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Applied Meteorology Unit (AMU) Quarterly Report

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NWS Melbourne/P. Blottman
NWS Melbourne/M. Volkmer

Continued on Page 2

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.

<u>Task</u> <u>Stable Low Cloud Evaluation</u>

Goal Examine archived data collected during rapid stable cloud development events resulting in cloud ceilings below 8000 ft at the Shuttle Landing Facility. Document the atmospheric conditions favoring this type of cloud development to improve the ceiling forecast issued by the Spaceflight Meteorology Group (SMG) for Shuttle landings at Kennedy Space Center (KSC).

Milestones Reviews of the final report were completed, and the document was sent to NASA for final approval prior to distribution. A conference paper describing this work was prepared and submitted for the American Meteorological Society (AMS) Annual Meeting.

Discussion The final report for this task was completed and is awaiting final approval by NASA. A conference paper was written containing the results of the final report, which will be presented as a poster at the upcoming annual AMS meeting in Atlanta, GA. The results were also presented at the SMG Weather Users Forum in November.

<u>Task</u> <u>Climatology of Cloud-to-Ground (CG) Lightning</u>

Goal Develop a climatology 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, ultimately benefiting all end-users of the product.

Milestones Created the climatologies of probability of lightning occurrence and mean number of strikes stratified by flow regime and 6- and 24-hour time periods, and provided the data to NWS MLB. Submitted a conference paper describing this work for presentation at the AMS Annual Meeting.

Discussion The code provided by Florida State University and NWS Tallahassee needed only minor modifications to compile and run on the AMU's computer systems and to output the climatologies desired by NWS MLB. Once created, the gridded climatologies were delivered to NWS MLB, where they were displayed graphically and used to calculate a first guess lightning threat index map.

Continued on Page 2

Distribution (continued from Page 1)

NWS Southern Region HQ/"W/SRH"/ X. W. Proenza
NWS Southern Region HQ/"W/SR3" D. Billingsley
NWS/"W/OST1"/B. Saffle
NWS/"W/OST12"/D. Melendez
NSSL/D. Forsyth
NSSL/C. Crisp
30 WS/DO/M. Fitzgerald
30 WS/DOR/R. Benz
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Executive Summary, *continued*

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 KSC/Cape Canaveral Air Force Station.

Milestones — Extracted data from the two data analysis and display tools and began populating a database in preparation for an objective analysis.

Discussion — Data from 6 southeast flow days were collected during October through December, bringing the total number of case days to 31. The data sets were incorporated into the display and analysis tools and evaluation of the case days 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 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 — Began development of the code in MIDDS to retrieve the data for the equations.

Discussion — Work began by reviewing the equations developed in Phase I. The next step was to develop a flow diagram of the processes needed to develop the MIDDS routine. This formed the basis for the code development.

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 — Analyzed 23 days of RSA and Legacy wind data from five towers on the WR from the period May–June 2005.

Discussion — The analysis indicated progressive positive biases of the RSA-sensor wind speeds, with respect to the Legacy-sensor wind speed, as follows: the RSA average speed bias increased from 0.5 kts at an average speed of 15 kts, to 1 kt at 25 kts, and the peak speed bias increased from 1 kt at a peak speed of 15 kts to 2 kts at 30 kts.

Continued on Page 3

TABLE
of
CONTENTS

Executive Summary, *continued*

<u>Task</u> <u>Volume Averaged Height Integrated Radar Reflectivity (VAHIRR)</u>

Goal Transition the VAHIRR algorithm into operations on the Weather Surveillance Radar 1988 Doppler. The current lightning LCC (LLCC) for anvil clouds to avoid triggered lightning are overly conservative and lead to costly launch delays and scrubs. The VAHIRR algorithm was developed as a result of the Airborne Field Mill program to evaluate 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 current LLCC.

Milestones Known problems with the VAHIRR output were debugged and the code is in the review process. A large percentage of the VAHIRR documentation was completed.

Discussion The VAHIRR output had 3 issues that were resolved. The issues included a scattering of unexpected data on the periphery of the display, a non-circular "cone of silence" surrounding the radar, and the display appeared rotated about the x-axis from the proper orientation when compared with the output from composite reflectivity product. Documentation of the algorithm was started and is almost complete.

<u>Task</u> <u>Mesoscale Model Phenomenological Verification Evaluation</u>

Goal Find model weather-phenomena verification tools in the literature that could be transitioned into operations. Forecasters use models to aid in forecasting weather phenomena important to launch, landing, and daily ground operations. Methods that verify model performance are needed to help forecasters determine the model skill in predicting certain phenomena.

Milestones Completed a second draft of the final report and re-submitted it for internal AMU review.

Discussion There were 10 phenomenological verification techniques found in the literature: 7 were developed to verify precipitation forecasts, 2 were developed to verify forecasts of multiple phenomena, and 1 was developed to verify wind forecasts. All techniques were at various stages of development, but none were determined to be ready for use in operations.

Continued on Page 4

Executive Summary, *continued*

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	Developed a prototype Advanced Regional Prediction System (ARPS) Data Analysis System (ADAS)/WRF configuration for the Advanced Research WRF (ARW) model. Tested the ADAS/ARW configuration on multiple domains, and ran test simulations of the WRF-Non Hydrostatic Mesoscale (WRF-NMM) model.
Discussion	A prototype ADAS/ARW configuration was developed by modifying existing scripts from the operational ADAS/ARPS configuration at NWS MLB, and writing new scripts for initializing and running the ARW model. The prototype can run either the ARPS or ARW models using ADAS for initial conditions. Test simulations of the WRF-NMM model were also conducted, which was found to run 2.5 times faster than the ARW model.

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

Stable Low Cloud Evaluation (Mr. Wheeler and Mr. Case)

Forecasters at the Spaceflight Meteorology Group (SMG) issue 30 to 90 minute forecasts for low cloud ceilings at the Shuttle Landing Facility for all Space Shuttle missions. Mission verification statistics have shown cloud ceilings to be the biggest forecast challenge. Forecasters at SMG are especially concerned with rapidly developing clouds/ceilings below 8000 ft in a stable, capped thermodynamic environment, since these events are the most challenging to predict accurately. The AMU was tasked to develop a database of these cases, identify the onset, location, and if possible, dissipation times, and document the atmospheric regimes favoring this type of cloud development.

Mr. Case and Mr. Wheeler completed the final report, incorporating comments from internal AMU and customer reviews. They will distribute the report once NASA gives final approval. The final report will also be available on the AMU's website at http://science.ksc.nasa.gov/amu/final.html. Mr. Case and Mr. Wheeler also wrote and submitted a conference paper presenting many of the results of the final report. This paper will be published and presented as a poster at the upcoming American Meteorological Society (AMS) Annual Meeting in Atlanta, GA in early February 2006. Mr. Case produced a set of Microsoft® PowerPoint® slides that Ms. Lambert presented at the SMG Weather Users Forum held at the Johnson Space Center in Houston, TX in November.

Contact Mr. Wheeler at 321-853-8205 or wheeler.mark@ensco.com, or Mr. Case at 321-853-8264 or case.jonathan@ensco.com for more information on this work.

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.

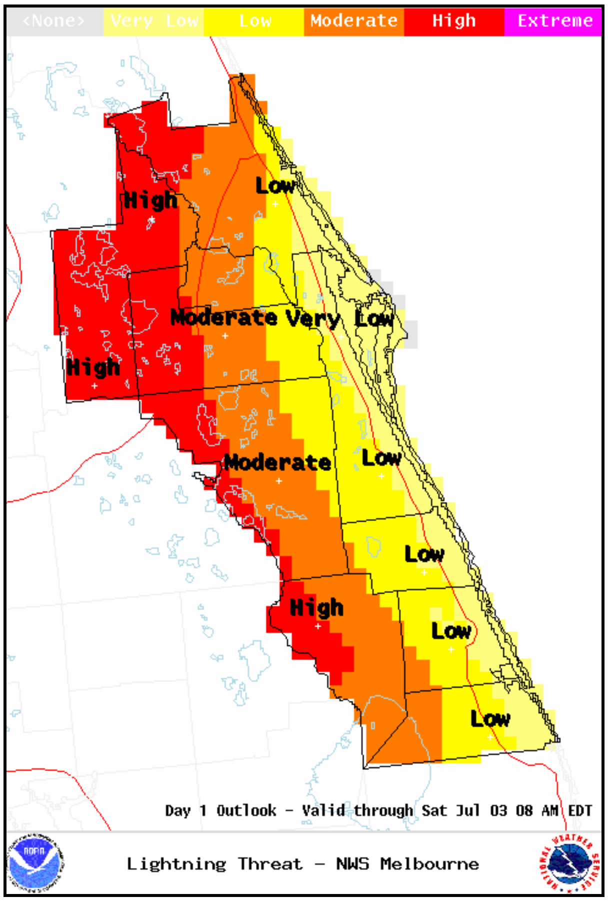

Figure 1. The NWS MLB Lightning Threat map for 3 July 2004. The color legend for each threat level is shown at the top of the image.

Calculation of Gridded Climatologies

Ms. Lambert was able to compile and run the programs provided by Mr. Shafer of NWS Tallahassee after minor modifications. The modifications were needed solely to satisfy the compiler on the AMU's Linux platform. The changes did not affect the logic of the programs. These programs, as provided, calculate the number of days in which lightning occurred in each grid box for each flow regime in 6- and 24-hour periods. The time periods followed the UTC-day, i.e. the 24-hour period was defined as

- 0000–2400 UTC (8:00–8:00 PM, local),

and the four 6-hour periods were defined as

- 0000–0600 UTC (8:00 PM–2:00 AM local),
- 0600–1200 UTC (2:00–8:00 AM local),
- 1200–1800 UTC (8:00 AM–2:00 PM local), and
- 1800–2400 UTC (2:00–8:00 PM local)

The NWS MLB forecasters requested gridded climatologies of lightning occurrence probability and the mean number of strikes per day for each flow regime. The lightning occurrence probability was easily calculated from the original program output by dividing the number of lightning days in each grid box by the number of flow regime days, as in the equation

$$P_L = \frac{\#LtgDays}{\#FRDays},$$

where P_L is the probability of lightning occurrence, #LtgDays is the number of lightning days in each grid box (stratified by flow regime and time period), and #FRDays is the number of days in the flow regime.

Minor code modifications were needed to calculate the mean number of strikes. While the original program output #LtgDays, the input to the program included the number of strikes in each grid box. Ms. Lambert modified the code to output the total number of strikes in each grid box for each flow regime and time period. She then calculated the mean number of strikes in each grid per flow regime day and per lightning day, as in the equations

$$M_{SF} = \frac{\#Strikes}{\#FRDays} \text{ and } M_{SL} = \frac{\#Strikes}{\#LtgDays},$$

where M_{SF} is the mean number of strikes per flow regime day, M_{SL} is the mean number of strikes per lightning day, and #Strikes is the number of CG strikes in each grid box for each flow regime and time period. The value for M_{SL} is conditional on the occurrence of lightning, i.e. it is the mean number of CG strikes when lightning occurred. On the other hand, M_{SF} is not influenced by whether or not lightning occurred.

Graphical Displays

The gridded climatologies P_L, M_{SF}, and M_{SL} were converted to a format that could be ingested by the Graphical Forecast Editor (GFE) in the Advanced Weather Interactive Processing System (AWIPS) at NWS MLB. With eight flow regimes, five time periods, and three different climatologies, a total of 120 GFE files were provided to NWS MLB. Mr. Volkmer of NWS MLB ingested the files into the GFE and displayed the values graphically in a color-coded map.

Figure 2a and 2b show the 24-hour P_L and M_{SF}, respectively, for the flow regime in which the low-level ridge, extending westward from a high pressure center over the Atlantic Ocean, was south of Tampa and north of Miami. Lightning occurred across the peninsula, with the highest occurrence in probability and number of strikes near the central east coast, over and just west of the Kennedy Space Center (KSC) / Cape Canaveral Air Force Station (CCAFS) area. Figures 3a and 3b show the P_L and M_{SF} values, respectively, for the same flow regime but for the 6-hour time period 0600–1200 UTC. Note the relative lack of lightning activity in this period. While stratifying by flow regime shows where the lightning occurrence will likely be focused, stratifying by time period shows the when the lightning would likely occur.

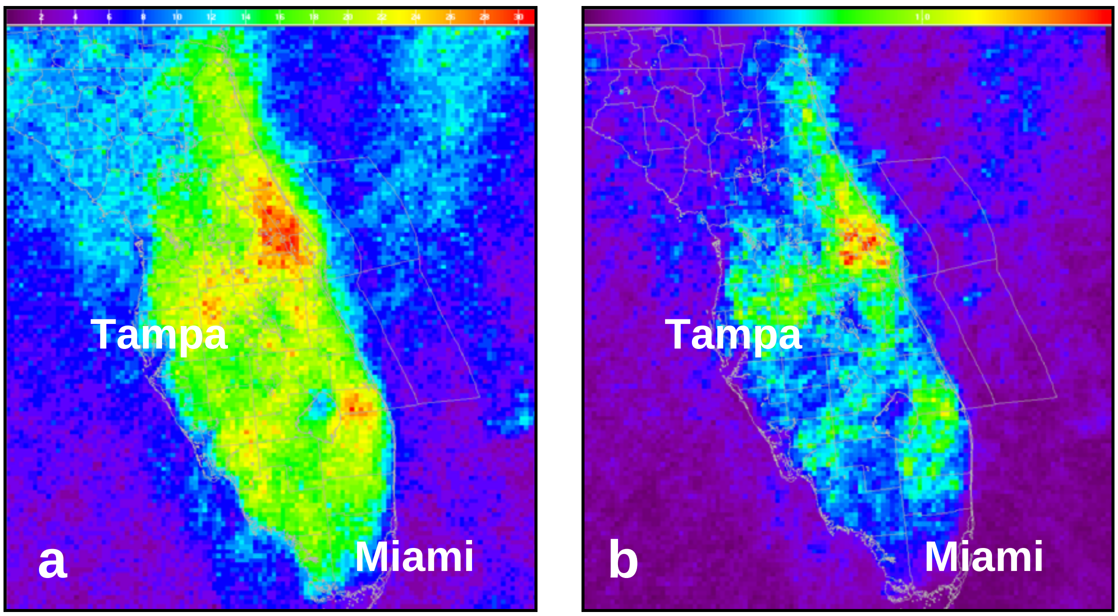

Figure 2. The 24-hour climatological (a) probability of lightning occurrence(P_L) and (b) mean number of lightning strikes (M_{SF}) for the flow regime in which the ridge extending westward over the peninsula is south of Tampa and north of Miami.

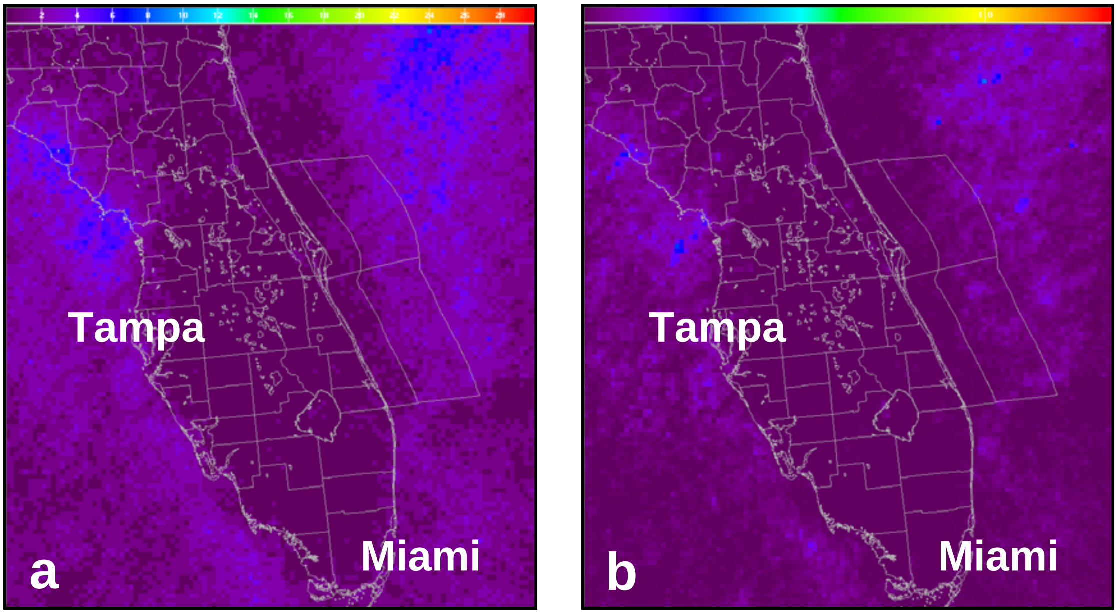

Figure 3. Same as Figure 2, except for the 6-hour period 0600–1200 UTC.

First Guess Field

The forecasters at NWS MLB are in the process of determining ways of combining the two climatologies, P_L and M_{SF}, to create a first guess lightning threat index map. Experiments using M_{SL} are also in progress. One possible objective method of combining fields is to multiply the fields together to produce a new field of values that can be thresholded according to the five threat levels in the threat index map (see Figure 1). Figure 4 shows an example of the calculation and resulting first guess map. The flow regime in Figure 4 is the same as that in Figures 2 and 3 and is for the 6-hour period 1800–2400 UTC. The map on the right in Figure 4 would be modified by the forecasters using observations and model forecasts of the atmospheric parameters that can influence the spatial and temporal distribution of thunderstorms over the NWS MLB CWA.

Ms. Lambert also co-authored a conference paper with Mr. Sharp, Mr. Spratt, and Mr. Volkmer of NWS MLB presenting the results of this task. This paper will be presented at the Second Conference on the Meteorological Applications of Lightning Data at the AMS Annual Meeting in Atlanta, GA in January 2006.

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

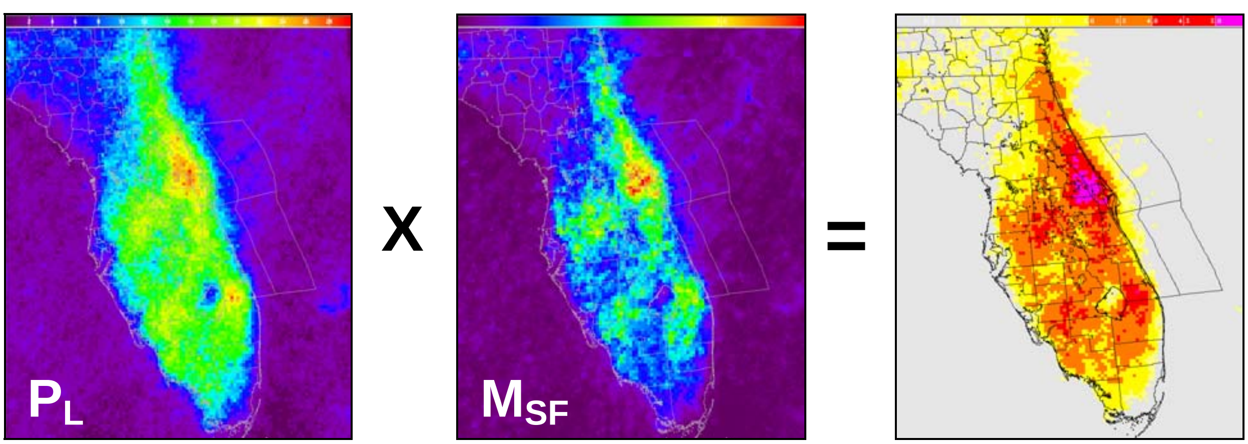

Figure 4. Schematic of a possible objective method to combine the climatologies of probability of lightning (P_L) and the mean number of strikes (M_{SF}) to create a first guess lightning threat index field (rightmost image).

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, CCAFS, and KSC.

Dr. Bauman added 6 southeast flow event days to the archive for a total of 31 events. The dates of the events are in the following table:

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

Dr. Bauman began populating a database in preparation to conduct a detailed and objective analysis of the data collected from the case days. He will compare 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 flow and Atlantic high pressure ridge position,
- Upper-level winds and 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.

His initial analysis on the data from ~1/3 of the days indicates possible relationships between convergent band formation and jet streak position and sea surface temperature.

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

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 save time and allow 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 began to develop the MIDDS tool that will retrieve the needed information for the equations and output a lightning probability for the operational forecasters. He first reviewed the work done on Phase I of this task and consulted with Ms. Lambert on the format of the equations. He then developed a flow diagram of the processes needed in the MIDDS program.

Contact Ms Lambert at 321-853-8130 or lambert.winfred@ensco.com or Mr. Wheeler at 321-853-8205 or wheeler.mark@ensco.com for more information.

INSTRUMENTATION AND MEASUREMENT

I&M and RSA Support (Mr. Wheeler)

Mr. Wheeler continued to review and assist the 45 WS in identifying display problems and missing data in Range Standardization and Automation (RSA) AWIPS. He also reviewed and commented on the Eastern Range (ER) Weather Legacy Shutdown Plan.

Lockheed Martin personnel began installing AWIPS Operational Build 4 (OB4) and ran into issues with the server, data ingest, and client/server network. They reinstalled OB4 and were able to get the client/server working. Several components and data sets are still not available

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 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 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 processed 23 days of WR 1-minute Legacy and RSA wind speed and direction data supplied by the 30 WS. The data were collected during 29 May–23 June 2005 from five towers on the WR: 301, 300, 102, 60 and 54. The WR Legacy data covers the 6-hour interval 1600–2200 UTC each day and includes the peak wind speed used to evaluate LCC during operations.

Table 1 lists the levels for which Legacy and RSA data were obtained. Data from one Legacy and two RSA wind sensors were obtained for each of the 17 levels. This report shows a comparative analysis of 1-minute data from all 34 Legacy-RSA sensor pairs and all 17 RSA-RSA sensor pairs on the 5 WR towers.

Table 1. Sensor levels for RSA and Legacy wind data from the five WR towers used in this report. Data from one Legacy and two RSA sensors were obtained at each level marked with the letter "Y."

Level (ft)	Tower				
	301	300	102	060	054
300	**Y**	**Y**	-	-	-
204	**Y**	**Y**	-	-	-
102	**Y**	**Y**	**Y**	-	-
054	**Y**	**Y**	**Y**	**Y**	**Y**
012	**Y**	**Y**	**Y**	**Y**	**Y**

Sensor Comparison Procedure

Dr. Short designed the data analysis procedure to compare Legacy and RSA sensor data at the highest temporal resolution available and to avoid wind sheltering effects by the tower. He accomplished this by first matching time series minute-by-minute for all three sensors (Legacy, RSA1 and RSA2) at each level on each tower. He then used the Legacy wind direction at each level on each tower to separate the matched time series into three sectors. Each sector was upwind of the tower for each of the three possible comparisons:

- Sector 1: Legacy versus RSA1,
- Sector 2: Legacy versus RSA2, and
- Sector 3: RSA1 versus RSA2.

The wind direction filter was based on the instrument mounting scheme for each tower and was designed to avoid effects of wind flow around the tower. This was done by restricting data for each sensor pair to wind flow from the up-wind side of tower. Figure 5 shows a schematic diagram of the mounting scheme for the Legacy and RSA wind sensors used on each of the five towers. In this example the Tower Orientation Direction (TOD) is 30°, putting the center of Sector 1 at 300°, the center of Sector 2 at 030°, and the center of Sector 3 at 345°. Note that the RSA sensors were mounted on opposite corners of the tower, while the Legacy sensor was mounted on one of the remaining two corners; the corner facing the dominant wind direction. There was one mounting scheme for each tower and sensors at different levels on the same tower were mounted using the same scheme, however the TOD did vary from tower-to-tower.

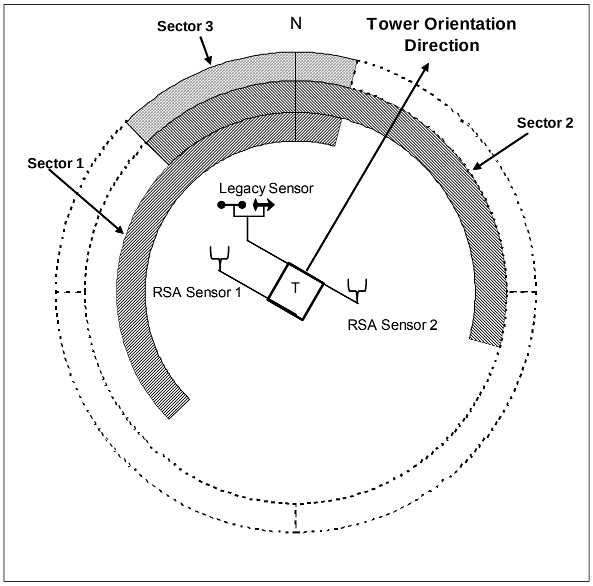

Figure 5. Schematic diagram of the Legacy and RSA sensor configuration and wind-direction sectors used for the wind speed comparisons. Sector 2, spanning the TOD by +/- 75°, was used for comparing the Legacy and RSA 2 sensors. Sector 1, spanning TOD – 90° by +/- 75°, was used for comparing the Legacy and RSA 1 sensors. Sector 3, spanning TOD – 45° by +/- 30°, was used for comparing the RSA 1 and RSA 2 sensors.

For each of the 17 wind sensor platforms identified in Table 1, the matched time series in Sectors 1, 2 and 3 were used to compare overall average wind speeds between RSA-Legacy pairs and RSA-RSA pairs. The results are shown in Table 2. The bias was defined as RSA – Legacy average wind speed for RSA-Legacy pairs and RSA1 – RSA2 for RSA-RSA pairs.

The values in bold font in Table 2 highlight the 10 RSA sensors that had bias values < -1 kt or > +1kt compared to the Legacy sensors. The eight bias values with question marks after them had wind direction biases that were ≥ 14° compared to the Legacy sensors. However, the bias values for these four pairs of RSA sensors were within just a few degrees of each other, suggesting that the Legacy directional readings for those four Legacy sensors (Tower 301 at 300 ft; Tower 300 at 102 ft; Tower 300 at 054 ft, and Tower 102 at 012 ft) may have some problems. The RSA sensor that is check-marked (✓) in Table 2 had a speed variance of 3 kts with respect to its Legacy sensor. This was 50% larger than the highest variance for the sensors in Table 2 that are not in bold font or have a question mark next to them.

Table 2. The average wind speed bias, in kts, from the sensor-to-sensor comparisons. Bias values in bold type have an absolute value exceeding 1 kt. The question marks indicate a wind direction bias exceeding 14°. The check mark (✓) indicates the RSA sensor that had a large speed variance with respect to the Legacy sensor. The 'Y' in the Tower/Level column indicates the sensors used in a composite comparison.

Tower/Level (ft)	**Sector 1** RSA1-Legacy	**Sector 2** RSA2-Legacy	**Sector 3** RSA1-RSA2
301/300	**1.06 ?**	**1.07 ?**	-0.20
301/204 **Y**	0.01	**1.27**	-1.28
301/102 **Y**	0.92	0.86	0.26
301/054 **Y**	0.26	0.66	-0.35
301/012 **Y**	0.03	0.05	-0.03
300/300 **Y**	0.16	0.06 ✓	0.22
300/204 **Y**	0.23	**-2.88**	3.43
300/102	0.15 **?**	-0.58 **?**	0.90
300/054	0.18 **?**	-0.82 **?**	1.06
300/012 **Y**	0.09	**1.80**	-1.53
102/102 **Y**	0.08	0.28	0.63
102/054 **Y**	**-1.49**	0.65	-0.77
102/012	**-1.62 ?**	0.20 **?**	-1.15
060/054	**-4.94**	**1.57**	-6.40
060/012 **Y**	0.08	**-2.33**	2.66
054/054 **Y**	0.26	0.08	-0.39
054/012 **Y**	0.68	0.01	0.30

There were 18 RSA sensors that showed consistent performance with respect to their corresponding Legacy sensors. They can be identified in Table 2 by excluding all RSA sensors with a bias value in bold type, or a **?** or ✓ afterward. The tower and height for each set of sensors is indicated by a **Y** in the first column. These 18 RSA sensors and their corresponding 12 Legacy sensors were used to produce composite comparisons.

Composite Comparisons

Dr. Short computed average wind speed of the 18 RSA sensors conditioned on the average from the corresponding 12 Legacy sensors. That is, for the Legacy one-minute average wind speeds of 1 kt at all levels marked with a **Y** in the first column of Table 2, the corresponding RSA one-minute average wind speed was computed from data from the 18 sensors. This procedure was followed for all Legacy average wind speeds, knot-by-knot, up to 25 kts. The results are plotted in Figure 6. Above 25 kts, the sample size used for Figure 6 fell below 30 for Legacy average wind speeds and the comparison results became noisy.

Dr. Short also computed a peak wind speed for the 18 RSA sensors, conditioned on the Legacy peak. The same procedure as for the average wind speeds in Figure 6 was followed for all Legacy peak wind speeds, knot-by-knot, up to 31 kts. The results are plotted in Figure 7. Above 31 kts the sample size fell below 30 for Legacy peak wind speeds and the comparison results became noisy.

Figures 6 and 7 show progressive positive biases of the RSA wind speeds with respect to the Legacy speeds. The average speed bias in the RSA sensors increased from 0.5 kts at 15 kts, to 1 kt at 25 kts, and the peak speed bias increased from 1 kt at 15 kts to 2 kts at 30 kts.

The results of the composite comparison showed the following overall average and peak wind values:

	Legacy	RSA
Average:	10.31	10.57
Peak:	13.42	14.48

Contact Dr. Short at 321-853-8105 or short.david@ensco.com, or Mr. Wheeler at 321-853-8205 or wheeler.mark@ensco.com for more information.

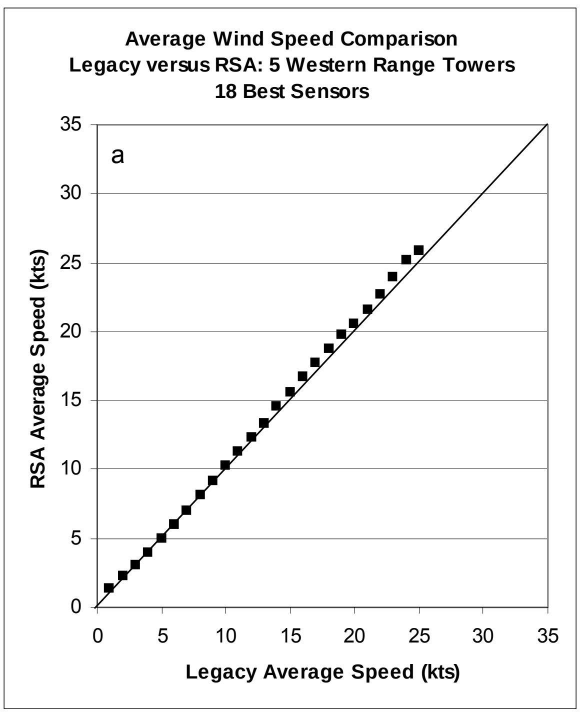

Figure 6. Average wind speed comparisons for the 18 RSA sensors. The period-of-record is 29 May–23 June 2005. The total sample size is 87,894. Each data point plotted had at least 30 one-minute samples.

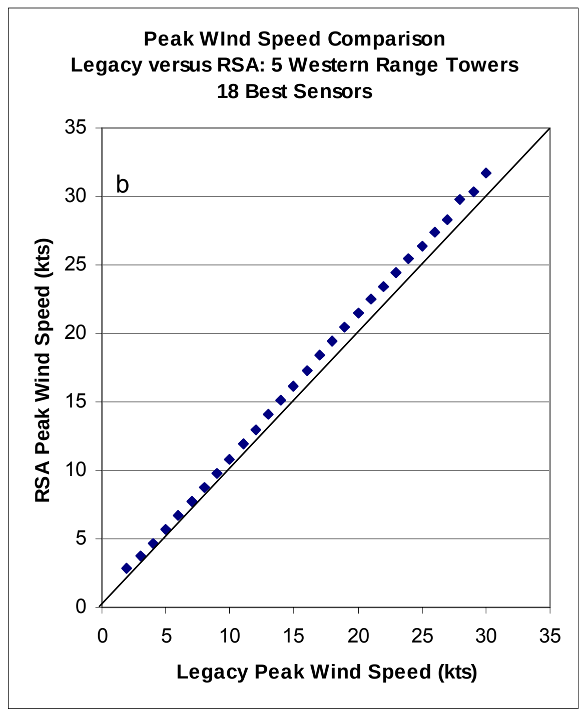

Figure 7. Same as Figure 6, only for the peak wind speeds.

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. These rules prevent 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 conservative. 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 which conducted a performance analysis of the VAHIRR algorithm from a safety perspective. The results suggested that this algorithm would assist forecasters in providing a lower rate of missed launch opportunities with no loss of safety compared with current LLCC. The VAHIRR algorithm, needed to evaluate the new LLCC, should be implemented on the Weather Surveillance Radar 1988 Doppler (WSR-88D) as it is the only radar available to most current and future users. The AMU will develop the new VAHIRR algorithm for implementation in the WSR-88D system under Option Hours funding. Mr. Gillen and software engineers of ENSCO, Inc. will work closely with key personnel at the Radar Operations Center (ROC) in Norman, OK and NASA to ensure smooth and proper transition of this product into operations.

VAHIRR Image

Ms. Miller completed formatting the VAHIRR output and displayed results. She noticed discrepancies in the output display, so she continued analyzing and debugging the code. She was able to associate unexpected data found on the periphery of the display with positive reflectivity returns on the outer edges of the volume scan. The VAHIRR will not be calculated to this extent (i.e. above the height of 0°C isotherm). Therefore, Ms. Miller put limits on the area for the calculation. Ms. Miller identified and corrected an error that erroneously reversed a routine's parameter sequence, causing the non-circular "cone of silence". She also corrected an error that did not properly alter the sign of the y-value when converting between Cartesian and array coordinates.

Figure 8 shows a sample image using data from the NWS MLB WSR-88D at 15:57 UTC 13 July 2005, approximately 3 hours before the scheduled launch time of STS-114, the Return-to-Flight Shuttle. The VAHIRR output is on the left and the Composite Reflectivity product on the right side of the image. A violation of the VAHIRR rule can be seen to the north of the radar, where values are > 33 dBZ-kft. The launch was scrubbed for mechanical reasons on this day.

Mr. Keen wrote a utility to create a launch trajectory for overlay on an AWIPS console and to be used in conjunction with the VAHIRR output product display.

Documentation

Personnel at the ROC provided Ms. Miller with sample algorithm report as a guide for the VAHIRR documentation. She documented the VAHIRR inputs, outputs, and procedure in the algorithm enunciation language. Dr. Merceret provided names, affiliations, and published papers on the history of the algorithm development that Ms. Miller also included in the report.

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.

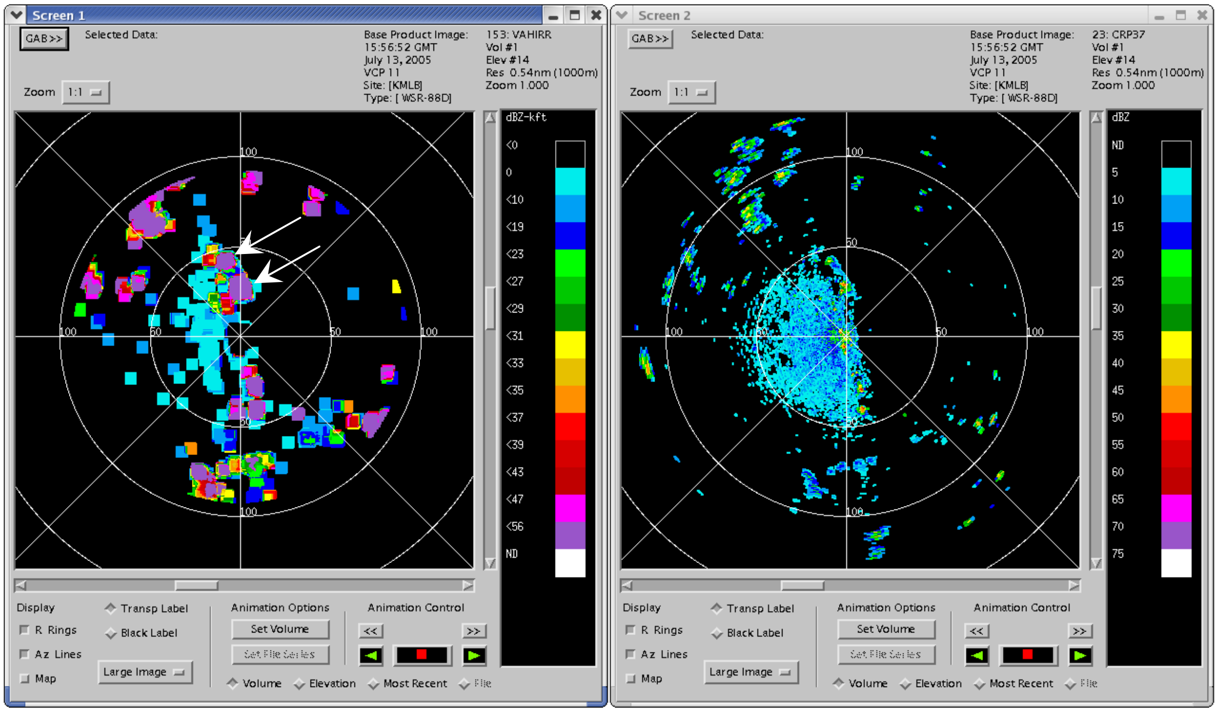

Figure 8. The left image is the VAHIRR product and the right is the Composite Reflectivity product from KMLB on 13 July 2005 at 15:57 UTC (11:57 PM EDT). The white arrows point to the high VAHIRR values (> 33 dBZ-kft).

MESOSCALE MODELING

Mesoscale Model Phenomenological Verification Evaluation (Ms. Lambert)

Forecasters at SMG, 45 WS, and NWS MLB use model output data on a daily basis to make their operational forecasts. Models such as the Advanced Regional Prediction System (ARPS), Rapid Update Cycle (RUC), North American Model (NAM), and Global Forecast System (GFS) aid in forecasting such phenomena as low- and upper-level winds, cloud cover, timing and strength of the sea breeze, and precipitation. Given the importance of these model forecasts to operations, methods are needed to verify model performance. Recent studies have indicated that traditional objective point statistics are insufficient in representing the skill of mesoscale models, and manual subjective analyses are costly and time-consuming. They also concluded that verification of local mesoscale models should be more phenomenologically-based. The AMU was tasked to determine if objective phenomenological verification tools exist in the literature that can be transitioned into operations. Candidate techniques were identified through a literature search, and then the feasibility of implementing the techniques operationally in the AWIPS at SMG, NWS MLB, and the 45 WS was assessed.

Ms. Lambert completed a second draft of the final report based on an extensive review of the first draft by Mr. Case, and re-submitted it for internal AMU review.

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

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 the ARPS Data Analysis System (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.

Mr. Case developed a prototype configuration for running the Advanced Research WRF (ARW) model using ADAS for initial conditions and the RUC and/or NAM models for boundary conditions. The design is based on the current ARPS scripts that are run operationally at NWS MLB. The configuration is capable of running either the ARPS or ARW models using ADAS for initial conditions. Post-processing utilities have also been tested for this ADAS/ARW configuration, with many of the same graphics capabilities as in the current ADAS/ARPS operational runs at NWS MLB.

The prototype configuration first generates fixed fields (terrain height, vegetation, and soil type), boundary conditions, and the ADAS analysis, as in the current operational ARPS configuration at NWS MLB. The fixed fields for the ARW model are then created using a utility called “wrfstatic”, written by the ARPS developers at the Center for Analysis and Prediction of Storms (CAPS). The ADAS data and boundary conditions are then converted to the WRF grid with a nearly identical resolution and map projection as the ARPS grid using another utility developed by CAPS called “arps2wrf”. Both of these utilities can initialize all fixed fields and boundary conditions for the ARW. In addition, these utilities are backwards compatible with data files from the older version of ARPS running at NWS MLB (version 5.1.2). Therefore, the unique AMU code changes used in ARPS/ADAS version 5.1.2 do not need to be ported to newer versions of the ARPS software in order to run “arps2wrf”.

Composite reflectivity and surface winds from a sample ADAS/ARW simulation are shown in Figure 9. The ARW model was initialized with Doppler radar data over the eastern Great Lakes Region on a day with significant lake-effect snow bands occurring. On 6 December 2005, lake-effect snow was occurring to the southeast of Lakes Ontario (easternmost lake) and Erie (southernmost lake) at the model initial time, 1200 UTC (Fig. 9a). An approaching low pressure trough from the north caused the low-level winds to back to a west-southwesterly direction, which resulted in a reorganization of the ARW-predicted snowbands into a west-southwest/east-northeast orientation over the 9-h forecast time, especially over Lake Ontario (Figure 9b-d). This simulation demonstrates that the prototype ADAS/ARW has the capability to be initialized and run over an arbitrary domain with realistic results.

Mr. Case also ran test simulations of the WRF-Non Hydrostatic Mesoscale (WRF-NMM) model. The ARW and WRF-NMM models represent the two different dynamical “cores” of WRF, as discussed in the previous AMU quarterly report (Q4, FY05). The WRF-NMM model has been advertised to run significantly faster than the ARW model, and AMU benchmark tests this past quarter confirmed that the WRF-NMM runs about 2.5 times faster than the ARW. Unfortunately, ADAS cannot currently be used to initialize the WRF-NMM model with high-resolution initial conditions because CAPS has not yet developed a routine to convert from the ARPS format to the WRF-NMM format. The Local Analysis and Prediction System (LAPS) could be used instead to initialize the WRF-NMM model, which provides a similar mechanism for assimilating data and initializing numerical weather prediction models as ADAS does. LAPS is already capable of initializing either the ARW or WRF-NMM models.

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

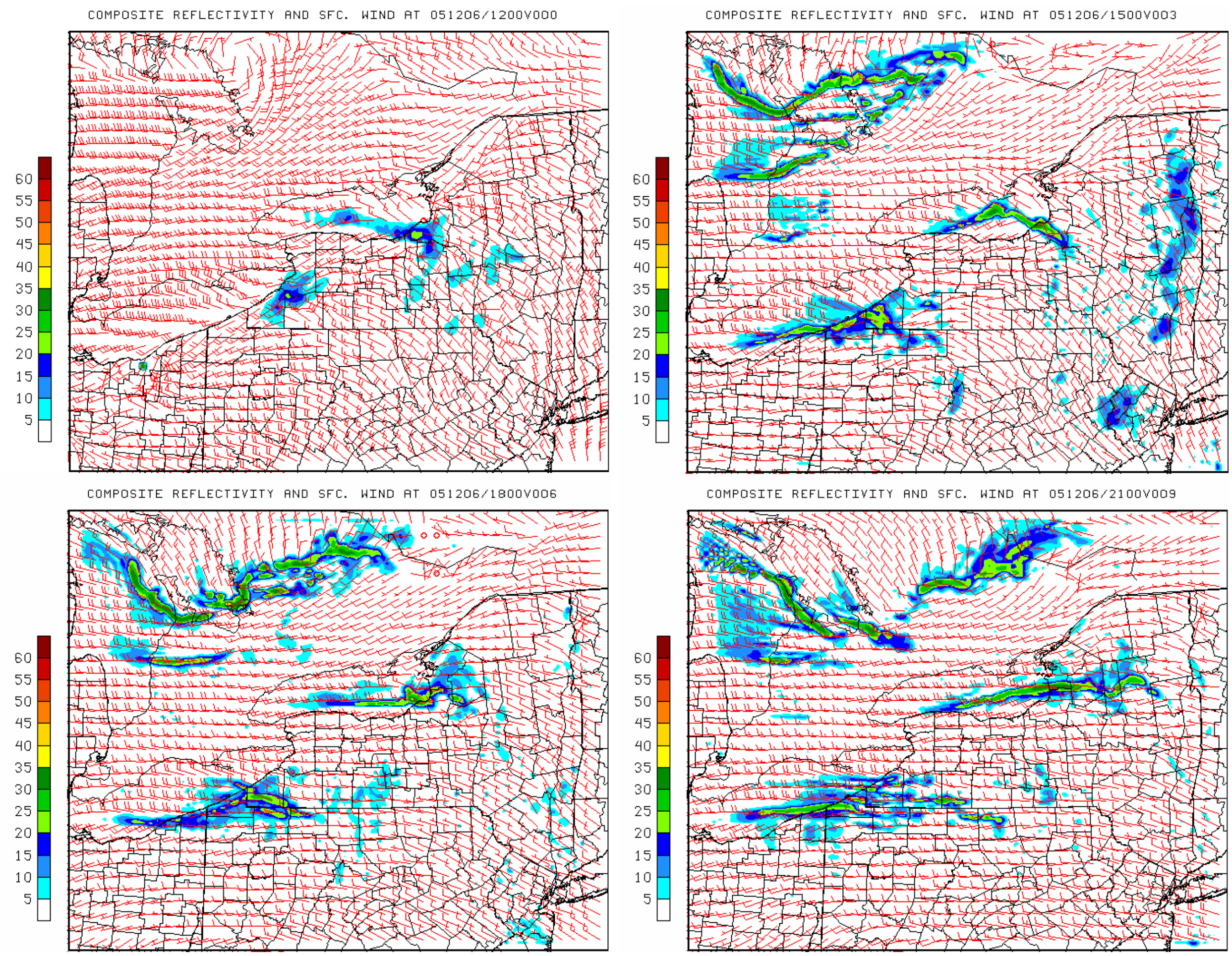

Figure 9. ARW-predicted composite reflectivity and surface winds depicting lake-effect snow bands from the 1200 UTC 6 December model run, with valid times at (a) 1200 UTC (0-h forecast), (b) 1500 UTC (3-h forecast), (c) 1800 UTC (6-h forecast), and (d) 2100 UTC (9-h forecast).

METEORLOGICAL TECHNIQUES AND STATE OF THE SCIENCE RESEARCH

While attending the National Weather Association (NWA) 30th Annual Meeting, Dr. Bauman and Ms. Lambert listened to a presentation by Mr. David Knapp of the Army Research Laboratory that described the Thunderstorm Potential Index (TPI). The TPI is a linear regression equation that uses certain sounding parameters as predictors and outputs the probability of thunderstorm occurrence. It was developed in the 1990's, and was recently tested to determine if it could be used to forecast non-severe and severe thunderstorm occurrence over a specified region in 12–24 hour forecast periods (Knapp et al., 2006).

The technique was compared against the Storm Prediction Center (SPC) convective outlook for Day 1 and Day 2, and against observations of severe and non-severe storms over the continental U.S. using NAM soundings. They found that the TPI output corresponded closely to the convective areas forecast by SPC, but the SPC guidance outperformed TPI when compared to observations of thunderstorms, both severe and non-severe. Work on this equation is continuing, to include testing with different models and creating different verification statistics. Mr. Knapp also stated that he will likely try using logistic regression and may test other predictors.

While the Objective Lighting Probability tool works well in predicting thunderstorm occurrence within the KSC/CCAFS area, a variation of the TPI may be useful in forecasting severe weather in east-central Florida. The AMU will monitor progress on the TPI for possible future transition to operations.

AMU CHIEF'S TECHNICAL ACTIVITIES (Dr. Merceret)

Dr. Merceret and Ms. Ward finished writing and testing software to do correlation, spectral, and coherence processing of the 915-MHz wind profiler data that the Marshall Space Flight Center (MSFC) Natural Environments Branch has been using for examination of winds in the Shuttle roll maneuver region. They processed the data and are preparing a paper that reports the results.

Dr. Merceret and Ms. Ward completed papers for presentations to be given at the 12th Aviation, Range, and Aerospace Meteorology Conference at the AMS Annual Meeting in Atlanta, GA on 29 January – 2 February 2006.

AMU OPERATIONS

All AMU personnel participated in a teleconference discussing the contents of the AMU Quarterly Report for the Fourth Quarter of FY 2005. Other teleconference participants included personnel from the 45 WS, SMG, NWS MLB, 30 WS, and the KSC Weather Office. All AMU personnel also completed the NASA Site for On-Line Learning And Resources (SOLAR) distance learning course on Basic Information Technology Security for 2006.

Mr. Wheeler configured an AMU workstation with current Red Hat Linux software and re-hosted several external data directories to its file system. This allowed the AMU to turn in an older UNIX workstation. He also decommissioned one AMU UNIX server and moved its data over to a LINUX data server. Mr. Wheeler also repaired two nodes that were lost on the AMU Model cluster after Hurricane Wilma.

Dr. Bauman and Ms. Lambert attended the NWA 30th Annual Meeting on 17–20 October. Ms. Lambert presented the results of the Objective Lighting Probability Forecasting Phase I task, and Dr. Bauman presented the results of the Severe Weather Forecast Tool task.

Ms. Lambert attended the Weather Users Forum (WUF) #5 and the Lightning Advisory Panel meetings in November, sponsored by SMG at Johnson Space Center in Houston, TX. She presented results from the Stable Low Ceiling and VAHIRR tasks at the WUF.

Dr. Bauman attended the 2005 Short-term Prediction Research and Transition (SPoRT) Center Science Advisory Committee (SAC) meeting at the National Space Science and Technology Center in Huntsville, AL. The goal of the SAC is to assess SPoRT activities and to provide insight and recommendations for future SPoRT projects.

The Range Operations Control Center was closed from 20–29 December for electrical system maintenance and upgrades. AMU personnel either worked from home or ENSCO's Cocoa Beach office, or took leave during this period.

REFERENCES

Knapp, D., E. Barker, G. Brooks, and S. Rentschler, 2006: Comparisons and Verification of an Automated Thunderstorm Potential Index Output to Manual Products. Preprint, 12th Conference on Aviation, Range, and Aerospace Meteorology, American Meteorological Society, 28 January – 2 February 2006, Atlanta, GA.

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
CAPS	Center for Analysis and Prediction of Storms
CCAFS	Cape Canaveral Air Force Station
CG	Cloud-to-Ground
CSR	Computer Sciences Raytheon
CWA	County Warning Area
ER	Eastern Range
FR	Flight Rules
FSU	Florida State University
FY	Fiscal Year
GFE	Graphical Forecast Editor
GFS	Global Forecast System
GSD	Global Systems Division
GUI	Graphical User Interface
JSC	Johnson Space Center
KSC	Kennedy Space Center
LAPS	Local Analysis and Prediction System
LCC	Launch Commit Criteria
LDAR	Lightning Detection and Ranging
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
NAM	North American Model
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
NWA	National Weather Association
NWS	National Weather Service
NWS MLB	NWS in Melbourne, FL
ROC	Radar Operations Center
RSA	Range Standardization and Automation
RUC	Rapid Update Cycle
SAC	Science Advisory Committee (SPoRT)
SMC	Space and Missile Center
SMG	Spaceflight Meteorology Group
SPC	Storm Prediction Center
SPoRT	Short-term Prediction Research and Transition
SRH	NWS Southern Region Headquarters
TOD	Tower Orientation Direction
TPI	Thunderstorm Potential Index
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
WRF-NMM	WRT Non-hydrostatic Mesoscale Model
WSR-88D	Weather Surveillance Radar 1988 Doppler

Appendix A

AMU Project Schedule
31 January 2006

AMU Projects	Milestones	Scheduled Begin Date	Scheduled End Date	Notes/Status
Stable Low Cloud Evaluation	Gather data, develop database	Oct 04	Jan 05	Completed
	Identify, classify weather characteristics of events	Jan 05	Jul 05	Completed
	Final report or memorandum	Aug 05	Oct 05	Completed
Shuttle Ascent Camera Cloud Obstruction Forecast	Develop 3-D random cloud model and calculate yes/no viewing conditions from optical sites for a shuttle ascent	Jan 04	Jan 04	Completed
	Analyze optical viewing conditions for representative cloud distributions and develop viewing probability tables	Feb 04	Feb 04	Completed
	Memorandum	Feb 04	Jan 05	Completed
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	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	Delayed due to customer request to collect more winter cases
	Data analysis	Jul 05	Feb 06	Delayed as above
	Final report	Feb 06	Mar 06	Delayed as above

AMU Project Schedule 31 January 2006				
AMU Projects	Milestones	Scheduled Begin Date	Scheduled End Date	Notes/Status
Objective Lightning Probability Phase II	Begin developing the MIDDS tool with McBASI	Dec 05	Feb 06	On Schedule
	Calculate new forecast parameters	Jan 06	Feb 06	On Schedule
	Develop and test new equations	Mar 06	Apr 06	On Schedule
	Update the MIDDS tool with new equations	Apr 06	Apr 06	On Schedule
	Final report	Mar 06	May 06	On Schedule
RSA/Legacy Sensor Comparison	Data Collection and Pre-Processing	Dec 04	May 05	Completed Jun 05, delayed due to request for more data
	Data Evaluation	Dec 04	Jun 05	Completed WR data evaluation. Delayed for extended ER data analysis
	Final Report	July 05	Sep 05	Delayed as above
Anvil Forecast Tool in AWIPS	AWIPS training at GSD	Jul 05	Nov 05	Delayed pending training
	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
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	Delayed due to new code development made necessary by requirements for final product
	ORPG documentation updates	Jun 05	Oct 05	Delayed as above
	Preparation of products for delivery and memorandum	Oct 05	Jan 06	Delayed as above

AMU Project Schedule 31 January 2006				
AMU Projects	Milestones	Scheduled Begin Date	Scheduled End Date	Notes/Status
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 Feb 05, delayed due work on the Objective Lightning task
	Determine operational feasibility of techniques found in the literature	Jul 04	Jan 05	Completed Mar 05, delayed as above
	Final Report	Jan 05	Mar 05	Delayed as above
ARPS/ADAS Optimization and Training Extension	Provide the NWS MLB with assistance in upgrading to ARPS version 5.x.	Aug 04	Dec 04	Completed
	Provide the NWS MLB with assistance in porting the operational ADAS to a Linux workstation	Oct 04	Jan 05	Completed
	Assist the NWS MLB in upgrading to the 20-km RUC pressure coordinate background fields	Oct 04	Jan 05	Withdrawn
	Develop routines for incorporating new data sets into ADAS	Dec 04	May 05	Completed
	Examine a limited number of warm-season convective cases	May 05	Jul 05	Completed
	Final Memorandum	Aug 05	Sep 05	Completed
User Control Interface for ADAS Data Ingest	Develop control GUI	Apr 04	Jan 05	Completed
	Installation assistance and documentation	Jan 05	Mar 05	Delayed for NWS MLB system upgrades
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

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