, 2000, and 3000 ft above the surface. Generally, the 0000 UTC model runs had a positive bias of 2 hours, with a positive bias around 2.5 hours in the 0600 UTC model runs. Despite being six hours closer to the start of the forecast period, the 0600 UTC model runs had a slightly higher MAE.

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

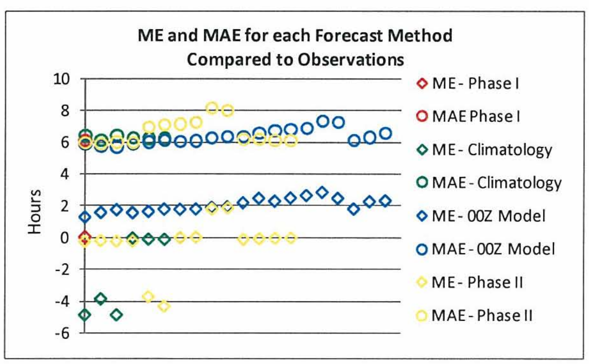

Figure 2. The ME and MAE (in hours) for Phase I, Phase II and climatology and MesoNAM model runs at 0000 UTC. Each method is plotted on a different point along the X-axis.

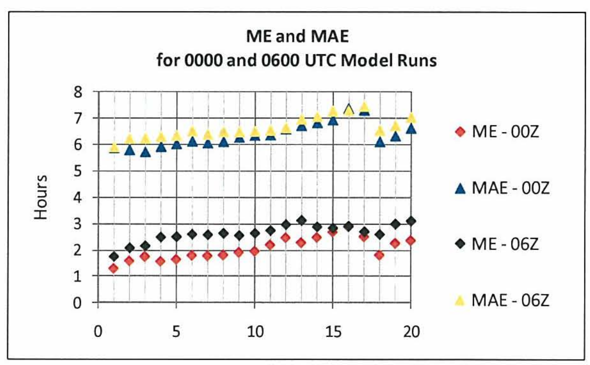

Figure 3. The ME and MAE (in hours) for the MesoNAM model runs at 0000 and 0600 UTC.

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 Existing Scripts

Dr. Watson continued to modify the previously written shell scripts and rewrite them using the Perl programming language. The existing suite of shell scripts runs a complete model system which includes the pre-processing step, the main model integration, and the post-processing step. As described in the previous AMU Quarterly Report (Q3 FY09), Dr. Watson modified the shell scripts that process the background model, the GOES infrared and visible satellite data, and the WSR-88D Level II radar data used to initialize ADAS. She also modified the National Oceanic and Atmospheric Administration (NOAA)/Earth System Research Laboratory (ESRL)/Global Systems Division (GSD) programs that convert all surface, rawinsonde, wind profiler, and Aircraft Communications Addressing and Reporting System (ACARS) data to ASCII format so they are ADAS-compatible.

During this quarter, Dr. Watson finished modifying the shell script that initializes soil temperature and moisture variables used in ADAS, modified the shells scripts that create the model initial and boundary conditions used in the WRF model, and wrote a Perl script that performs a temporal interpolation of the first-guess background model fields in the ADAS analyses. This will allow users to create analyses between model output times.

In the soil initialization script, model forecast soil temperatures are interpolated to the ARPS grid. Two files are generated from the General Meteorological Package (GEMPAK) program 'gdlist', which creates a 2-D grid listing of near-surface soil temperature and deep soil temperature. The soil moisture variables are initialized by using the Antecedent Precipitation Index (API) scheme available in the ARPS soil code. The initial soil moisture is determined at each grid point by computing a weighted summation of daily precipitation amounts using the rain gauge measurements from each site.

There are currently two ARPS programs that create model initial and boundary conditions for the WRF model. The program 'arps2wrf' (used in conjunction with the 'wrfstatic' program) converts the ARPS initialization data to the Advanced Research WRF (ARW) grid format. The program 'arps4wrf' converts the ARPS initialization data to the grid format of either the ARW core or the Nonhydrostatic Mesoscale Model (NMM) core of the WRF system. The resulting data files can then be used as input for the WRF modeling system. However, the cloud and precipitation microphysics derived by the ADAS cloud analysis scheme cannot currently be initialized into the NMM core due to limitations in the WRF code.

Dr. Watson wrote the new Perl scripts that control the ADAS system to allow the user more flexibility in the directory structure of the model/scripts than in the previous versions and the user is allowed more input options. She also wrote the Perl scripts so they can be run independently of the rest of the model.

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 use the 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.

Tower Number	*Supported Activity and Facility*	*Sensor Heights*
0002	Delta II (LC-17)	6 ft, 54 ft, 90 ft
0006	Delta IV (LC-37)	54 ft
0108	Delta IV (LC-40)	54 ft
0110	Atlas V/Falcon (LC-41)	54 ft, 162 ft, 204 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

File Formatting

Dr. Bauman completed reformatting the wind tower observations to calculate the mean value for each observed parameter at the top of every hour using the observations from 30 minutes before and 30 minutes after the hour.

The ACTA MesoNAM model forecast files were provided to the AMU as space-delimited text files. In the last AMU Quarterly Report (Q3 FY09), Dr. Bauman noted 57%, or 134, of the MesoNAM files from January – February 2009 were missing. Mr. Barrett requested and received 127 of these missing 2009 files from ACTA. For the Oct 2006 – April 2009 POR, Dr. Bauman then re-inventoried the MesoNAM files and found there were 128 missing files, or model runs out of a possible 3772 files for the 943-days. Some days were missing less than four model runs while others were missing all four model runs. This resulted in a total of 910 days containing at least one model run.

Dr. Bauman wrote Microsoft Visual Basic scripts to import the MesoNAM files into Excel spreadsheets and reformat them to match the wind tower observation spreadsheets. This included converting the temperature and dew point from Celsius to Fahrenheit and moving rows and columns in the MesoNAM spreadsheets to match the wind tower spreadsheets. He then wrote Visual Basic scripts to create an Excel workbook for each of the 910 days with at least one model run. Each workbook included up to four worksheets, one for each available model run, containing combined wind tower observations and MesoNAM data for each sensor on every tower resulting in a total of 24,570 workbooks. Next, Dr. Bauman will stratify the worksheets by month, cool season and warm season to calculate the statistics that will help determine model performance.

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

HYSPLIT Graphical User Interface (Mr. Wheeler)

Both NWS MLB and SMG requested the AMU to develop a GUI for the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model. Both groups use HYSPLIT for computing trajectories, complex dispersion, and deposition during releases of hazardous atmospheric pollutants and during wildfires. This is a continuation of the recent AMU task in which the AMU installed and configured a Linux version of HYSPLIT that provides trajectory and concentration guidance automatically using output from the NCEP models and from the WRF Environmental Modeling System (EMS) run at NWS MLB and SMG. The AMU developed Linux parameter files containing the various model runtime options for the HYSPLIT simulations. However, changing the values in the parameter files for different scenarios is a time-consuming task prone to human error. The forecasters at NWS MLB and SMG requested the AMU create a GUI to interface with the parameter files and change the variables in an operational environment easily and quickly. The HYSPLIT GUI will reduce the possibility of human error and increase efficiency, allowing forecasters to do other duties.

Software Development

Mr. Wheeler used the parameter files developed in the previous AMU task (Dreher 2009) as a starting point for the development of the HYSPLIT GUI. Several meetings were convened over the course of the task at the NWS MLB office to review the task and discuss in detail the layout and functionality of the GUI. The concept of a Local Configuration Manager layout came out of these meetings as well as the parameter baseline for the GUI development.

The GUI is divided into three sections; Daily, Scheduled and Emergency Response. This allows the forecaster to monitor real-time events. The Tool Command Language/Tool Kit (Tcl/Tk) programming language was used for the GUI development and data manipulation. This allows the GUI to run under several different operating systems. Features of the HYSPLIT GUI include

- **Tcl/Tk**: A script and interpreter type programming language.
- **Configuration File**: A text file that has default or real-time parameter settings. The text file is used at program startup or when defaults are requested.
- **Scripts**: User- or code-defined text files that control file execution or start other process.
- **Fixed Sites:** 10 sites for which the HYSPLIT model runs daily. The forecaster can enter or update information such as, Name, Latitude, Longitude, Forecast Time, Model choice, Emission Duration and Rate on the 10 daily updated sites.
- **Floating Sites**: An additional five sites that can be added. The forecaster can enter or update the same information as for Fixed Sites. Once changed, these sites are added to the 10 daily HYSPLIT model run.
- **Emergency Site**: A single site entry was developed for emergencies. The forecaster can enter or update the same information as for Fixed Sites along with a playbook option on a single site and then have the HYSPLIT model run with those parameters once the submit button is clicked.
- **Playbook Option**: The forecaster can select the category of the source release particulate.

The Playbook option allows the forecaster to select the initial release pollutant. The values for the chosen release particulate are updated in the parameter file so the HYSPLIT model computes the correct trajectory and concentration plumes.

As Mr. Wheeler reached certain milestones during development, he shared the code with NWS MLB for their review and input to ensure the final product would be useful in their operations. He made adjustments to the GUI code based on their comments. Once the parameter selection, layout and button functionality were developed, Mr. Wheeler inserted code to manipulate the model parameter files and code to save and retrieve the different parameter input file settings.

HYSPLIT GUI

Figure 4 shows an example of the HYSPLIT GUI. It has many input windows, parameter pull-down menus, option buttons, widgets and control files that allow the user to choose the information selected for output to build the parameter files and run the HYSPLIT model. The forecaster has control over all input and selectable fields. All titles, fields and labels have mouse-over help that describes their functionality. Once the forecaster has completed updating the site(s) incident and other parameter information, a "Submit" button is highlighted. This updates the selected model parameter files and/or makes an emergency HYSPLIT model run.

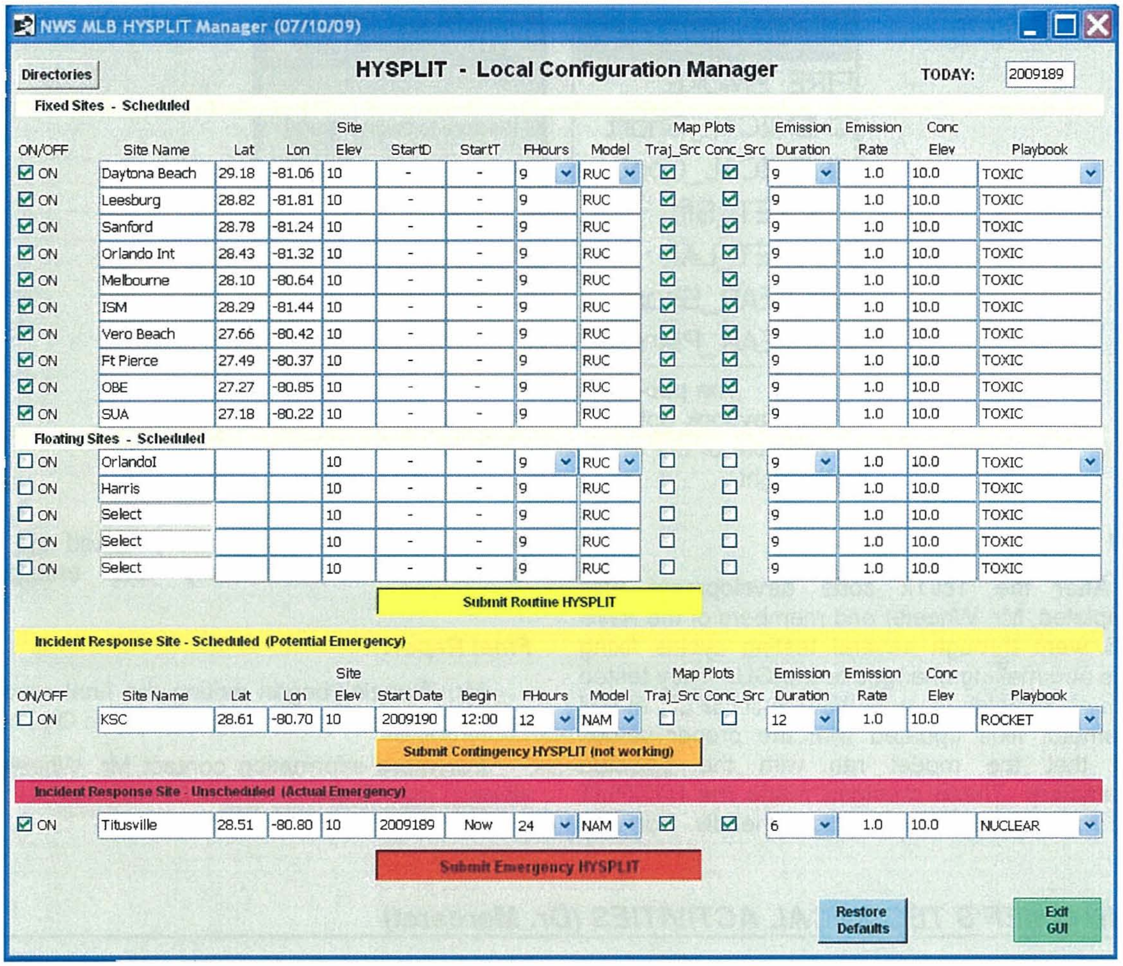

Figure 4. Example of the HYSPLIT Local Configuration Manager GUI.

To allow control over where the different parameter files are written, Mr. Wheeler developed a menu popup window "Setup Directories" (Figure 5). This allows the forecaster to change the directory path depending on the operating system used.

Mr. Wheeler developed several additional popup menus that allow the forecaster to select playbook options and restore parameter settings. Figure 6 shows two examples. The playbook selection menu on the left allows the forecaster to select from a preset number of likely events. The playbook choice changes several chemical or particulate parameters in the HYSPLIT model. One of the options in the restore popup window on the right in Figure 6 is "Restore to Last Previous State". This option restores the HYSPLIT GUI parameters to the same values the last time the GUI was closed. A text file is written when the GUI is closed to keep track of the parameter values.

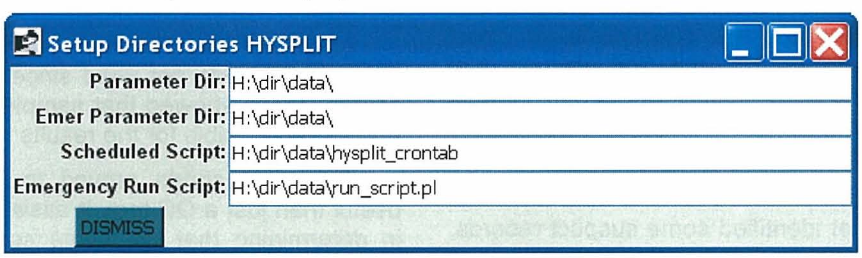

Figure 5. Example of the Directories popup menu. The parameter directories and script names can be changed.

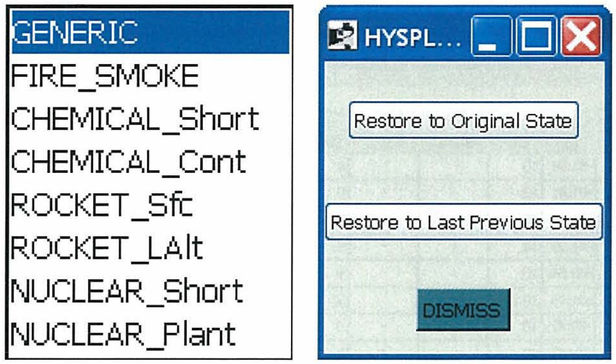

Figure 6. The pop-up window on the left shows a list of the Playbook options that the user can select, and an example of the Parameter Restore popup menu is on the right.

GUI Testing

After the Tcl/Tk code development was completed, Mr. Wheeler and members of the NWS MLB went through several testing cycles fixing bugs and making changes to the GUI. They tested each of the fields to verify that the HYSPLIT model parameter files updated with the proper values and that the model ran with the selected parameters. These changes made the HYSPLIT GUI more responsive and user friendly. For final testing, NWS MLB successfully tested the GUI functionality in both daily and emergency configurations.

Final Report

Mr. Wheeler began writing the final report. It will be completed and delivered early in Q1 FY10.

For more information contact Mr. Wheeler at wheeler.mark@ensco.com or 321-853-8264.

AMU CHIEF'S TECHNICAL ACTIVITIES (Dr. Merceret)

Comparison of Tropical Storm (TS) and Non-TS Peak Winds (Dr. Merceret and Ms. Crawford)

This is a continuation of the work reported in the last AMU Quarterly Report (Q3 FY09). The planned next steps were to (a) complete the quality control (QC) process including determining whether our hypothesis about the asymmetry of Tower 313 is correct; (b) where appropriate, combine data from the opposite sides of a tower to create a single stratification category rather than two for that tower; and (c) establish a validated master database from which all future analysis can proceed. These steps are prerequisite to direct comparisons with the TS data. The ultimate goal was to be able to build models for the non-TS gust factor (GF) similar to the TS models reported in Merceret (2009).

Ms. Crawford provided revised data after she and Dr. Merceret identified some suspect records. Dr. Merceret recomputed the statistics and reviewed the corrected data. With the initially limited expectation of using the technique to facilitate a final QC pass through the data, Dr. Merceret stored the data in Excel® pivot tables and displayed them in pivot charts. This permitted easy examination of the mean GF or its standard deviation (GFSD) as a function of any one of the following variables stratified by any combination of the remaining variables:

- Wind speed bins in 5 kt intervals from 15 to 45 kt,
- Height by any available tower level, and
- Tower ID where each side of each tower has a unique ID.

Additional stratification by sample size was available but was not used since a quick look at several cases showed that sample size limitations are not responsible for the results that follow.

The pivot charts proved to be much more useful than just a QC tool. It assisted Dr. Merceret in determining that the same sort of GF model used in the TS case is not possible for the non-TS case. In the TS case, both the GF and the GFSD are well behaved in all of the following senses, allowing the production of a TS GF model:

- They decrease monotonically and smoothly as a function of increasing height,
- They decrease monotonically and smoothly as a function of wind speed,
- They have the same statistics on opposite sides of a given tower,
- The results from different towers are similar enough to warrant combining the data
- A single model suffices for all towers

For the non-TS case, none of the above properties appear to be generally true. Each of the first three is sometimes true, though not necessarily at the same time. An example is shown in Figure 7. These are the gust factors at 295 ft for offshore flow, defined as wind directions from 160° to 340°, or SSE to NNW. There was not a decrease of gust factor with speed, as with the TS data, but an increase from 15 to 25 and 30 kt, then a decrease to 40 kt.

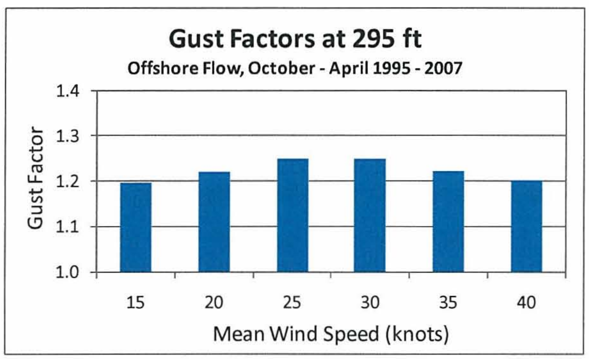

Figure 7. Gust factors for each 5-kt mean wind speed bin at 295 ft in offshore flow.

While this was disappointing, it should have been expected. As was noted in Merceret (2009) and the references cited therein, it is well established that GF are a function of the surface properties, especially the roughness length (Z_0), and atmospheric stability in the vicinity of the measurements. The TS and non-TS environments are often quite different in respect to the effects of these parameters.

The higher the wind speed and the greater the height of measurement, the further away from the tower the relevant surface properties occur. In the TS case, all of the winds were from the onshore direction (roughly north through southeast) and the mean wind speeds were high. The towers are close enough to the shoreline that by and large the relevant surface properties under these conditions are those of the ocean, which is the same for all of the towers. Also in the TS case, the storm environment was well mixed due to the high winds and large shear in the surface layer so that the stratification is close to neutral stability at all towers throughout the storm. These features provided homogeneity of the environment not present in the non-TS climatology.

The AMU non-TS database did not attempt to determine or stratify by surface properties or stability. Data from a wide range of stratifications are certainly lumped together in the statistics. Cool, bright sunny days (very unstable in the lowest layers) are lumped together with clear nights having marked radiation inversions (very stable) and everything in between. Depending on the stability, wind speed and wind direction within the selected directional stratification, the effective value of Z_0 can vary by an order of magnitude or more. This was not an oversight. The 45WS specifically requested the AMU do a climatology based on time of year (by month) for the cool season rather than one requiring a more complex analysis based on stability and surface properties. Stratifying by stability would be feasible, but is time consuming. Surface properties are difficult to measure and parameterize and probably not feasible to include in an operational tool.

There are consequences if these conclusions are correct. The first is that a general non-TS model is not possible. Second, comparisons between different directional regimes are not justifiable since any observed differences will be dominated by local terrain effects. The local effects are more than just "over water vs. over land" since the land near the wind towers varies from sandy beaches to scrub to marshland to forest. The environment is too complex for meaningful analysis. Third, since the effect of stability, including its indirect effect on Z_0, is very different between the TS and non-TS cases, even a direct comparison of the same wind direction stratification in the TS and non-TS cases must be made with caution.

Future work on this task will involve a careful review of the data and the hypotheses suggested above with the goal of getting as much meaningful information from the TS vs. non-TS comparison as possible within the limitations of the data. Ideally, the non-TS data could be stratified by stability and only the near neutral cases used in the comparison, but the labor required to do that would be prohibitive given the other priorities of the AMU and KSC Weather Office.

Electromagnetic Modeling of Lightning Strikes to the Shuttle Launch Pad Catenary Protection System (Dr. Merceret)

The space shuttle launch pad LC39A has a lightning protection system consisting of a catenary wire attached to a lightning mast at the top of the fixed service structure and grounded at both ends. A diagram is presented in Figure 8. Like a Franklin-type "lightning rod", the concept is that lightning will strike the mast or one of the two catenary wires and be conducted harmlessly to ground rather than striking the vehicle or service structures. At each end of the catenary, the resulting lightning current is measured by a set of coils called the Catenary Wire Lightning Instrumentation System (CWLIS).

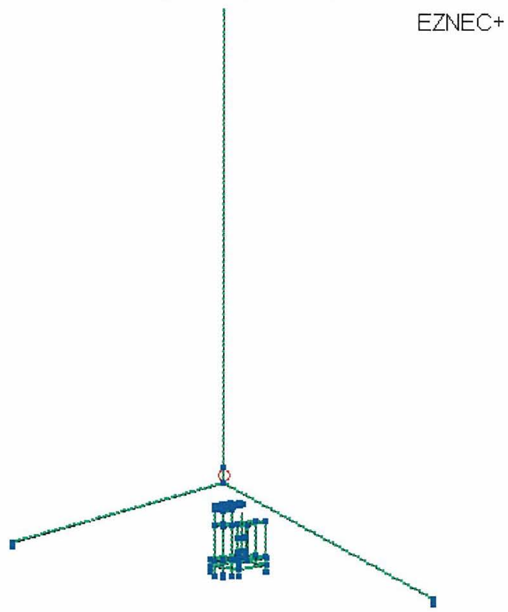

Figure 8. The modeled catenary wires (oblique) and lightning strike (vertical, extending beyond the top of the figure).

During the summer while STS-127 was on the pad, there was a direct lightning strike to the mast. The lightning current in the return stroke was estimated from CGLSS at about 32 kA. The two CWLIS sensors recorded currents of 28.4 and 36.6 kA, respectively. The incident was reviewed by several shuttle panels to determine whether time-consuming and expensive retests of STS-127 systems would be required. During these discussions, it was suggested that the CWLIS readings should be disregarded for quantitative purposes since they did not add up to about 32 kA. The supposition was that the imposed lightning current would be split between the two catenary wires, whose readings should therefore sum to the incident current.

The supposition that the two catenary currents should sum to the imposed lightning current assumes that transmission line effects of the catenary wires are negligible. That is, the lightning behaves like a direct current (DC) source. In fact, lightning is a broadband source with components from DC to VHF and beyond. Dr. Merceret decided to examine the "DC behavior" assumption using electromagnetic modeling.

To facilitate the examination, Dr. Merceret obtained a commercial software package used for modeling antenna systems with wire elements. The program, EZNEC 5.0 ®, provides a graphical and tabular user interface for modeling antennas with straight wire segments and applying specified current or voltage sources where desired within the model. The resulting currents and fields are computed using the National Electrical Code version 2 (NEC2) algorithms, which are generally accepted in the field of electromagnetic analysis.

The catenary wire system was modeled as two wires extending in opposite directions from the LC39 lightning mast, grounded at the ends through a short vertical section in which the currents would be those measured by CWLIS. The fixed and mobile service structures and mobile launch platform were modeled as wire frame structures. The space shuttle vehicle was modeled by large cylindrical "wires" for the external tank, each solid rocket booster and orbiter. The lightning strike was modeled by a vertical wire much longer than any other wire in the model and connected to the catenary wires where they join at the top of the mast. A source current of 32 kA was imposed just above the lightning mast. Figure 8 shows the model with emphasis on the catenary and lightning strike. Figure 9 shows the model with emphasis on the structures.

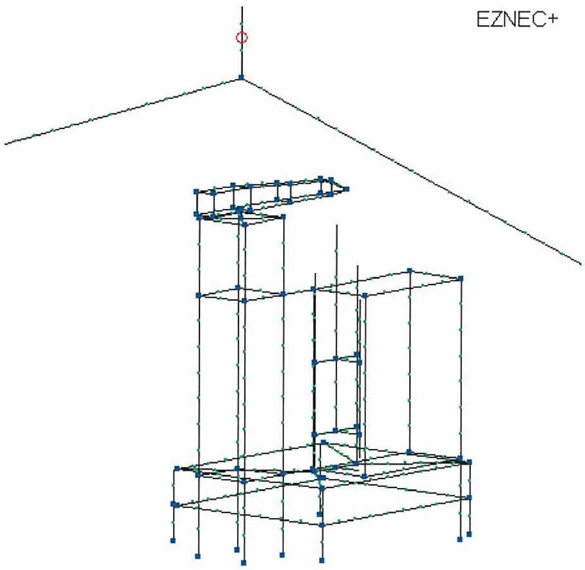

Figure 9. Close up view of the model showing how the structures are modeled beneath the catenary at the pad.

EZNEC computes the currents only at a single frequency specified by the user. To properly model the overall effect, the lightning and CWLIS currents were represented by their Fourier components within the bandwidth of the CWLIS from DC to 1.5 MHz in 30 steps, each 50 KHz wide. The actual energy spectrum of the lightning had not been measured, so the spectrum suggested by Uman (1969) Equation 4.1 was used. The Uman spectrum was scaled so that the Fourier components added up to a total current of 32 kA. The resulting Fourier sums were computed for both legs of the catenary.

Given the simplicity of the model, the results were remarkably close to the measurements. The resulting currents in the two catenary wires were both about 25 kA. The spectral results are shown in Figure 10. The Uman spectrum is the dashed line. Several resonances appear as peaks and valleys in the CWLIS currents which are so close to identical in the two wires that their spectra completely overlap.

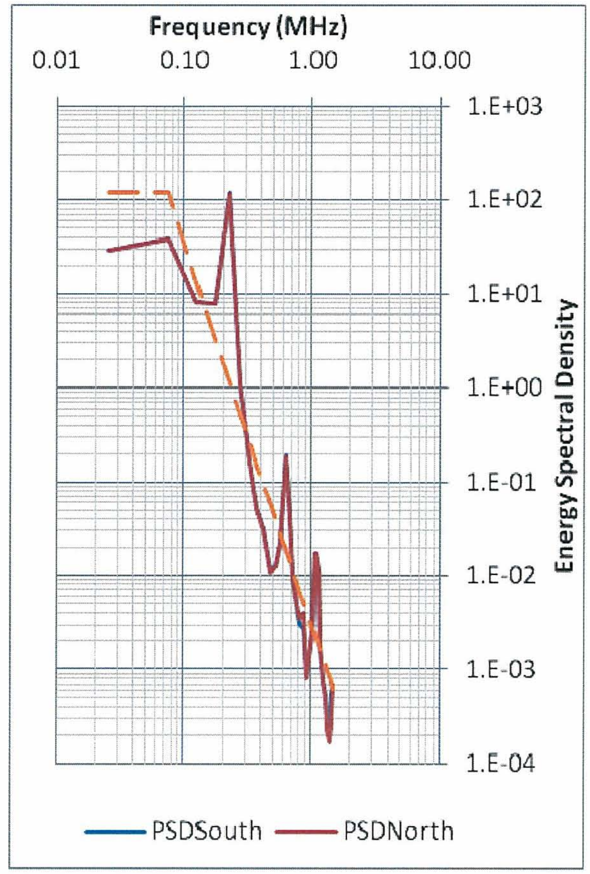

Figure 10 Lightning and CWLIS current energy spectra. The Uman spectrum is the dashed line. PSDNorth and PSDSouth are the north and south CWLIS sensors.

The asymmetry in the measurements is probably due to a combination of instrument error and the fact that the lightning strike was not truly vertical all the way up. A few "what if" scenarios that tilted the modeled lightning strike (not shown) gave asymmetries that were the same order of magnitude as those observed.

The results were presented at a Shuttle Lightning Technical Interchange Meeting and were well received.

AMU OPERATIONS

Mission Immediate

The 45 WS requested the AMU conduct a comparison of specific radar output parameters between the Patrick Air Force Base WSR-74C and NWS MLB WSR-88D weather radars. This was a time-critical request in which realistic threshold values were needed for an upcoming test of the new 45 WS Radtec TDR 43-250 weather radar. Mr. Wheeler conducted the comparison of Maximum Reflectivity, Echo Top and Volume Integrated Liquid between the two radars. He gathered the data and developed a spreadsheet showing the of parameter values from each radar and their differences.

The 45 WS indicated that the values Mr. Wheeler calculated proved valuable in testing the new radar, which passed all the tests given.

Information Technology

Mr. Magnuson addressed some hardware issues and reloaded the operating system on the former RSA model cluster and installed AWIPS on a fourth client.

Conferences, Meetings, and Training

Dr. Bauman, Dr. Merceret, Ms. Crawford, and Ms. Wilson attended the Southern Thunder Workshop in Cocoa Beach, FL 28–30 July. This workshop focused on aspects of total lightning observations and research.

Lanch Support

- Dr. Bauman supported the launch of STS-127 on 15 July.
- Dr. Bauman supported the Delta II GPS launch on 17 August.
- Mr. Wheeler supported a launch attempt of STS-128 on 24 August, and Mr. Barrett supported its successful launch on 28 August.
- Dr. Watson supported the Atlas IV PAN launch on 8 September
- Dr. Watson supported the launch attempt of the Delta II STSS Demo on 23 September, and Dr. Bauman supported the successful launch of the Delta II on 25 September.

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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
ACARS	Aircraft Communications Addressing and Reporting System
ADAS	ARPS Data Analysis System
AFSPC	Air Force Space Command
AFWA	Air Force Weather Agency
AMU	Applied Meteorology Unit
API	Antecedent Precipitation Index
ARPS	Advanced Regional Prediction System
ARW	Advanced Research WRF
AWIPS	Advanced Weather Interactive Processing System
CCAFS	Cape Canaveral Air Force Station
CGLSS	Cloud-to-Ground Lightning Surveillance System
CSR	Computer Sciences Raytheon
CWLIS	Catenary Wire Lightning Instrumentation System
EMS	Environmental Modeling System
ESRL	Earth System Research Laboratory
FR	Flight Rules
FSU	Florida State University
FY	Fiscal Year
GEMPAK	General Meteorological Package
GF	Gust Factor
GFSD	GF Standard Deviation
GSD	Global Systems Division
GUI	Graphical User Interface
HYSPLIT	Hybrid Single-Particle Lagrangian Integrated Trajectory
JSC	Johnson Space Center
KSC	Kennedy Space Center
LCC	Launch Commit Criteria
LDIS	Local Data Integration System
LDM	Local Data Manager
MAE	Mean Absolute Error
ME	Mean Error
MesoNAM	12-km resolution NAM
MIDDS	Meteorological Interactive Data Display System
MSFC	Marshall Space Flight Center
NAM	North American Model
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NMM	Nonhydrostatic Mesoscale Model
NOAA	National Oceanic and Atmospheric Administration
NWS MLB	National Weather Service in Melbourne, FL
POR	Period of Record
PW	Precipitable Water
QC	Quality Control
SMC	Space and Missile Center
SMG	Spaceflight Meteorology Group
SPoRT	Short-term Prediction Research and Transition
Tcl/Tk	Tool Command Language / Tool Kit
TS	Tropical Storm
USAF	United States Air Force
UTC	Universal Coordinated Time
WRF	Weather Research and Forecasting Model

Appendix A

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 in Jul 09
	Create distributions for 12-hour prognostic peak probabilities and incorporate into GUI	Apr 09	Jul 09	Delayed
	Final report	Jul 09	Sep 09	On Schedule
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	On Schedule
	Determine dates for lightning season stratifications	Jun 09	Sep 09	Reprogrammed
	Collect sounding data for May–Sep 2006–2008, and Oct 1989–2008 if needed, create candidate predictors for each stratification.	Jul 09	Nov 09	On Schedule
	Create and test new equations; compare performance with previous equations	Dec 09	Mar 10	On Schedule
	Incorporate equations in Excel GUI	Apr 10	Apr 10	On Schedule
	Final Report	May 10	Jul 10	On Schedule

Table title: AMU Project Schedule, 31 October 2009

AMU Project Schedule 31 October 2009				
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	On Schedule
	Create and test Excel GUI application	Dec 09	Jan 10	On Schedule
	Transition tool to MIDDS to provide 5-day peak wind forecasts, using model data	Jan 10	Jun 10	On Schedule
	Final Report and training	Jul 10	Sep 10	On Schedule
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	On Schedule
	Update GUI software code	Dec 09	Feb 10	On Schedule
	Final Report and training	Feb 10	Mar 10	On Schedule

AMU Project Schedule 31 October 2009				
AMU Projects	Milestones	Scheduled Begin Date	Scheduled End Date	Notes/Status
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	On Schedule
	Final report	Apr 10	Jun 10	On Schedule
HYSPLIT GUI Task	Develop, Code and Configure GUI	Apr 09	Sep 09	Completed
	Test and Evaluate GUI	Sep 09	Oct 09	On Schedule
	Final report and training	Oct 09	Nov 09	On Schedule

NOTICE