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Applied Meteorology Unit (AMU) Quarterly Report

Second Quarter FY-06 | Contract NAS10-01052 | 30 April 2006

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Executive Summary

This report summarizes the Applied Meteorology Unit (AMU) activities for the first quarter of Fiscal Year 2006 (October - December 2005). A detailed project schedule is included in the Appendix.

Task — Climatology of Cloud-to-Ground (CG) Lightning

Goal Develop climatologies of gridded CG lightning densities and frequencies of occurrence for the Melbourne, FL National Weather Service (NWS MLB) county warning area. These grids will be used to create a first-guess field for the lightning threat index map that is available on the NWS MLB website. Forecasters currently create this map from scratch. Having the climatologies as a background field will increase consistency between forecasters and decrease their workload.

Milestones Discovered and corrected two logic errors in the code that calculates the climatologies, created new climatologies from the corrected logic, and then delivered the new files to NWS MLB.

Discussion Some of the climatological values were incorrect for certain flow regimes and time periods. Two logic errors in the code were found while cleaning up and commenting the code for delivery to NWS MLB. One of the logic errors was the cause for the incorrect values in the climatologies. The errors were corrected and new climatologies were calculated.

Task — Forecasting Low-Level Convergent Bands Under Southeast Flow

Goal Provide guidance that will help improve forecasting of convergent bands under synoptic southeast flow. When these convergent bands occur, they can lead to missed cloud, rain, and thunderstorm forecasts that adversely affect operations at Kennedy Space Center/Cape Canaveral Air Force Station.

Milestones The data analysis was completed and the final report was started.

Discussion Data from 2 easterly-flow days were collected during January through March, bringing the total number of case days to 33. This number was reduced to 21 after 12 days were found to be contaminated by large scale synoptic features. The data sets were incorporated into the display and analysis tools and evaluated. It appears that the low-level wind speed and upper-level jet streak position have the greatest influence on convergent band formation and movement.

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Executive Summary, *continued*

Task: Objective Lightning Probability Tool: Phase II

Goal Develop a routine in the Meteorological Interactive Data Display System (MIDDS) that automatically gathers the data needed as input to the lightning probability forecast equations developed in Phase I of this task. The 45th Weather Squadron (45 WS) forecasters currently use a graphical user interface (GUI) in which they have to manually enter the data values to interact with the equations. The automated tool will save time in the process and allow the forecasters to do other duties relating to the daily forecast for operations.

Milestones The MIDDS utility was developed and tested.

Discussion The new MIDDS utility calculates the daily lightning probability through automatic collection of the predictor values and some additional information requested from the user. Several tests showed that output from the utility was equal to output from the GUI.

Task: RSA and Legacy Wind Sensor Evaluation

Goal Compare wind speed and direction statistics from the Legacy and RSA sensors on the Eastern (ER) and Western (WR) Ranges to determine the impact of the sensor changes on wind measurements. The 45 WS and 30th Weather Squadron need to know of any differences in the measurements between the two systems as they use these winds to issue weather advisories for operations.

Milestones Compared results from analyses of RSA and Legacy wind data from five towers on the ER and five towers on the WR.

Discussion Average wind speeds from the ER and WR RSA sensors show a small positive bias with respect to the Legacy sensors (< 0.5 kts). Peak wind speeds from the RSA sensors show a slightly larger bias with respect to the Legacy sensors (~1kt) with a tendency for the bias to increase at higher wind speeds.

Task: Volume Averaged Height Integrated Radar Reflectivity (VAHIRR)

Goal Transition the VAHIRR algorithm into operations on the Weather Surveillance Radar 1988 Doppler. The previous lightning launch commit criteria (LLCC) for anvil clouds to avoid triggered lightning were extremely restrictive and lead to unneccesary launch delays and scrubs. The VAHIRR algorithm was developed as a result of the Airborne Field Mill program as part of a new LLCC for anvil clouds. This algorithm will assist forecasters in providing fewer missed launch opportunities with no loss of safety compared with the previous LLCC.

Milestones Completed the VAHIRR code, test procedure, and algorithm report. Wrote the final memorandum and circulated for review.

Discussion Minor code modifications were made to the software for cleanup. A test approach was written to ingest data so that all the capabilities of the program can be used. The data dictionary was organized and added to the algorithm report to complete this document, and the final memorandum was written and circulated for review.

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Executive Summary, *continued*

Task	User Control Interface for ADAS Data Ingest
Goal	Develop a GUI to help forecasters at NWS MLB and the Spaceflight Meteorology Group (SMG) manage the data sets assimilated into the operational Advanced Regional Prediction System (ARPS) Data Analysis System (ADAS) at those offices.
Milestones	Made several bug corrections for the Linux operating system, and installed software onto the NWS MLB's new ADAS workstation.
Discussion	Several bugs and inconsistencies were identified and corrected between the Linux and Windows operating systems. Also, the NWS MLB's workstation was missing two key package manager files, which the AMU provided to NWS MLB for the final installation.
Task	Operational Weather Research and Forecasting (WRF) Model Implementation
Goal	Test and implement an appropriate configuration of the WRF model over the Florida peninsula for forecasting operations at SMG and NWS MLB to assist in the WRF transition effort taking place at both locations.
Milestones	Obtained a Beta version of the WRF Environmental Modeling System (EMS) software. Ran benchmark simulations to test the functionality of the EMS software. Configured the AMU's prototype ARPS ADAS/WRF to generate hourly analyses for input into the WRF EMS framework.
Discussion	Based on customer feedback, this task is proceeding by configuring and implementing an operational version of the WRF EMS software that uses ADAS for initial conditions. Designed specifically for use in the NWS, the EMS runs the model end-to-end, including output for visualization. Therefore, ADAS is being configured to provide initial conditions to WRF within the EMS.
Task	ADAS/ARPS Modifications for Improvement of Forecast Operations Task
Goal	Provide assistance in assimilating new datasets into ADAS, optimize the ADAS operating parameters, develop graphics that display the likelihood of supercell and significant tornado occurrence, and graphics showing the potential for CG lightning. Other ADAS fields have become an integral part of forecast operations at NWS MLB and SMG. These groups requested modifications and graphical products further improve the utility of ADAS/ARPS output.
Milestones	Created analysis products to display the threat for supercell thunderstorms and significant tornadoes, and designed a radar-based analysis graphic that depicts the threat for CG lightning.
Discussion	The supercell composite and significant tornado parameters were added to the ADAS output graphical data sets to provide high-resolution graphics that depict the threat areas for these phenomena. This will be especially helpful in tropical storm and hurricane environments. It is suggested that the radar-based lightning threat graphic be created every 5 minutes in a separate ADAS analysis cycle, to help with nowcasting of lightning initiation.

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 Lambert (321-853-8130, lambert.winifred@ensco.com). If your mailing information changes or if you would like to be removed from the distribution list, please notify Ms. Lambert 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 on each task.

AMU ACCOMPLISHMENTS DURING THE PAST QUARTER

SHORT-TERM FORECAST IMPROVEMENT

Climatology of Cloud-to-Ground Lightning (Ms. Lambert)

The forecasters at the National Weather Service in Melbourne, FL (NWS MLB) produce a daily cloud-to-ground (CG) lightning threat index map for their county warning area (CWA) that is available on their web site. Given the hazardous nature of frequent lightning in central Florida, especially during the warm season months of May through September, this map helps users discern the probable lightning threat for the day at any location of interest. The map is color-coded in five levels from Very Low to Extreme threat (Figure 1). The placement of the different threat levels in the CWA depend on the location of the low-level ridge, forecast sea breeze propagation, and other factors that influence the spatial distribution of thunderstorms over the CWA. The forecasters create each threat index map manually from a blank map using considerable time and effort. As a result, the NWS MLB forecasters requested the AMU to create gridded warm-season CG lightning climatologies that could be used as a first-guess starting point when creating the lightning threat index map. This would increase consistency between forecasters and decrease workload, ultimately benefiting the end-users of the product. It would also provide forecasters the ability to extend the lightning threat forecast into Day-2 and beyond during the warm season.

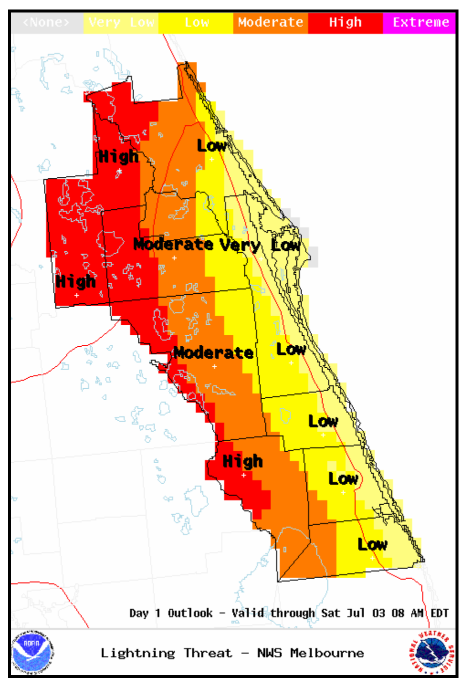

Figure 1. The NWS MLB Lightning Threat map for 3 July 2004. The color legend for each threat level is at the top of the image.

Issues with Data and Code

Ms. Lambert delivered all files for the 24- and 6-hour climatologies of CG frequency and density to NWS MLB. While creating the images for the climatologies, Mr. Matt Volkmer of NWS MLB noticed that the SE-1 flow regime (low-level ridge axis between Tampa and Jacksonville, FL) climatological values in the 0600–1200 UTC time period were not as expected. In general, this is a period of minimal to no lightning activity, yet significant values of frequency and density appeared along the west coast of the Florida peninsula (see Figure 2a).

The AMU was also tasked to deliver the code that calculates the climatologies to NWS MLB. While cleaning up and adding comments to the code prior to delivery, Ms. Lambert discovered two logic errors in how the data were processed. The first error caused incorrect days to be included in the flow regime climatologies, but the difference in the climatological values caused by this error were minimal at worst, negligible at best. Nonetheless, climatological values for all regimes had to be re-calculated after this error was corrected. The second error caused the erroneous values noted by Mr. Volkmer in the SE-1 regime. This error also affected the PAN (ridge extending eastward over the Florida panhandle) and OTHER (undefined flow regime) regimes.

Ms. Lambert fixed both logic errors, added comments to identify where the code had been changed and why, and then recalculated all the climatologies with the corrected logic. The new files for the SE-1 regime were sent to NWS MLB for display and analysis, and the images showed the climatologies to be consistent with what would be expected for each time period. Figure 2b shows the density climatology after the logic errors were corrected. There is little to no lightning activity over the peninsula, and minimal activity over the adjacent waters.

NWS MLB personnel selected a date in April for Ms. Lambert to deliver the code and data, and provide training on how to run the programs.

Documentation

Ms. Lambert presented the results of this task at the 2nd Conference on Meteorological Applications of Lightning Data that was held during the American Meteorological Society (AMS) Annual Meeting in Atlanta, GA. She also began writing a final memorandum that will discuss aspects of the data and code, and provide instructions on how to run the programs.

For more information on this work, contact Ms. Lambert at lambert.winnie@ensco.com or 321-853-8130.

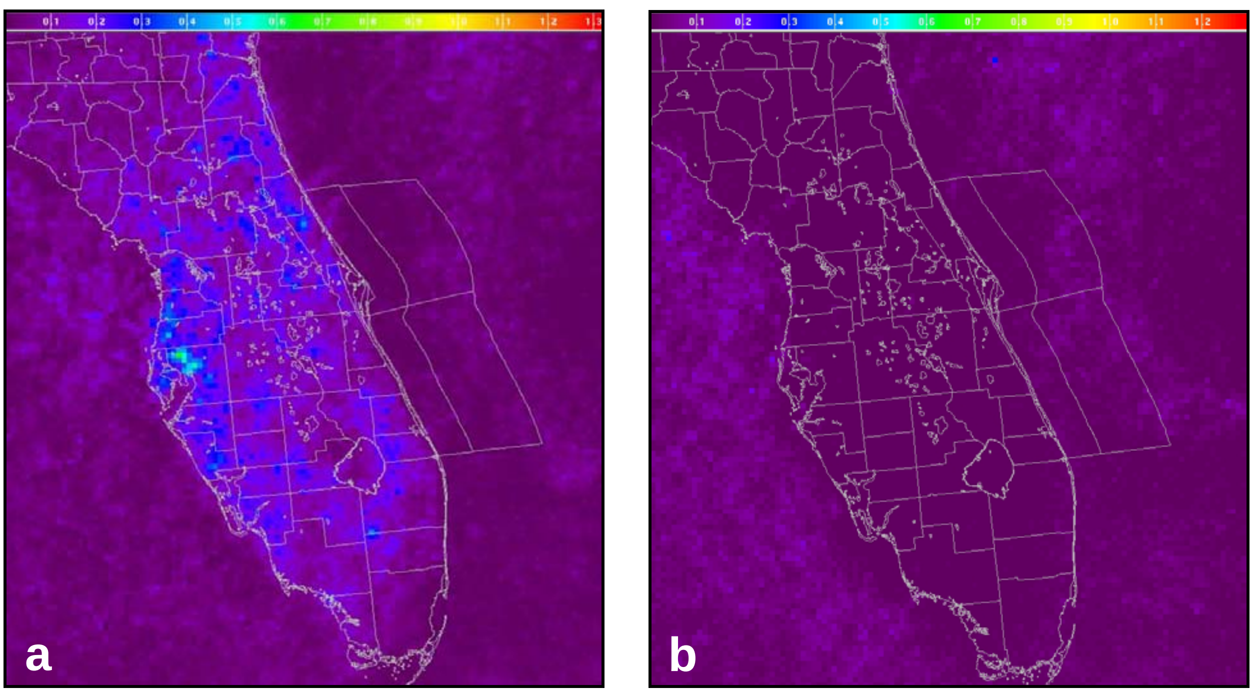

Figure 2. The 0600–1200 UTC CG lightning density climatology for the SE-1 flow regime: a) the values calculated with the logic errors in the code, and b) the values calculated after the logic errors were corrected.

Forecasting Low-Level Convergent Bands Under Southeast Flow (Dr. Bauman)

Forecasting the occurrence and timing of convergent bands under synoptic southeast flow is challenging for 45th Weather Squadron (45 WS) operational personnel. When the convergent bands occur, they are sometimes associated with rain, gusty winds and thunderstorm activity. Such weather could cause suspension of daily ground operations as well as violations of Launch Commit Criteria (LCC) and Flight Rules (FR) during operations. At other times the convergent bands only produce benign clouds. There have also been cases of southeast flow with no clouds present. Southeast flow leading to the production of convergent bands has occurred in every month of the year, though the forecast precursors may vary seasonally. The 45 WS requested that the AMU study convergent band formation under southeast flow and attempt to determine precursors to convergent band formation during southeast flow regimes. The ability of the 45 WS to predict weather caused by these convergent bands would work toward enhancing protection of personnel and material assets of the 45th Space Wing, Cape Canaveral Air Force Station (CCAFS), and Kennedy Space Center (KSC).

Dr. Bauman noticed that convergent bands were not just developing during southeast flow, but during any flow with an easterly component. Therefore, he collected data for days with any prevailing low-level easterly flow. He added 2 days from January–March to the archive resulting in a total of 33 events. The dates of all the events are in the following table:

Apr 2005	5	11	12				
May	12	13	16	17	18	19	20
Jun	9	14	27	28			
Jul	7	20	25				
Aug	15	16	18	23	24		
Sep	19	26	28				
Oct	3	11					
Nov	4	14	15				
Dec	14						
Jan 2006	20						
Feb	16						

Of the 33 case days collected, 21 were valid easterly flow days. Twelve days were eliminated from the analysis due to contamination from tropical cyclones or large scale synoptic features impacting the KSC/CCAFS weather. Of the 21 case days, 6 had a southeasterly component, 3 had a northeasterly component and the other 12 days presented either easterly or light and variable low-level winds.

Dr. Bauman conducted a detailed analysis of the data collected from the 21 case days. He compared the information in the database to look for similarities, differences and patterns for days with and without convergent bands. The data included the following parameters:

- Low-level wind speed and direction,
- Atlantic high pressure ridge position,
- Upper-level wind speed and direction plus any jet streak position,
- Convergent band location/movement,
- Precipitation location/movement,
- Sea surface temperatures,
- Water vapor satellite images, and
- Skew-T indices from five Florida and the Nassau, Bahamas sounding sites.

Dr. Bauman found that the most influential parameters that appear to drive convergent band formation, or lack of it, are low-level (≤ 700 mb) wind speed and the 250 mb jet streak position. Convergent bands tended to develop and/or move onshore only when the low-level easterly flow was in excess of about 9 kts. Using the Uccellini jet streak model (Uccellini and Kocin 1987) the ageostrophic motions and divergence at jet streak level are shown in Figure 3. Although at times subtle, a jet streak with speeds of only 20–40 kts can be enough to influence the upper-level divergence and convergence in the vicinity of the jet streak. In the KSC/CCAFS area, especially during the warm season, the jet streak core wind speed could be significantly higher than the surrounding winds at 250 mb, which can be nearly calm. Dr. Bauman conducted an analysis of the upper-level winds using 40 km Rapid Update Cycle (RUC) model output and 4 km Advanced Regional Prediction System (ARPS) output and determined that the right jet exit region or left jet entrance region significantly suppressed convection on days that appeared similar to days with convection.

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

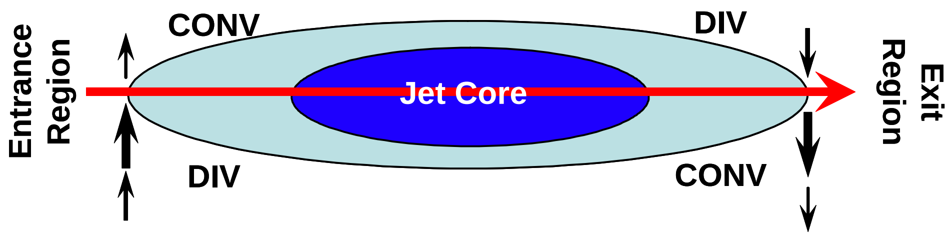

Figure 3. Four quadrant straight jet streak model showing ageostrophic motions at upper levels (250 mb).

Objective Lightning Probability Tool: Phase II (Ms. Lambert and Mr. Wheeler)

The 45 WS forecasters include a probability of lightning occurrence in their daily morning briefings. This information is used by personnel involved in determining the possibility of violating LCC, evaluating FR, and planning for daily ground operation activities on KSC/CCAFS. A set of logistic regression equations that calculate the probability of lightning occurrence was developed by the AMU in Phase I of this task. These equations outperformed several standard forecast methods used in operations. The graphical user interface (GUI), developed in Phase I allows forecasters to interface with the equations by entering parameter values to output a probability of lightning occurrence. The forecasters must gather data from the morning sounding and other sources, then manually input that data into the GUI. The 45 WS requested that a tool be developed on the Meteorological Interactive Data Display System (MIDDS) that retrieves the required parameter values automatically for the equations to calculate the probability of lightning for the day. This will reduce the possibility of human error and increase efficiency, allowing forecasters to do other duties. The 45 WS also requested modifications to the data that are input to the equations in the hope of improving accuracy.

Mr. Wheeler developed the MIDDS utility that calculates the daily lightning probability. This utility collects the predictor values automatically from the MIDDS, only requiring the user to input the flow regime for the day and to answer whether or not lightning occurred on the previous day. Output from the MIDDS utility was compared to that of the GUI and found to be equal. Therefore, the utility is ready to be used by the 45 WS.

Ms. Lambert prepared and submitted a preprint describing this task that will be presented at the 1st International Lightning Meteorology Conference (ILMC) in Tucson AZ. The ILMC will be held on April 26–27 immediately following the 19th International Lightning Data Conference, which will be held on April 24–25. Both conferences are sponsored by Vaisala.

Contact Ms Lambert at 321-853-8130 or lambert.winfred@ensco.com or Mr. Wheeler at wheeler.mark@ensco.com for more information.

INSTRUMENTATION AND MEASUREMENT

I&M and RSA Support (Mr. Wheeler)

There are still issues with the Advanced Weather Interactive Processing System (AWIPS) Operational Build 4 (OB4) installation, all of which were analyzed by Lockheed Martin personnel. Mr. Wheeler worked with Mr. Wahner of CSR to update the data sets and displays. Mr. Wheeler also identified several software and data problems with AWIPS and FXC. Mr. Wahner fixed most of the problems, and installed OB4 on the NASA AWIPS workstation.

RSA and Legacy Wind Sensor Evaluation (Dr. Short and Mr. Wheeler)

Launch Weather Officers, forecasters, and Range Safety analysts need to understand the performance of wind sensors at the Eastern Range (ER) and Western Range (WR) for weather warnings, watches, and advisories, special ground processing operations, launch pad exposure forecasts, user LCC forecasts and evaluations, and toxic dispersion support. Through the Range Standardization and Automation (RSA) program, the current weather tower wind instruments are being switched from the Legacy cup-and-vane sensors to sonic sensors. The Legacy sensors measure wind speed and direction mechanically, but the sonic RSA sensors have no moving parts. These differences in wind measuring techniques could cause differences in the statistics of peak wind speed and wind direction variability. The 45 WS and the 30th Weather Squadron (30 WS) requested that the AMU compare the data between RSA and Legacy sensors to determine if there are significant differences between the systems.

Dr. Short and Mr. Wheeler completed their analyses of Legacy and RSA wind sensor data from the WR and ER. They processed a large sample of 1-minute Legacy and RSA data from five towers on each range. The Legacy and RSA instrument pairs used in the analyses were mounted at the same levels on each tower, ranging from 12–492 ft above ground level. The instrument pairs were in within ~15 ft of each other. The wind sensor data included information used to evaluate user LCC: the 1-minute average wind speed/direction, and the associated 1-minute peak wind speed/direction. The average and peak wind data were created from 60 samples of 1-sec observations taken each minute.

A total of 153,951 minutes from the WR and 317,056 minutes from the ER were processed. The comparisons were done using data from the instruments on the upwind side of each tower and excluded instruments that showed inconsistent performance. Performance tests were based on differences between Legacy and RSA readings of 1-minute average wind speed and direction. Details of the performance tests for each RSA/Legacy pair are documented in the final reports (Short and Wheeler, 2006a and 2006b). Instruments that passed the performance tests were used for the composite comparisons of average and peak wind data. The composite comparisons of average and peak wind statistics were based on 57% of the WR sample and 54% of the ER sample.

The overall average and peak wind values found during the comparison are in the following table:

	WR Legacy	WR RSA	ER Legacy	ER RSA
Average:	10.31	10.57	8.09	8.47
Peak:	13.42	14.48	9.79	10.73

The overall average and peak wind speeds were higher at the WR because that data was confined to a 6-hour interval during the afternoon hours (1600–2000 UTC), which tends to be a windy time of day near the coast. The ER data sample spanned the full diurnal cycle with frequent low wind speeds during the late night and early morning hours and higher wind speeds in the afternoon.

Composite Comparisons

In order to evaluate sensor performance over the full range of observed wind speeds, Dr. Short compared data from all Legacy/RSA sensor pairs that passed the performance tests, conditioned on the Legacy wind speed. That is, for each Legacy sensor having a one-minute average wind speed of 1 kt the corresponding RSA one-minute average wind speed was identified. This procedure was followed for all Legacy average wind speeds, knot-by-knot, up to 25 kts. The average results are plotted in Figure 4a. Above 25 kts, the sample size used for Figure 4a fell below 30 observations for Legacy average wind speeds and the comparison results became noisy.

Dr. Short also computed a peak wind speed for all Legacy/RSA sensor pairs that passed the performance tests, conditioned on the Legacy peak. The same procedure as for the average wind speeds in Figure 4a was followed for all Legacy peak wind speeds up to 31 kts for the WR and 29 kts for the ER. The results are plotted in Figure 4b. Above 31 kts the sample size fell below 30 observations for WR Legacy peak wind speeds and the comparison results became noisy. The same was true for the ER Legacy peak wind speeds above 29 kts.

Figure 4a shows a small positive bias of the RSA average wind speeds with respect to the Legacy speeds, over the range from 1 to 25 kts. Figure 4b shows a slightly larger positive bias of RSA peak wind speeds, and suggests a weak tendency for the RSA peak wind speed bias to increase with increasing wind speed.

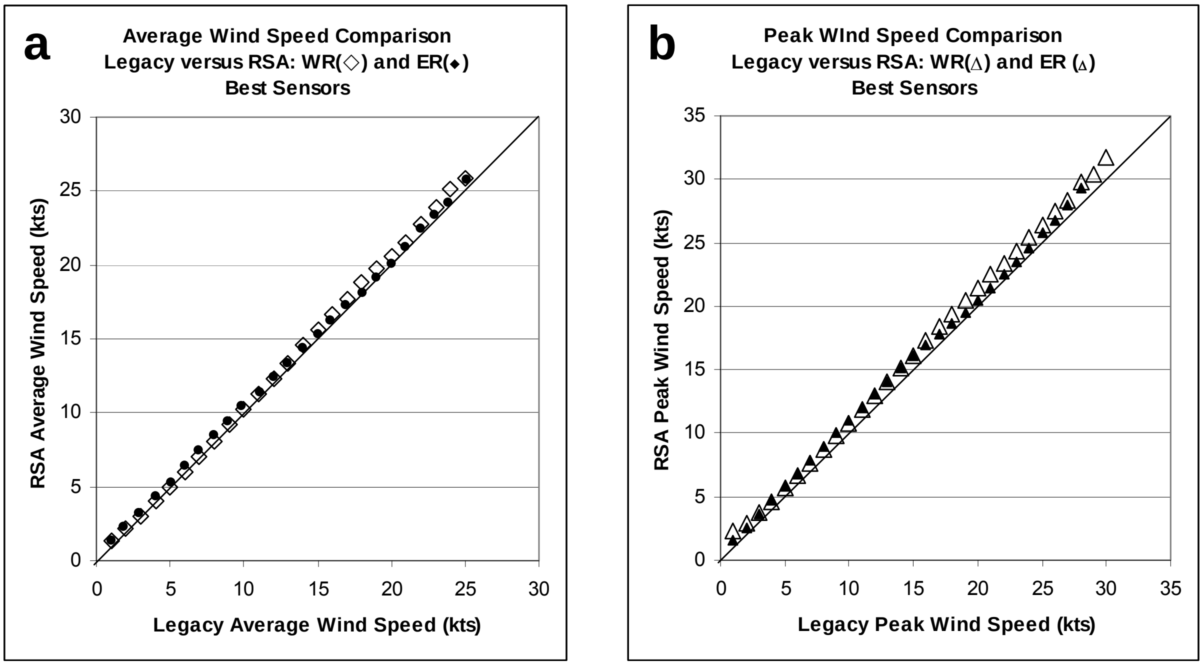

Figure 4. a) Average and b) peak wind speed comparisons for the sensors on 5 ER and 5 WR towers, using data from May and June 2005. Each data point had at least 30 1-minute samples.

The seemingly small differences in average and peak wind speeds reported by the Legacy and RSA sensors are actually statistically significant. This is due to the large sample size and the small standard deviation (0.9 kts) of the 1-minute wind speed differences between the sensors. From a practical point of view the differences in peak wind speeds are the most important. They indicate that the change to ultrasonic sensors will result in a small increase in the observed peak wind speeds. A small increase in peak speeds can decrease launch availability, depending on the LCC threshold wind speed. For example, the percentage of peak wind speeds ≤ 20 kts in the Legacy data was 95.2%. For the same 20 kt threshold the percentage for RSA data was 92.3%, indicating more occurrences of higher wind speeds.

One significant difference between the ER and WR studies was the presence of anomalously high peak wind speeds found in the data from one ER RSA sensor. The anomalous peak wind directions were clustered at 60° intervals and the anomalous peaks were absent in the afternoon, suggesting either interference from wildlife (birds, bats, insects) or the signature of a failure mode in the instrument influenced by the diurnal cycle in temperature and humidity.

Because the WR data were restricted to the afternoon hours, it may be prudent to examine some night-time or early morning data to determine if similar anomalous behavior is detected.

Final Reports

Dr. Short and Mr. Wheeler distributed the final report containing the WR results (Short and Wheeler 2006a). The final report for the ER results will be completed soon (Short and Wheeler 2006b).

Contact Dr. Short at 321-853-8105 or short.david@ensco.com, or Mr. Wheeler at wheeler.mark@ensco.com for more information.

Volume Averaged Height Integrated Radar Reflectivity (VAHIRR) Algorithm (Ms. Miller, Mr. Gillen, and Dr. Merceret)

Lightning LCC (LLCC) and FR are used for all launches and landings, whether Government or commercial, using a Government or civilian range (Willett et al. 1999). These rules are designed to avoid natural and triggered lightning strikes to space vehicles, which can endanger the vehicle, payload, and general public. The current LLCC for anvil clouds, meant to avoid triggered lightning, have been shown to be overly restrictive. They ensure safety, but falsely warn of danger and lead to costly launch delays and scrubs. A new LLCC for anvil clouds, and an associated radar algorithm needed to evaluate that new LLCC, were developed using data collected by the Airborne Field Mill (ABFM) research program managed by KSC (Dye et al. 2006). Dr. Harry Koons of Aerospace Corporation conducted a performance analysis of the VAHIRR algorithm from a safety perspective. The results suggested that the LLCC based on this algorithm would assist forecasters in providing a lower rate of missed launch opportunities with no loss of safety compared with the previous LLCC.

The VAHIRR algorithm, needed to evaluate the new LLCC, is being implemented using data from the Weather Surveillance Radar 1988 Doppler (WSR-88D) as it is the only radar available to users outside of the ER. The AMU developed the new VAHIRR software for implementation using WSR-88D data (Gillen et al. 2006). Mr. Gillen and software engineers of ENSCO, Inc. are working closely with key personnel at the Spaceflight Meteorology Group (SMG) and NASA to ensure smooth and proper transition of this product into operations at SMG. Transition to 45 WS and 30 WS is not part of the current tasking, but the software should also work at those sites with appropriate modifications.

Ms. Miller made changes to the source code to complete the definitions of the routines and variables, then deleted all unused variables to clean up the code. She also compiled a list of the requirements around which the VAHIRR algorithm was designed, and then mapped all possible execution scenarios into a single concise test case. She searched for a means to create tailored Level II WSR-88D data for input with assistance from personnel at the ROC. They instructed Ms. Miller on how to modify a task in the ORPG that preprocesses WSR-88D base data to create Radar Product Generator (RPG) base data for consumption by RPG algorithms such as VAHIRR. This method was used in tests that satisfied and failed the algorithm conditions, provided position interpretation over a cross section of azimuth and range combinations, and demonstrated variable control to produce clear results. Ms. Miller compiled a list of all variable definitions, units, and ranges for the algorithm report data dictionary, and is in the process clarifying and adding final changes to the VAHIRR memorandum.

Mr. Gillen presented the results of this work at the 12th Conference on Aviation, Range, and Aerospace Meteorology that was held during the American Meteorological Society (AMS) Annual Meeting in Atlanta, GA.

For more information on this task, contact Ms. Miller at miller.juli@ensco.com or 321-783-9735 ext. 221; Mr. Gillen at gillen.robert@ensco.com or 321-783-9735 ext. 210; or Dr. Merceret at Francis.J.Merceret@nasa.gov or 321-867-0818.

MESOSCALE MODELING

User Control Interface for ADAS Data Ingest (Mr. Keen and Mr. Case)

The integrity of real-time, continuous diagnostic grids from the operational ARPS Data Analysis System (ADAS) has become very important, with a requirement to be operationally managed at the forecaster level. Forecasters at NWS MLB and SMG have the need for a user-friendly GUI in order to quickly and easily interact with ADAS to maintain or improve the integrity of each 15-minute analysis cycle. The intent is to offer operational forecasters the means to manage and quality control the observational data streams ingested by ADAS without any prior expertise of ADAS required. Therefore, the AMU was tasked to develop a GUI tool to help forecasters manage the data sets assimilated into ADAS.

Mr. Case discovered some inconsistencies between the Windows and Linux screen images upon installing the GUI software on a Linux system. As a result, he captured new images for the final task memorandum / User's Guide based on the Linux installation of the application. This will ensure that the User's Guide examples are consistent in appearance with a Linux platform, on which SMG and NWS MLB will run the application.

Mr. Case also identified some software bugs that need to be corrected before final release. Mr. Keen wrote and implemented the software fixes for the control GUI. Mr. Case then installed the GUI on the NWS MLB ADAS workstation; however, missing package manager files in the Red Hat Enterprise operating system prevented the application from running properly at first. Mr. Keen identified the package manager files required for proper functionality. The final installation was completed in early April.

Contact Mr. Case at 321-853-8264 or case.jonathan@ensco.com, or Mr. Keen at 321-783-9735 x248, or keen.jeremy@ensco.com for more information on this work.

Operational Weather Research and Forecasting (WRF) Model Implementation (Mr. Case)

The WRF model is the next generation community mesoscale model designed to enhance collaboration between the research and operational sectors. The NWS as a whole has begun a transition toward WRF as the mesoscale model of choice to use as a tool in making local forecasts. AMU customers have derived great benefit from the maturity of ADAS in support of its varied forecast programs, and would like to use ADAS for providing initial conditions for WRF. To assist in the WRF transition effort, the AMU has been tasked to conduct preliminary work towards testing and implementing an appropriate configuration of the WRF model over the Florida peninsula. This includes conducting a hardware performance comparison study, configuring and testing an ADAS/WRF setup, and modifying the ADAS GUI for controlling the tunable initialization and parameterization settings for ADAS/WRF.

Personnel at SMG and NWS MLB agreed to have the AMU develop a configuration of ADAS that will serve to initialize the WRF model within the Environmental Modeling System (EMS) software framework. Developed by the NWS Science Operations Officer (SOO) Science and Training Resource Center (STRC), the EMS is a complete, full physics, numerical weather prediction package that incorporates dynamical cores from both the National Center for Atmospheric Research's Advanced Research WRF (ARW) and the National Centers for Environmental Prediction's Non-Hydrostatic Mesoscale Model (NMM) into a single end-to-end forecasting system (Rozumalski 2005).

The EMS performs nearly all pre- and post-processing and can be run automatically to obtain external grid data for WRF boundary conditions, run the model, and convert the data into a format that can be viewed within AWIPS. The EMS has also incorporated the WRF Standard Initialization (SI) GUI, which allows the user to set up the domain, dynamical core, resolution, etc., as described in the AMU Quarterly Report from the 4th Quarter (July–September) FY-2005. In addition to the SI GUI, the EMS contains a number of configuration files with extensive comments to help the user select the appropriate input parameters for model physics schemes, integration timesteps, etc. Therefore, because of its streamlined capability, it is quite advantageous to configure ADAS to provide initial condition data to the EMS WRF. Also, the ADAS GUI will probably not need to be modified for controlling tunable initialization and parameterization settings since the EMS already provides much of this capability.

One of the biggest potential benefits of configuring ADAS for ingest into the EMS is that the ADAS analyses could be used to initialize either the ARW or NMM versions. Currently, the ARPS and ADAS software have a conversion routine only for the ARW dynamical core. However, since the NMM runs about 2.5 times faster than the ARW, it would be advantageous to run an ADAS/NMM configuration due to the increased efficiency. To accomplish this, Mr. Case obtained a Beta version of the WRF EMS software from the NWS SOO STRC. The software installed easily on an ENSCO Linux cluster, and he ran a benchmark simulation prior to a run with near real-time data.

Next, Mr. Case configured a set of shell scripts to generate 0-hour initialization files for the ADAS/ARW. This process creates the ADAS analysis, converts it to an ARW initialization file, and then writes the initialization file to a pressure-coordinate file in the GRIdded Binary (GRIB) data format, which is the standard input data format for WRF. To ingest the pressure-coordinate ADAS GRIB files into WRF, Mr. Case created a file specific to the variables found in the ADAS dataset. This file defines the GRIB numerical identifiers for each variable, the vertical coordinates, etc. of the external grid dataset being interpolated to the WRF grid. Finally, a configuration file unique to the EMS was created for the ADAS initialization files in which the file-naming convention, directory location, and time attributes are defined.

Mr. Case ran a successful NMM simulation using an ADAS analysis for the initial conditions. However, there is one deficiency that needs to be corrected for this procedure to work properly. The cloud and precipitation mixing ratios derived by ADAS were not interpolated to the NMM grid. There appears to be a mismatch in the variable naming convention during the NMM pre-processing that occurs in the vertical interpolation step. Mr. Case will collaborate with the WRF Developmental Testbed Center to identify and correct this problem.

For more information, contact Mr. Case at (321)-853-8264 or case.jonathan@ensco.com.

ADAS/ARPS Modifications for Improvement of Forecast Operations (Mr. Case)

For the past several years, ADAS mesoscale analyses have been produced in an experimental, operational mode at NWS MLB and SMG. Since that time, ADAS fields have become an integral part of forecast operations and additional modifications and graphical products are desired to further improve their utility. The AMU was tasked to

- Ingest additional unique local data sets,
- Examine the ADAS parameters for an optimized configuration when analyzing observations,
- Implement new visualization products to help forecasters assess the potential for supercell thunderstorms and significant tornadoes, especially those associated with tropical activity, and
- Implement techniques to improve threat assessments of lightning potential.

The following sections focus on the new ADAS visualization products developed by Mr. Case for this task.

Severe Weather Threat Graphics

The two severe weather threat assessment parameters tasked to be implemented within ADAS are the Supercell Composite Parameter (SCP) and Significant Tornado Parameter (STP) (Thompson et al. 2002). The SCP was designed to identify areas with supercell thunderstorm potential through a combination of several instability and shear parameters that are then normalized to supercell "threshold" values based on previous studies. The STP was designed to identify areas that favor supercells producing significant tornadoes (F2 or greater intensity) versus non-tornadic supercells, also normalized by key threshold values based on previous studies. Both indices apply only to discrete storms, not other convective modes.

Taken from Thompson et al. (2003), the formulations for the fixed-layer SCP and STP are:

$$SCP = \left(\frac{MUCAPE}{1000\ J\ kg^{-1}}\right) \times \left(\frac{BRN\ Shear}{40\ m^2 s^{-2}}\right) \times \left(\frac{0\text{-}3\ km\ SRH}{100\ m^2 s^{-2}}\right) \quad (1)$$

$$STP = \left(\frac{SBCAPE}{1500\ J\ kg^{-1}}\right) \times \left(\frac{0\text{-}6\ km\ Shear}{20\ m\ s^{-1}}\right) \times \left(\frac{0\text{-}1\ km\ SRH}{150\ m^2 s^{-2}}\right) \times \left(\frac{[2000 - SBLCL]}{1000\ m}\right) \quad (2)$$

where MUCAPE is the convective available potential energy (CAPE) based on the most unstable parcel in the lowest 300 mb, SBCAPE is the surface-based CAPE, BRN Shear is the shear term of the bulk Richardson number, SRH is the storm relative helicity, and SBLCL is the surface-based layer lifting condensation level.

Values of SCP greater than 1 indicate a strong threat for supercells while values under 1 indicate ordinary thunderstorms. For the STP, values greater than 1 indicate a strong threat for significant tornadic supercells, whereas values under 1 suggest non-tornadic supercells. In the Storm Prediction Center's study, they found that the mean SCP exceeded 4 for supercells, but averaged only 0.2 for non-supercells. They also found that the mean STP for significantly tornadic supercells at 3.4 was statistically significantly larger than the mean STP of 1.2 for non-tornadic supercells (Thompson et al. 2003).

Mr. Case calculated a variation of SCP by replacing MUCAPE with SBCAPE in Equation 1, and STP as in Equation 2 for graphical output in the ADAS using a 4-km horizontal grid spacing. The graphical images were generated every 15 minutes on 13 August 2004, the day that Hurricane Charley approached and made landfall on the Florida peninsula. Several tornadoes struck the interior of the peninsula in advanced of Hurricane Charley's landfall during the daylight hours of 13 August. The NWS MLB provided Mr. Case with briefing slides from the Storm Prediction Center (SPC), containing graphical output of the SCP and STP from the RUC model, which serves as background fields to the ADAS analyses. Therefore, this day served as a good benchmark to compare and validate the ADAS graphics for SCP and STP against the smoother RUC analyses from SPC.

The composite reflectivity at 1700 UTC mapped to the ADAS 4-km grid depicts a substantial band of convection across the south-central interior portion of the peninsula (Figure 5). Many cells in this band were capable of producing tornadoes due to the large amounts of instability and shear present. The SPC plots of SCP (Figure 6a) and STP (Figure 6b) from the RUC analyses shows a threat area for supercells and significant tornadoes across much of south Florida, then extending northeast to offshore of east-central Florida at 1700 UTC (Figure 6a). Tornadoes were reported after this analysis time from Lake Okeechobee northward towards central Florida (Figure 6b).

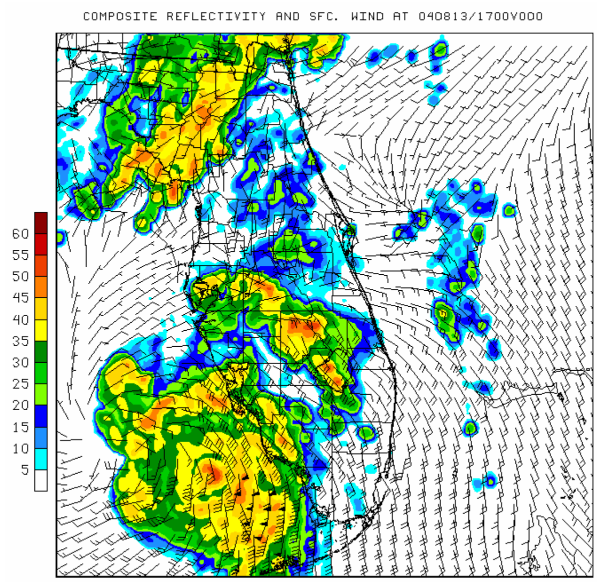

Figure 5. ADAS composite reflectivity and surface winds at 1700 UTC 13 Aug 2004.

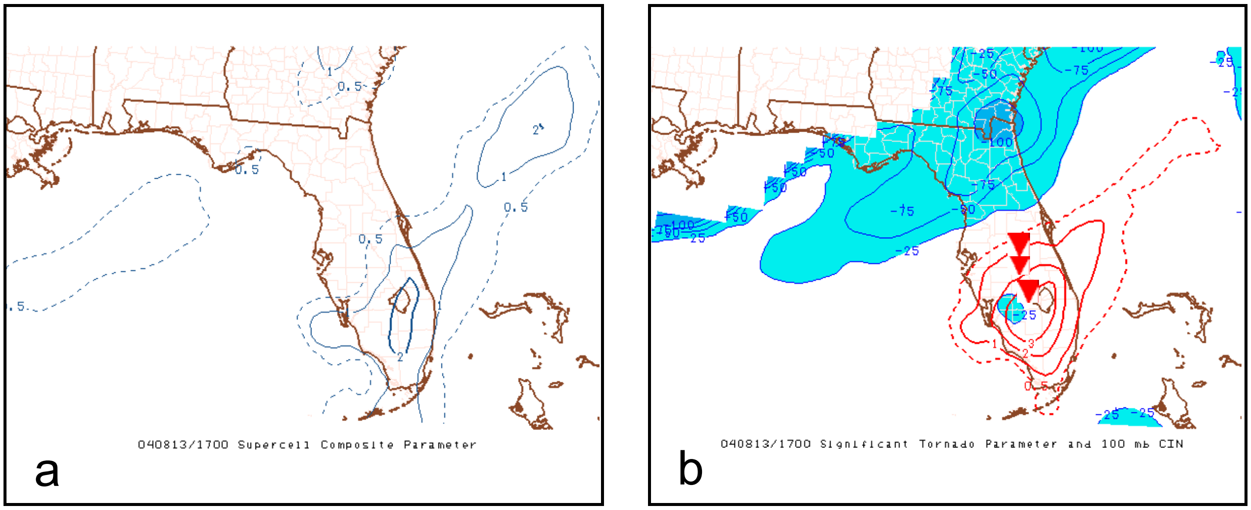

Figure 6. SPC graphics derived from the RUC model for (a) the SCP, and (b) the STP (red contours) with tornado reports following the time of the analysis (red triangles).

The 4-km ADAS analyses of SCP and STP are shown in Figures 7 and 8, respectively. Mr. Case proposes two 4-panel graphics for operational use, depicting the SCP, STP, and the individual plots of instability and shear contributing to the composite parameters. Much more detail can be seen in the ADAS plots primarily due to the ingest of Level II WSR-88D data from all Florida sites. The reflectivity and radial velocity data provide a substantial amount of detail in three dimensions, thereby providing the capability of a more precise diagnosis of the developing severe weather threat. Notice that the SCP and STP are mostly valid for convective-free regions, as much of the instability is lost in areas of active convection. This reduces the parameters to below a value of 1 north and west of Lake Okeechobee.

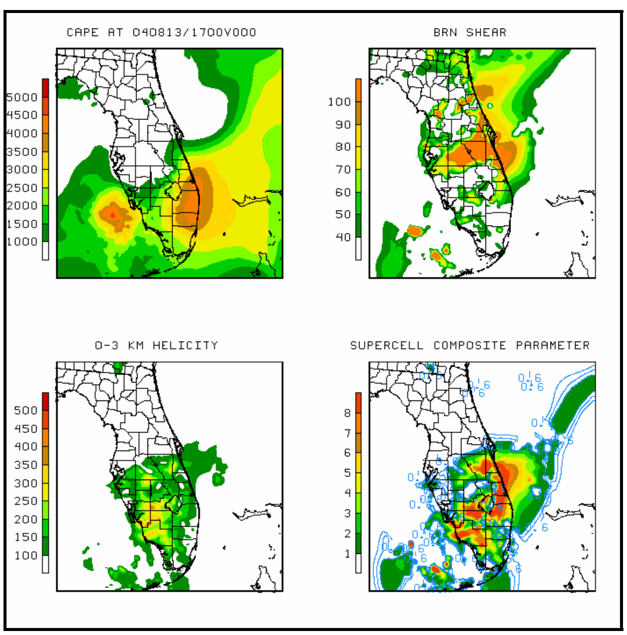

Figure 7. AMU-proposed 4-panel graphic of the CAPE (*upper left*), Bulk Richardson Number Shear (*upper right*), 0-3 km helicity (*lower left*), and SCP (*lower right*) from the 4-km ADAS analysis at 1700 UTC 13 Aug 2004.

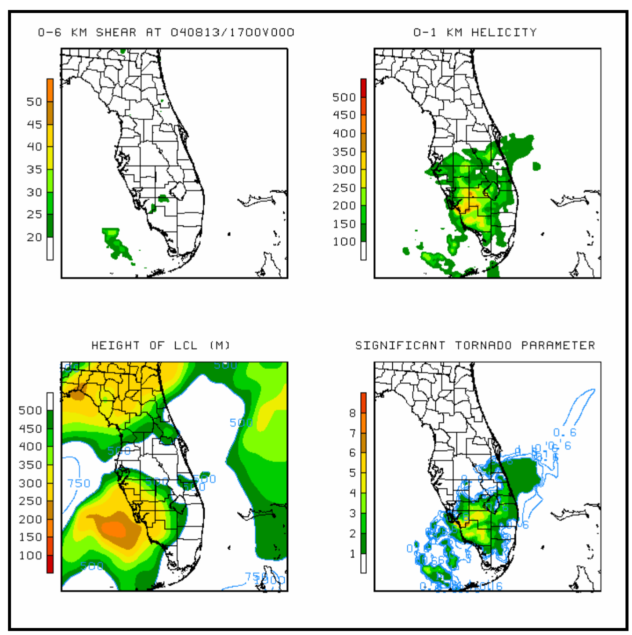

Figure 8. Same as Figure 7 but for the 0-6 km shear (*upper left*), 0-1 km helicity (*upper right*), LCL height (*lower left*), and STP (*lower right*).

CG Lightning Threat Graphic

Gremillion and Orville (1999) conducted a study at KSC for identifying CG lightning initiation signatures based on reflectivity thresholds from the WSR-88D at key thresholds in the vertical temperature profile. They interpolated radar data from the NWS MLB WSR-88D onto a Cartesian grid with 1-km horizontal spacing and 0.5-km vertical spacing. Using results from 39 total storm cells in the KSC area (31 with CG lightning and 8 without), the authors computed skill scores of various lightning initiation signatures based on reflectivity thresholds at the -10°C, -15°C, and -20°C levels. The most skillful reflectivity thresholds were > 40 dBZ at -10°C, > 30 dBZ at -15°C, and > 20 dBZ at -20°C. The skill decreased with colder temperatures.

Mr. Case developed a 4-panel graphic that displays the ADAS composite reflectivity, and the reflectivity thresholds at the -10°C, -15°C, and -20°C temperature levels. The goal was to create a product that would provide forecasters with a meaningful decision aid in nowcasting CG lightning threats in real time. To accomplish this and to keep the skill scores meaningful, an ADAS grid was devised at the same resolution as that used in the Gremillion and Orville (1999) study. Mr. Case modified the horizontal and vertical dimensions in order to maximize the analysis domain while minimizing the amount of computational time it took to complete the analysis cycle. Ultimately, it would be most helpful to create the 1-km ADAS product every 5 min, in order to generate a product for each volume scan of the WSR-88D.

A sample 4-panel graphic valid at 1900 UTC 13 August 2004 is shown in Figure 9. The composite reflectivity in the upper-left panel shows strong convective cells (> 50 dBZ) west of the KSC/CCAFS area. These cells were propagating south to north and producing CG lightning as seen in the hourly National Lightning Detection Network plot in Figure 10. Each of the reflectivity threshold plots in Figure 9 are in the vicinity of the actual CG lightning in Figure 10. Follow-on work could be done to examine the skill of these ADAS products and determine the best reflectivity thresholds that indicate concurrent CG lightning.

For more information, contact Mr. Case at (321)-853-8264 or case.jonathan@ensco.com.

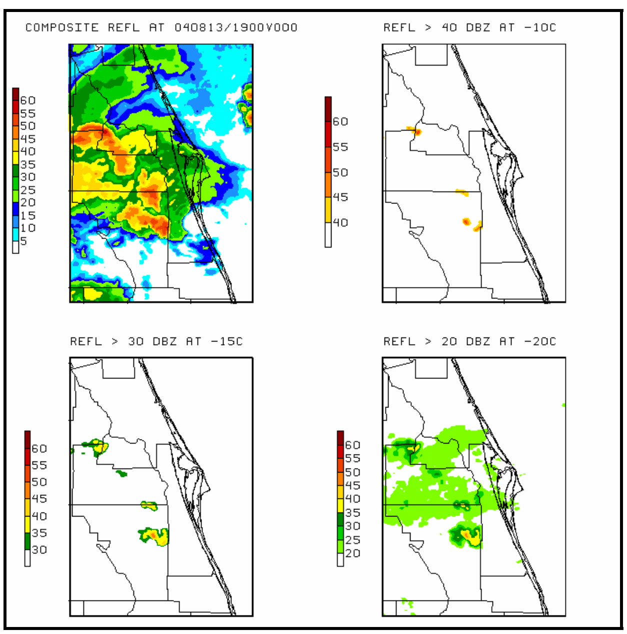

Figure 9. AMU-proposed 4-panel graphic showing the composite reflectivity (*upper left*), reflectivity > 40 dBZ at the -10°C level (*upper right*), > 30 dBZ at the -15°C level (*lower left*), and > 20 dBZ at the -20°C level (*lower right*) in the 1-km ADAS at 1900 UTC 13 Aug 2004.

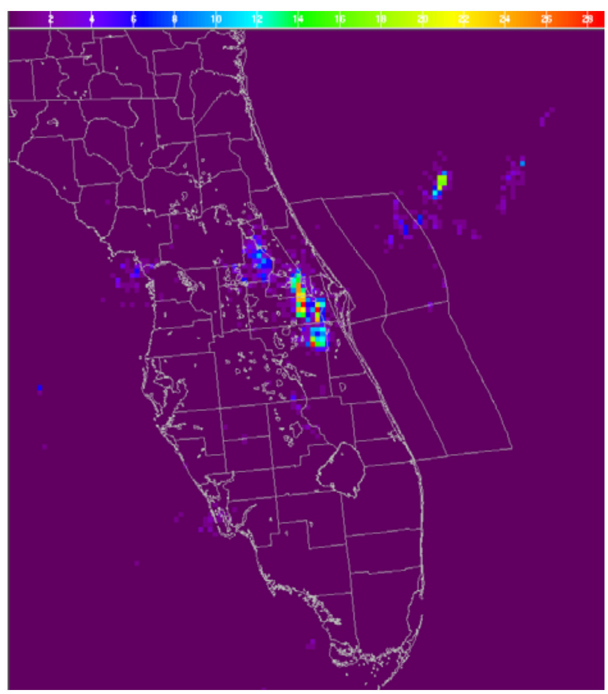

Figure 10. The number of observed CG lightning strikes from 1900–2000 UTC within 2.5 km x 2.5 km grid boxes.

AMU CHIEF'S TECHNICAL ACTIVITIES (Dr. Merceret)

Dr. Merceret supported the launch of the Atlas V rocket carrying the Pluto New Horizons payload. He attended the 86th AMS Annual Meeting in Atlanta, GA where he was lead or co-author on five papers. Those papers included two on the VAHIRR-based LLCC, one on LLCC in general, one on the Airborne Field Mill program science results and one presenting an analysis of boundary layer winds in the region of the Shuttle roll maneuver.

Dr. Merceret assisted the Shuttle Program in assessing methods for detecting birds in the vicinity of Launch Complex 39. He also assisted the Constellation Program in defining its weather-related requirements for infrastructure and operations.

AMU OPERATIONS

Mr. Wheeler researched and received quotes on several different AMU technology purchases for FY06. He completed the purchase requests and submitted them to the NASA Procurement office. He also ordered a new model cluster, new PCs, laptops and additional hardware Mr. Wheeler tended to several hardware and software issues on the AMU model cluster, and rebuilt the IBM UNIX server with new internal hard drives and loaded the current operating system and programming tools.

Ms. Lambert updated all the documents containing information on journal articles, final reports, and conference proceedings by AMU authors and added the updated information to the AMU website. She also updated the AMU General Brief slides in preparation for a briefing to the 45 WS. Dr. Short supported the Atlas V launch of the New Horizons probe.

Dr. Bauman, Ms. Lambert, and Mr. Case attended the 86th AMS Annual Meeting in Atlanta, GA. Ms. Lambert presented a paper titled *Using Cloud-To-Ground Lightning Climatologies to Initialize Gridded Lightning Threat Forecasts for East Central Florida*. Dr. Bauman and Mr. Case presented posters titled *Recent Weather Support Improvement Initiatives by the 45th Weather Squadron* and *A Study Of Rapidly Developing Low Cloud Ceilings In A Stable Atmosphere at the Florida Spaceport*, respectively.

All AMU team members participated in the Annual AMU Tasking meeting, held on 6 March in ENSCO's Cocoa Beach office. Other participants included personnel from the 45 WS, SMG, NWS MLB, 30 WS, the KSC Weather Office, and Marshall Space Flight Center. Several new tasks were assigned:

- Tower Data Skew-T Tool (30 WS) task to validate the effectiveness of the 30 WS tool that monitors the progress of marine layer incursions;
- Situational Lightning Climatologies for Central Florida, Phase II (NWS MLB) task to create composite soundings for each flow regime, 12-hour climatologies, and climatologies for the 5-, 10-, 20-, and 30-n mi circles around the Shuttle Landing Facility (SLF);
- Stable Low Cloud Phase II (SMG) task to extend the database back to 1990 and study nocturnal cases of rapid low cloud development over the SLF;
- WRF Sensitivity Studies (SMG) task to determine the best configuration for operations when predicting cool-season low ceilings and warm season convection initiation;
- Peak Wind Tool for General Forecasting (45 WS) task to analyze the local sounding and wind tower network data for predictors of the magnitude and timing of the highest peak wind for the day; and
- Peak Wind Tool for User LCC Phase II (45 WS) task to update the current probabilities of meeting or exceeding specific peak speed values and create a GUI to access the probabilities.

After the Tasking Meeting, all attendees participated in a teleconference discussing the contents of the AMU Quarterly Report for the First Quarter of FY 2006.

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List of Acronyms

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
ABFM	Airborne Field Mill
ADAS	ARPS Data Analysis System
AFSPC	Air Force Space Command
AFWA	Air Force Weather Agency
AMS	American Meteorological Society
AMU	Applied Meteorology Unit
ARPS	Advanced Regional Prediction System
ARW	Advanced Research WRF
AWIPS	Advanced Weather Interactive Processing System
CCAFS	Cape Canaveral Air Force Station
CG	Cloud-to-Ground
CSR	Computer Sciences Raytheon
CWA	County Warning Area
EMS	Environmental Modeling System
ER	Eastern Range
FR	Flight Rules
FSU	Florida State University
FY	Fiscal Year
GRIB	GRIdded Binary
GSD	Global Systems Division
GUI	Graphical User Interface
JSC	Johnson Space Center
KSC	Kennedy Space Center
LCC	Launch Commit Criteria
LLCC	Lightning LCC
McBASI	McIDAS BASIC Language Interpreter
McIDAS	Man Computer Interactive Data Access System
MIDDS	Meteorological Interactive Data Display System
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NLDN	National Lightning Detection Network
NMM	Non-hydrostatic Mesoscale Model
NOAA	National Oceanic and Atmospheric Administration
NSSL	National Severe Storms Laboratory
NWS	National Weather Service
NWS MLB	NWS in Melbourne, FL
OB4	Operational Build 4
ROC	Radar Operations Center
RPG	Radar Product Generator
RSA	Range Standardization and Automation
RUC	Rapid Update Cycle
SCP	Supercell Composite Parameter
SI	Standard Initialization
SMC	Space and Missile Center
SMG	Spaceflight Meteorology Group
SOO	Science Operations Officer
SPC	Storm Prediction Center
SPoRT	Short-term Prediction Research and Transition
SRH	NWS Southern Region Headquarters
STP	Significant Tornado Parameter
STRC	Science and Training Resource Center
USAF	United States Air Force
UTC	Universal Coordinated Time
VAHIRR	Volume Averaged Height Integrated Radar Reflectivity
WR	Western Range
WRF	Weather Research and Forecasting Model
WSR-88D	Weather Surveillance Radar 1988 Doppler

Appendix A

AMU Project Schedule 30 April 2006				
AMU Projects	Milestones	Scheduled Begin Date	Scheduled End Date (*New End Date*)	Notes/Status
Situational Climatology of CG Lightning Flash Counts	Collect NLDN data and FORTRAN code from Florida State University and NWS Tallahassee	Apr 05	Jun 05	Completed
	Analyze and test code on AMU or NWS system	Jul 05	Aug 05	Completed - Delayed due to issues in data transmission and analysis
	Modify code to produce desired gridded output, deliver code and output to NWS MLB	Aug 05	Oct 05	Completed - Delayed as above
	Memorandum	Nov 05	Dec 05 (*Apr 06*)	Delayed as above
Forecasting Low-Level Convergent Bands Under Southeast Flow	Develop standard data/graphics archive procedures to collect real-time case study data	Apr 05	Apr 05	Completed
	Collect data real-time during southeast flow days	Apr 05	Jan 06	Completed - Delayed due to customer request to collect more winter cases
	Data analysis	Jul 05	Feb 06	Completed - Delayed as above
	Final report	Feb 06	Mar 06 (*May 06*)	Delayed as above

AMU Project Schedule 30 April 2006				
AMU Projects	Milestones	Scheduled Begin Date	Scheduled End Date (*New End Date*)	Notes/Status
Objective Lightning Probability Phase II	Begin developing the MIDDS tool with McBASI	Dec 05	Feb 06	Completed - Delayed due to final software corrections
	Calculate new forecast parameters	Jan 06	Feb 06 (*Apr 06*)	Delayed due to delays in Lightning Climatology task
	Develop and test new equations	Mar 06	Apr 06 (*May 06*)	Delayed as above
	Update the MIDDS tool with new equations	Apr 06	Apr 06 (*May 06*)	Delayed as above
	Final report	Mar 06	May 06 (*Jun 06*)	Delayed as above
RSA/Legacy Sensor Comparison	Data Collection and Pre-Processing	Dec 04	May 05	Completed - Delayed due to request for more data
	Data Evaluation	Dec 04	Jun 05	Completed - Delayed as above
	Final Report	July 05	Sep 05 (*May 06*)	Delayed as above
Anvil Forecast Tool in AWIPS	AWIPS training at GSD	Jul 05	Nov 05 (*Uncertain*)	Delayed pending transfer of funds
	Develop software for calculation and display of anvil threat corridor	Dec 05	Apr 06	Delayed as above
	Test and evaluate performance of the software	Apr 06	May 06	Delayed as above
	Final memorandum	May 06	June 06	Delayed as above

AMU Project Schedule 30 April 2006				
AMU Projects	Milestones	Scheduled Begin Date	Scheduled End Date (*New End Date*)	Notes/Status
Volume-Averaged Height Integrated Radar Reflectivity (VAHIRR)	Acquisition and setup of development system and preparation for Technical Advisory Committee (TAC) meeting	Mar 05	Apr 05	Completed
	Software Recommendation and Enhancement Committee (SREC) meeting preparation	Apr 05	Jun 05	Completed
	VAHIRR algorithm development	May 05	Oct 05	Completed – Delayed due to new code development made necessary by final product requirements
	ORPG documentation updates	Jun 05	Oct 05	Completed – Delayed as above
	Preparation of products for delivery and memorandum	Oct 05	Jan 06 (*Apr 06*)	Delayed as above
Mesoscale Model Phenomenological Verification Evaluation	Literature search for studies in which phenomenological or event-based verification methods have been developed	Jun 04	Jan 05	Completed - Delayed due work on the Objective Lightning task
	Determine operational feasibility of techniques found in the literature	Jul 04	Jan 05	Completed - Delayed as above
	Final Report	Jan 05	Mar 05 (*Mar 06*)	Completed - Delayed as above
User Control Interface for ADAS Data Ingest	Develop control GUI	Apr 04	Jan 05	Completed
	Installation assistance and documentation	Jan 05	Mar 05 (*Apr 06*)	Delayed waiting for operating system upgrades at NWS MLB

AMU Project Schedule 30 April 2006				
AMU Projects	Milestones	Scheduled Begin Date	Scheduled End Date (*New End Date*)	Notes/Status
Operational Weather Research and Forecasting (WRF) Model Implementation	Hardware performance comparison study	Jul 05	Aug 05	Completed
	Configure and test WRF with ADAS initialization	Aug 05	Apr 06	On Schedule
	Modify ADAS GUI to Control WRF Initialization and Run-Time	Jan 06	Apr 06	On Schedule
	Operational Implementation and Memorandum	Apr 06	Jun 06	On Schedule
ADAS/ARPS Modifications for Improvement of Forecast Operations	Provide assistance in creating programs for assimilating new data sets into ADAS	Jan 06	May 06	On Schedule
	Develop diagnostic/prognostic graphics that display the potential for CG lightning, and likelihood of supercells and significant tornado events.	Jan 06	Apr 06	On Schedule
	Improve ADAS weighting scheme and influence radii to optimize the blend of background and observations	Feb 06	Apr 06	On Schedule
	Final memorandum	Jun 06	Jun 06	On Schedule

NOTICE