Applied Meteorology Unit (AMU) Quarterly Report

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Executive Summary

This report summarizes the Applied Meteorology Unit (AMU) activities for the fourth quarter of Fiscal Year 2004 (July - September 2004). A detailed project schedule is included in the Appendix.

Task Objective Lightning Probability Forecast: Phase I

Goal Develop a set of statistical equations to forecast the probability of lightning occurrence for the day. This will aid forecasters in evaluating flight rules and determining the probability of launch commit criteria violations, as well as preparing forecasts for ground operations.

Milestones Five equations were developed, one for each month in the warm season, to forecast the probability of lightning occurrence at Kennedy Space Center (KSC) / Cape Canaveral Air Force Station (CCAFS). Development of a graphical user interface (GUI) began to allow forecasters user-friendly access to the equations.

Discussion The new equations show improved skill in forecasting daily lightning occurrence over forecasts using 1-day persistence, daily climatology, monthly climatology, and the flow regime lightning probabilities. These equations will be transitioned for operational use.

Task Severe Weather Forecast Decision Aid

Goal Create a new forecast aid to improve the severe weather watches and warnings for the protection of KSC/CCAFS personnel and property.

Milestones Lightning and non-lightning days were determined using the Cloud-to-Ground Lightning Surveillance System (CGLSS) data. An analysis of stability indices from the morning CCAFS sounding for lightning/non-lightning days was completed. Florida National Weather Service (NWS) Office severe weather procedures were reviewed and the 45 WS severe weather checklist was revised.

Discussion The analysis of stability parameters revealed no clear predictors to forecast thunderstorm or severe weather days. Therefore, work began on reviewing details of current operational NWS and 45 WS severe weather checklists.

Task Hail Index

Goal Evaluate current techniques used by the 45 WS to forecast the probability of hail occurrence and size. Hail forecasts are required to protect personnel and material assets at KSC, CCAFS, PAFB and the Melbourne International Airport. The evaluation results will be used by the 45 WS to determine if a new technique is needed.

Milestones Obtained operational computer code and a 15-year archive of CCAFS rawinsonde data from Computer Sciences Raytheon personnel. The code was modified to run on AMU computer systems.

Discussion The hail forecasts generated with the AMU version of the operational code were confirmed to be consistent with a limited 45 WS archive of forecasts generated during the summer of 2000.

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Task — Shuttle Ascent Camera Cloud Obstruction Forecast

Goal In response to a request from the Shuttle Program to implement a recommendation of the Columbia Accident Investigation Board, develop a model to forecast the probability that at least three of the shuttle ascent imaging cameras will have a view of the shuttle launch vehicle unobstructed by cloud at any time from launch to Solid Rocket Booster separation.

Milestones Computer simulations and analyses of viewing probabilities were completed and a draft final report is being revised. The AMU remains on standby to present briefings to the Shuttle Launch Director and Integration Control Boards as required.

Discussion Model tests with variations in the three cloud characteristics of base height, thickness, and size show that cloud thickness has the greatest impact on the ability of the imaging network to maintain three simultaneous views of a launch vehicle. The sides of thicker clouds increase the effective cloud cover because the camera viewing angles are usually shallow at less than 45°.

Task — ARPS Optimization and Training Extension

Goal Provide assistance and support for upgrading and improving the operational Advanced Regional Prediction System (ARPS) and ARPS Data Analysis System (ADAS) at the NWS Melbourne (MLB) and Spaceflight Meteorology Group (SMG) forecast offices.

Milestones Obtained ARPS software release version 5.1.2 from Weather Decision Technologies Inc., and modified/compiled source code from this software version to include unique AMU-developed features.

Discussion The latest version of ARPS was obtained and configured with AMU-unique features from the current ARPS version. ARPS version 5.1.2 has many improvements and features that will make future maintenance much easier at NWS MLB.

Task — User Control Interface for ADAS Data Ingest

Goal Develop a GUI to help forecasters manage the data sets assimilated into the operational ADAS run at NWS MLB and SMG.

Milestones Developed an interactive map of Florida that will allow users to monitor and quality control individual surface observations across the ADAS domain.

Discussion Work continued on the development and enhancement of the framework and features for the control GUI. The primary focus was on the dynamic interactive map for quality controlling surface observations. This map shows all the locations of the Florida surface observations sites, and allows the user to see the data from each station by moving a mouse over the station of interest on the map.

Special Notice to Readers

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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

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

The 45th Weather Squadron (45 WS) forecasters include a probability of thunderstorm occurrence in their daily morning briefings. This information is used by personnel involved in determining the possibility of violating Launch Commit Criteria (LCC), evaluating Flight Rules, and planning for daily ground operation activities on Kennedy Space Center/Cape Canaveral Air Force Station (KSC/CCAFS). Much of the current lightning probability forecast is based on a subjective analysis of model and observational data. The forecasters requested that a lightning probability forecast tool based on statistical analysis of historical warm-season data be developed. Such a tool would increase the objectivity of the daily thunderstorm probability forecast. The AMU is developing statistical lightning forecast equations that will provide a lightning occurrence probability for the day by 1100 UTC (0700 Eastern Daylight Time (EDT)) during the months May – September (warm season). The tool will be based on the results from several research projects. If tests of the equations show that they improve the daily lightning forecast, the AMU will develop a PC-based tool from which the daily probabilities can be displayed by the forecasters. The three data types to be used in this task were described in previous AMU Quarterly Reports (Q4 FY03 and Q1 FY04):

- Cloud-to-Ground Lightning Surveillance System (CGLSS) data,
- 1200 UTC sounding data from synoptic sites in Florida, and
- 1000 UTC CCAFS sounding (XMR) data.

Ms. Lambert is using the S-PLUS® software package (Insightful Corporation 2000) to process and analyze the data, and to develop the lightning forecast equations.

Equation Development and Testing

Previous AMU Quarterly Reports (Q4 FY03 – Q3 FY04) described the predictand and predictors to be used in the equation development. The CGLSS data were used to create a binary predictand for lightning occurrence (1) and non-occurrence (0). The predictors include the stability parameters from the XMR sounding and the flow regime probabilities developed from the synoptic Florida rawinsonde sites. Once the predictand and predictors were prepared, equation development began. The data were first stratified into development and testing data sets, then by month to create individual monthly forecast equations. Of the 15 years in the period of record, 13 were used for equation development and two were set aside for testing the equations. The stratification did not involve choosing individual warm season years, but individual warm season days. There are 153 days in the warm season, and two different years were chosen for each day. The random number generator in Microsoft® Excel© was used to create two sets of 153 numbers between and including 1989 and 2003. The resulting sets of years were assigned to each day in the warm season, such that there were essentially two-years worth of data in the data set. For example, the testing data set contains May 1 1992 and 2000, May 2 1998 and 1999, May 3 1989 and 2002, and September 30 1990 and 2003. All other dates were made part of the development data set. This random method was chosen to reduce the likelihood of capturing any transient climatological patterns in the development data set, and producing results with the testing data that are not representative of the long-term skill of the equations.

The method of choice when using binary predictands (1=lightning 0=no lightning) is logistic regression:

$$y = \frac{e^{(b_0 + b_1 x_1 + \ldots + b_k x_k)}}{1 + e^{(b_0 + b_1 x_1 + \ldots + b_k x_k)}},$$

where y is the predicted probability of occurrence, b_0 is the intercept, b_k are the coefficients for the predictors, x_k, and k is the number of predictors. This method is cited by Wilks (1995) as most appropriate when using binary predictands, and was proven by Everitt (1999) to produce superior results when compared to linear regression. There were 13 predictors available for the equations: 10 stabilitiy indices from the XMR sounding including

- Total Totals (TT),
- K-Index (KI),
- Cross Totals (CT),
- Lifted Index (LI),
- Severe WEAther Threat (SWEAT) Index,
- Showalter Index (SSI),
- Thompson Index (TI)
- Temperature at 500 mb, (T500),
- Mean Relative Humidity in the 800-600 mb layer (RH),
- Precipitable water up to 500 mb (PW),

the individual flow regime probabilities and the monthly climatology from the synoptic soundings and CGLSS data, and the smoothed daily climatology values calculated from the CGLSS data.

The S-PLUS© 6 statistical software package (Insightful Corporation 2000) was used to develop and test the equations.

Equation Development

One equation was developed for each month in the warm season, for a total of five. The logistic regression equations were created using the development data set. Each predictor was added one at a time to a logistic regression equation to determine its contribution to the reduction in residual deviance of the forecast for the binary predictand. First, each of the predictors was tested as the lone variable in the equation and its contribution to the reduction in residual deviance determined. The variable with the largest contribution to the reduction in the deviance was chosen as the first predictor in the equation. Next, the other predictors were added individually with the first in a two-predictor set of equations. The second predictor that reduced the residual deviance by the largest amount in combination with the first was chosen for the equation. This iterative process continued for all 13 predictors. At times, the deviance explained for two or more variables was very similar. In these cases, individual equations were created using each of the predictors. As many as seven equations were created for each month in this manner. While more automatic predictor selection methods, such as principal component analysis, could have been employed, the manual process used here allowed for more control over understanding exactly how each individual predictor contributed to the variance. It was also facilitated by the small number of predictors available for selection.

Figure 1 shows the plot of the reduction in residual deviance as each predictor was added for the August equation. The S-PLUS ANOVA function (analysis of variance) was used to determine the values in Figure 1. This function shows the reduction in residual deviance from that of an equation that produces a probability equal to the monthly climatological value (M Climo in Figure 1). As seen in Figure 1, KI reduced the residual deviance beyond the monthly climatology forecast by the largest amount (~20%), followed by the flow regime lightning probabilities (Flw Reg), TT, the daily climatologies (D Climo), SSI, etc.

The final predictor sets for each equation were chosen in a two-step process. The first was to eliminate the predictors that created a reduction in the deviance of less than 0.5%, close to where the slope of the curve in Figure 1 begins to flatten. Next, the Brier Score (BS) for the probability predictions from each equation was calculated for the development and testing data sets. The BS is calculated using the equation

$$BS = \frac{1}{n}\sum_{i=1}^{n}(p_i - o_i)^2 ,$$

where n is the number of forecast/observation pairs, p is the probability forecast from the equation, and o is the binary lightning observation (Wilks 1995). Since there were two or more possible equations for each month, the equation that produced the lowest BS values for both the development and testing data sets was chosen as the final equation for the month.

Three predictors stood out in all five equations: 1) the flow regime lightning probabilities, 2) the smoothed daily climatology, and 3) the 1-day persistence. The flow regime probabilities and the daily climatology were used in every equation, while persistence was in every equation except for August. The mean RH in the 800-600 mb layer was the next most common predictor. The August equation contains the first five predictors (not including M Climo) in Figure 5: KI, Flw Reg, TT, D Climo, and SSI..

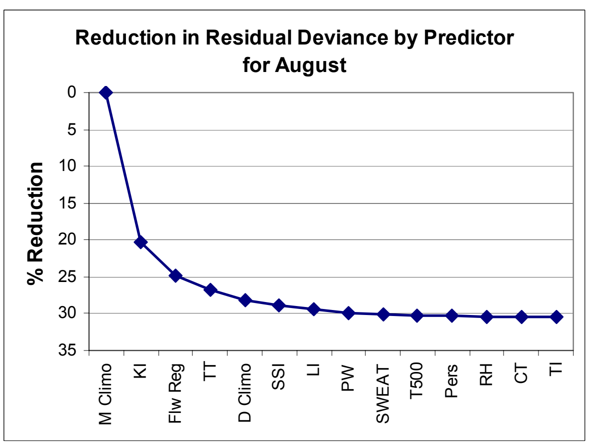

Figure 1. Plot of the reduction in residual deviance from a monthly climatology prediction (M.Climo) as each predictor was added for the August equation. The percent reduction is on the y-axis and the names of each predictor are on the x-axis.

Equation Testing

The first test of the equations was whether or not they showed an improvement in skill over benchmark forecast methods. This involved calculation of the Brier Skill Score (SS) as

$$SS = \frac{BS - BS_{ref}}{BS_{perfect} - BS_{ref}} ,$$

where BS is the Brier Score of the equation being tested, BS_{ref} is the reference or benchmark forecast, and $BS_{perfect}$ is the Brier Score of a perfect forecast, which is always 0. Four methods were used as benchmark forecasts: the smoothed daily climatology, the monthly climatology, the flow regime probabilities, and 1-day persistence. The results with the testing data are in Table 1.

The equations produce an increase in skill over all four forecast methods in all months, although the improvement values are mixed. It appears that the improvement over the daily climatology and flow regime probabilities is minimal in August.

Table 1. The percent (%) improvement in skill of the logistic regression equation forecasts over the benchmark forecasts of persistence, climatology, and flow regime probabilities. These results were calculated using the testing data.

Forecast Method	May	Jun	Jul	Aug	Sep
Persistence	31	53	38	39	43
Daily Climatology	27	18	27	7	21
Monthly Climatology	34	20	27	12	22
Flow Regime	34	13	20	3	21

In the next test, the equation probability forecasts for the testing data were stratified by the lightning observations of 0 and 1, then the distributions of the probability values for each stratification, lightning days and non-lightning days, were calculated. The testing data for each month contained no more than 62 observations, so all months were combined to make the resulting distributions more robust. Figure 2 shows the two probability distributions for lightning and non-lightning days. The blue curve for non-lightning days shows a peak above 40% at probability values of 0.2 then decreasing to below 15% at 0.4, followed by a slight rise then a slow decrease to just below 10% at 1. This curve would indicate an increased possibility of false alarm forecasts. The pink curve for lightning days shows low frequencies below 5% up to probability values of 0.4, then gradually increasing to 40% at 1, increasing above the non-lightning day curve at ~ 0.56 probability. This would show that probability forecasts above ~ 0.56 are more likely to be calculated on lightning days as opposed to non-lightning days.

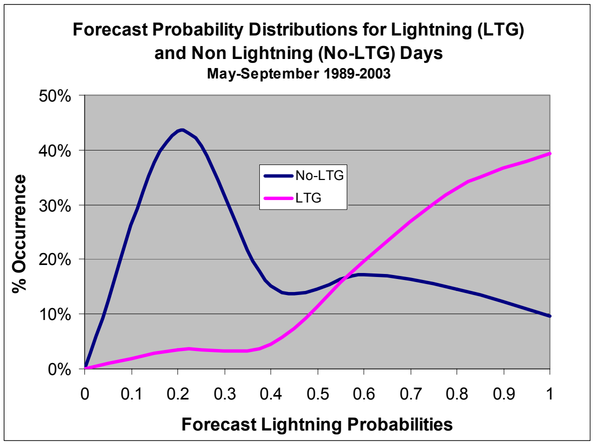

Figure 2. The forecast probability distributions for lightning (pink) and non-lightning (blue) days in the testing data. The y-axis values represent the frequency of occurrence of each probability value, and the values on the x-axis represent the forecast probability values output by the equations.

Figure 3 shows the reliability diagram for probability forecasts using the testing data set. The forecast probability is along the x-axis and the frequency of lightning occurrence for each probability value is along the y-axis. The pink curve represents perfect reliability and the blue curve is the reliability of the forecast equations. Once again, the forecasts for all months were combined to increase the size of the data set. The inset rectangle shows the number of observations in each probability range used to calculate the reliability curve. That the blue line is below the pink line indicates that the equations consistently overforecast lightning occurrence below probabilities of 0.4, but show good reliability at higher probability forecasts, except for 0.8. A detailed examination of the data revealed no clear pattern of why there was such a discrepancy at this value. It could be an artifact of the data set, and a larger data set may not exhibit such behavior.

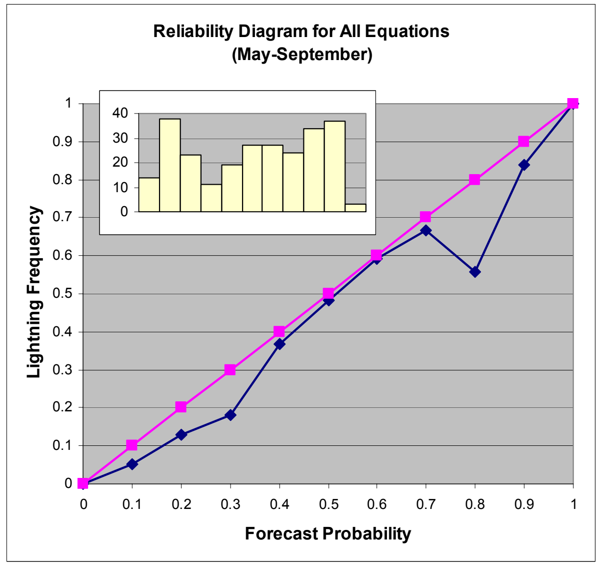

Figure 3. The reliability diagram of the probability forecasts for all months. The pink curve represents perfect reliability and the blue curve represents the probability forecast reliability. The inset rectangle is the histogram showing the number of observations in each probability range.

The final test was to create a contingency table and calculate statistics such as probability of detection (POD) and false alarm ratio (FAR). This type of forecast verification is most appropriate for categorical forecasts. It is less clear-cut for probability forecasts that express levels of uncertainty in which no probability value in the range 0 – 1 is necessarily wrong or right (Wilks 1995). Nonetheless, it is a familiar and easily understood method that can shed light on forecast performance provided an appropriate probability threshold value is defined representing the yes/no forecast division. Once again, the forecasts for all months were combined to calculate more robust statistics. The observations were well defined at yes (1) and no (0). After several tests a cutoff probability value of 0.61 was chosen because the hit rate (HR) was highest at this point. The contingency table and results are in Table 2. Definitions for HR, critical success index (CSI), POD, FAR, Heidke skill score (HSS), and Kuipers skill score (KSS) can be found in Wilks (1995) and Everitt (1999).

Table 2. The contingency table for the cutoff probability value of 0.61. Probability values ≥ 0.61 are considered a 'yes' forecast, and values < 0.61 are considered 'no' forecasts.

		Observation	
		Yes	No
Probability Forecast (0.61)	Yes	**80**	**41**
	No	**32**	**104**

POD = **71.4%** FAR = **33.9%** HR = **71.6%**
CSI = **0.523** HSS = **0.428** KSS = **0.432**

The HR, POD, FAR, and CSI values are 100% for a perfect forecast and 0% for the worst possible forecast. The HSS and KSS are 1 for perfect forecasts, 0 for performance equivalent to a random forecast, and < 0 for performance worse than that of a random forecast. The HR is the percentage of forecasts that were correct, lightning or not, and the POD is the percentage of 'yes' forecasts in the number of 'yes' observations. These values are relatively high at 71.6% and 71.4%, respectively. The FAR is the percentage of 'no' observations in the number of 'yes' forecasts. It is relatively low at 33.9%, but still high enough to be considered as a factor when using these equations for forecasting lightning occurrence. The CSI is the percentage of correct 'yes' forecasts in the sum of all 'yes' forecasts and observations. The value is better than 0.5, but not an indicator of good performance. The HSS and KSS values are scores representing the forecast performance compared to a reference random forecast, the difference being that in the KSS the random forecast is constrained to be unbiased. The values are not high, but are positive indicating performance better than that of random forecasts.

Graphical User Interface

All of the equations showed an increase in skill over the benchmark forecasts of daily and monthly climatology, persistence, and the flow regime lightning probabilities. As a result, the new equations will be added to the current set of tools and procedures used by the 45 WS forecasters to make the daily lightning probability forecast.

In order to use these equations, the forecasters need an interface that will facilitate user-friendly input and fast output. A graphical user interface (GUI) is being developed using Microsoft® Excel© Visual Basic. The 45 WS is involved in the GUI development by providing comments and suggestions on the design. This will ensure that the final product will address their operational needs.

For more information on this work and for copies of the memorandum and tables mentioned, contact Ms. Lambert at 321-853-8130 or lambert.winifred@ensco.com.

Severe Weather Forecast Decision Aid (Mr. Wheeler and Dr. Bauman)

The 45 WS Commander's morning weather briefing includes an assessment of the likelihood of local convective severe weather for the day in order to enhance protection of personnel and material assets of the 45th Space Wing, CCAFS, and KSC. The severe weather elements produced by thunderstorms include tornadoes, wind gusts ≥ 50 kts, and/or hail with a diameter ≥ 0.75 in. Forecasting the occurrence and timing of these phenomena is challenging for 45 WS operational personnel. The AMU has been tasked with the creation of a new severe weather forecast decision aid, such as a flow chart or nomogram, to improve the various 45 WS severe weather watches and warnings. The tool will provide severe weather guidance for the day by 1100 UTC (0700 EDT).

As described in the previous AMU Quarterly Report (Q3 FY04), analyses of 14 different stability indices provided little information to distinguish severe weather days from non-severe weather days. Dr. Bauman and Mr. Wheeler briefed the 45 WS on the status of this task and began to conduct additional analyses and methodologies based on suggestions from the 45 WS personnel to see if it would still be possible to develop an objective forecasting tool based on data from the 1000 UTC XMR sounding.

In the first part of the task, the data were stratified between severe/non-severe event days and the XMR stability indices were checked to see if they could be used to discern between the two. However, the stability indices between severe/non-severe weather days were found to be indistinguishable. After meeting with the 45 WS, Dr. Bauman and Mr. Wheeler decided to re-stratify the data set into thunderstorm/non-thunderstorm days and attempt to discern between them using the XMR stability indices. Dr. Bauman developed a database of lightning strike data using CGLSS data to distinguish between thunderstorm and non-thunderstorm days. The database contains soundings from the warm season, May - September, in the years 1994 - 2003. Inclusion of the years 1989 - 1993 will be completed in the next Quarter. Creation of this database was one of the suggestions from the briefing to the 45 WS. The CGLSS data was obtained from Mr. Paul Wahner of Computer Sciences Raytheon (CSR) in the form of text files containing tables of UTC date & time, latitude, longitude, and intensity of individual lightning strikes. The data were re-formatted for input to the ArcView Graphical Information System software. An example of CGLSS data displayed on a map of east-central Florida using ArcView software is shown in Figure 4.

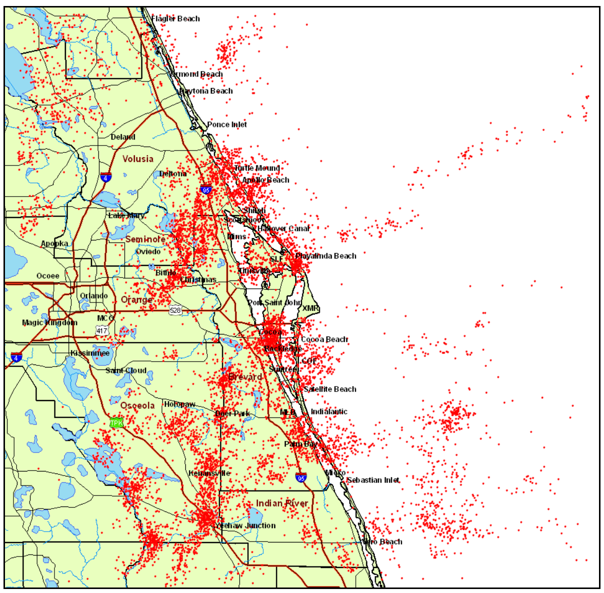

Figure 4. CGLSS data (red dots) plotted using the ArcView software on a map of east-central Florida for 6 August 2003. Each red dot represents one cloud-to-ground lightning strike.

As the CGLSS data were incorporated into ArcView for display, Dr. Bauman created tables that contained the date, location (county or KSC/CCAFS), and number of strikes in Microsoft Excel. Table 3 shows an example of data from the first 15 days in May 2003. These tables will be used to create scatter diagrams that will aid in determining which, if any, of the stability indices can be used to forecast thunderstorm versus non-thunderstorm days with confidence, with the intent of expanding the information to include severe versus non-severe event days.

The graphs in Figures 5 and 6 were generated from the tables and show the number of lightning days per location and percent of days with lightning, respectively, for 2003. The 2003 data are generally representative of the 10 years analyzed thus far and indicate KSC/CCAFS have lightning days ~ 40% of the time during the warm season compared to an average of ~ 64% for the six counties in east-central Florida.

Also, the severe weather event and rawinsonde databases were filtered into several different categories. The severe weather days were stratified into either tornado, hail or wind events and the XMR 1200 UTC sounding data were grouped into either thunderstorm or non-thunderstorm days. The 1-day difference values were computed for the stability parameters including KI, TT, T500, SWEAT, Convective Available Potential Energy, and others. The daily changes of these stability parameters proved not to be useful predictors for both severe weather events and thunderstorm occurrence.

Finally, Dr. Bauman and Mr. Wheeler reviewed other National Weather Service (NWS) office's ideas for severe weather worksheets and techniques in forecasting severe weather events for possible use in an updated severe weather checklist. They started designing the layout of a proposed update to the 45 WS Severe Weather checklist.

Contact Mr. Wheeler at 321-853-8205 or wheeler.mark@ensco.com, or Dr. Bauman at 321-853-8202 or bauman.bill@ensco.com for more information on this work.

Table 3. Example of lightning strike data for the first 15 days in May 2003 obtained from CGLSS and displayed in the ArcView software. Cells with "Y" indicate lightning occurred in that county, or at KSC/CCAFS. Days with no lightning in any region are shaded in gray.

Date	*Indian River*	*Brevard*	*KSC/CCAFS*	*Volusia*	*Seminole*	*Orange*	*Osceola*	*Strikes*
1	**Y**	**Y**					**Y**	**97**
2	**Y**						**Y**	**13**
3				**Y**				**31**
4								0
5								0
6								0
7								0
8								0
9								0
10								0
11								0
12				**Y**				**76**
13								**10**
14	**Y**	**Y**		**Y**	**Y**	**Y**		**171**
15	**Y**	**Y**					**Y**	**1112**

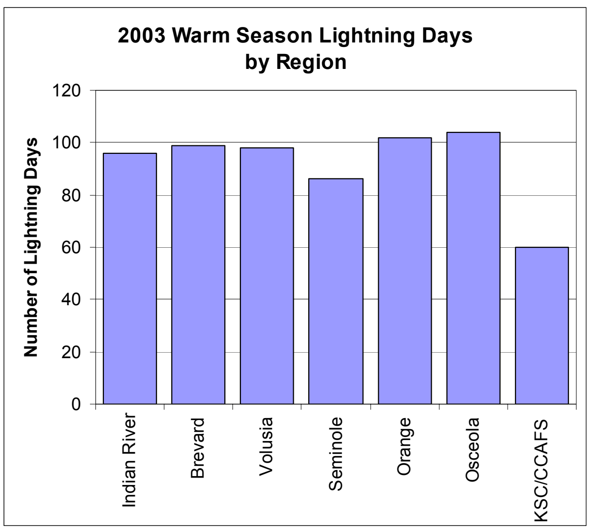

Figure 5. Number of lightning days by region for the period May – September 2003.

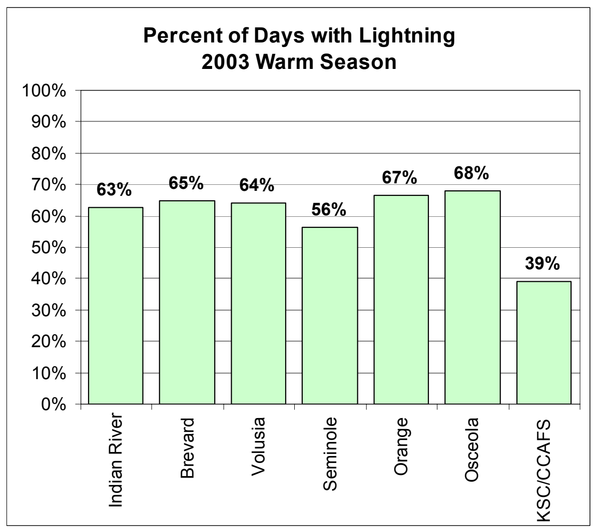

Figure 6. Percent of lightning days by region for the period May – September 2003.

Hail Index (Dr. Short and Mr. Wheeler)

The 45 WS has an operational requirement to issue weather advisories for hail of any size and for severe weather elements, a subset of which is hail with a diameter ≥ 0.75 in. These advisories are issued for KSC, CCAFS, Patrick Air Force Base (PAFB), and the Melbourne International Airport to protect personnel and material assets. The forecasters must also provide the probability of hail at any of these locations for the day at the 0700L weather briefing. The 45 WS tasked the AMU to evaluate the current operational tools used to make daily hail forecasts and, if needed, to develop a new tool tuned to the local area.

In the first phase of this task Dr. Short and Mr. Wheeler will evaluate the operational technique used by the 45 WS to forecast hail. The Neumann-Pfeffer (NP) technique for forecasting thunderstorm probability is combined with the Fawbush-Miller (FM) hail graph for forecasting hail size. The FM technique is documented in the Air Force Weather Agency Technical Note 98/002 (Meteorological Techniques). Dr. Short and Mr. Wheeler will generate hail forecasts for the 15-year period from 1989 – 2003 using an archive of XMR rawinsonde data and the operational computer programs run by CSR personnel at the CCAFS weather station. Hail forecasts will be compared to hail reports in east-central Florida obtained from the National Climatic Data Center. The current hail forecasting technique will be evaluated using standard statistical measures of skill such as the POD, FAR, HSS and others. As part of the initial evaluation, consideration of any improvements that could be implemented in the current hail forecasting technique, such as a bias correction, will be included. The results of the evaluation will be presented to the 45 WS to help them determine if the task should continue with development of a new technique.

Dr. Short obtained the operational computer code for generating hail forecasts from CSR (Mr. Rick Kulow) and made minor modifications to enable it to run on the AMU computer system. He also obtained a 15-year archive of XMR data, 1989 - 2003 from CSR (Mr. Paul Phipps), specially formatted for ingest by the operational code. Dr. Short confirmed that the hail forecasts he generated were correct by comparing them to hard copies of the operational output archived by 45 WS (Mr. Clark Pinder) during the warm season (May - September) of the year 2000.

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 on this work.

Shuttle Ascent Camera Cloud Obstruction Forecast (Dr. Short and Mr. Lane)

Optical imaging of the Space Shuttle launch vehicle (hereinafter the Shuttle) from ground-based and airborne cameras is susceptible to obstruction by clouds. The Columbia Accident Investigation Board (CAIB) recommended that the Shuttle ascent imaging network be upgraded to have the capability of providing at least three useful views of the Shuttle from lift-off to Solid Rocket Booster (SRB) separation. In response, the NASA/KSC Weather Office tasked the AMU to develop a model to forecast the probability that, at any time from launch to SRB separation, at least three of the Shuttle ascent imaging cameras will have a view of the Shuttle unobstructed by cloud. The resulting model was based on computer simulations of 1) idealized, random cloud coverage scenarios, 2) the optical lines-of-sight from cameras to the Shuttle using the camera network before and after upgrades for Return to Flight and 3) a Shuttle ascent trajectory for a launch from Pad 39B to the International Space Station (ISS).

The computer simulation model was used to estimate the probability that a network of cameras could obtain at least three simultaneous views of the Shuttle continuously from lift-off to SRB separation in the presence of clouds. The model generated line-of-site (LOS) data for the camera network and Shuttle ascent trajectory, which were embedded in a three-dimensional (3-D) field of randomly distributed clouds. The LOS from each camera to the Shuttle was computed along its trajectory and cloud obscuration was noted as a binary variable, either obscured (1) or clear (0). The obscuration data were then analyzed to determine the fraction of time from liftoff to SRB separation that at least N simultaneous views of the Shuttle were obtained by the camera network, where N ranged from 2 to 6. A total of 1000 trials with randomly distributed clouds were analyzed for each of 19 different cloud scenarios. The cloud scenarios had defined cloud bases, tops and sizes, with cloud coverage ranging from clear (0/8) to overcast (8/8) in increments of 1/8.

Shuttle Ascent Imaging Network Before and After Upgrade

In response to the CAIB recommendation, the Intercenter Photo Working Group proposed a substantial upgrade to the imaging network. The upgrade included additional long-range ground-based and airborne cameras. Figure 7 shows 10 ground-based, and 2 airborne long-range camera sites in the proposed upgrade. The original network consisted of five long-range camera sites. The proposed upgrade drops the southernmost site and adds 6 ground-based sites and 2 airborne cameras located 15 n mi NW and SE of the SRB separation point, at 65 000 ft.

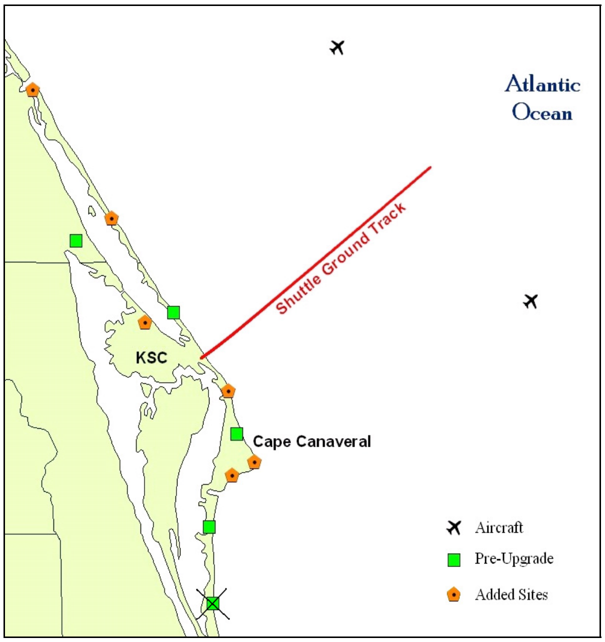

Figure 7. Locations of all original and proposed-upgrade long-range camera sites. The airborne cameras are at 65 000 ft 15 n mi NW and SE of the SRB separation point. The solid line represents the ground-track of a Shuttle ascent trajectory to the ISS from lift-off to SRB separation.

Sensitivity of Post-Upgrade Camera Network Performance to Cloud Characteristics

Dr. Short completed a sensitivity analysis of the performance in the proposed-upgrade camera network to variations in cloud base height, cloud thickness and cloud horizontal dimensions. The measure of performance was the ability of the network to provide at least three simultaneous views of the Shuttle continuously from launch to SRB separation. Because natural clouds show variability in altitude, thickness and size, it was important to develop an understanding of the impact of these variations on the camera network performance.

Figure 8 shows fractional cloud coverage versus the percent of time between lift-off and SRB separation that the Shuttle was viewable simultaneously by at least three cameras in the upgraded network for cloud bases at 4000, 8000, and 30 000 ft, with a 500 ft cloud thickness, and a cloud horizontal dimension of 4 n mi. For overcast conditions (8/8 or 1) the percent time viewable is greatest for 30 000 ft bases due to the increased time it takes the Shuttle to reach cloud base and be obscured from the ground-based cameras for the remainder of the ascent. Once the Shuttle is above the overcast, the two airborne cameras cannot satisfy the requirement for three simultaneous views. For cloud coverages of 6/8 and less the time viewable exceeds 90 % for the low, middle, and high cloud base thresholds.

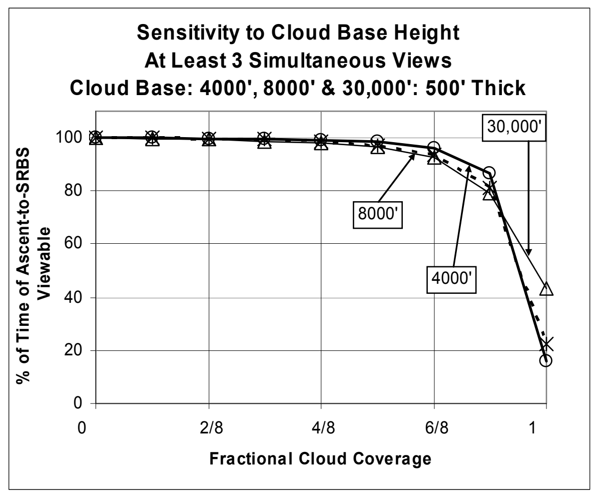

Figure 8. Fractional cloud cover versus % of time from lift-off to SRB separation that the Shuttle was viewable simultaneously by at least three cameras for cloud bases at 4000 ft, 8000 ft, and 30 000 ft.

Figure 9 shows fractional cloud coverage versus percent of time between lift-off and SRB separation viewable by at least three cameras, for cloud bases at 8000 ft and cloud thicknesses of 500 ft (solid curve) and 5000 ft (dashed curve). It is evident that thick clouds are more efficient at obscuring views of the Shuttle than thin clouds due to 3D effects. The sides of thick clouds obscure a greater part of the sky than thin clouds, when viewed at elevation angles < 90°.

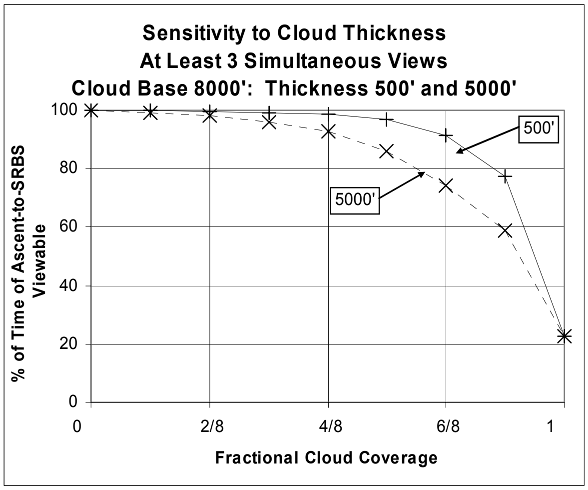

Figure 9. Fractional cloud cover versus % of time between lift-off and SRB separation that the Shuttle was viewable simultaneously by at least three cameras for cloud bases at 8000 ft and cloud thicknesses of 500 ft and 5000 ft.

Figure 10 shows fractional cloud coverage versus percent of time between lift-off and SRB separation viewable by at least 3 cameras, with cloud bases at 8000 ft, cloud thicknesses of 500 ft, and horizontal dimensions of 1, 4 and 8 n mi. The thin solid curve is for a horizontal dimension of 1 n mi, the dashed curve is for a dimension of 4 n mi, and the thick solid curve is for a horizontal dimension of 8 n mi. The percent of time viewable was relatively insensitive to cloud horizontal dimensions over the range of 1 - 4 n mi. For a dimension of 8 n mi the percent of time viewable was lower for cloud coverages of 1/8 to 5/8. As cloud coverage increased toward overcast conditions the percent viewable time became less sensitive to the cloud horizontal dimensions.

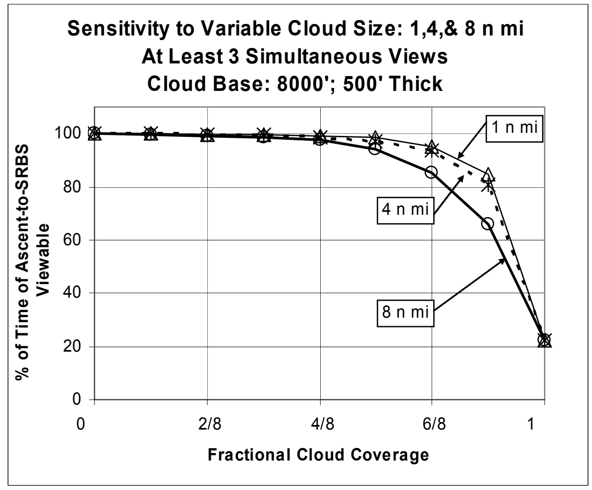

Figure 10. Fractional cloud cover versus % of time between lift-off and SRB separation that the Shuttle was viewable simultaneously by at least three cameras for cloud bases at 8000 ft, cloud thicknesses of 500 ft and cloud horizontal dimensions of 1, 4, and 8 n mi.

Contact Dr. Short at 321-853-8105 or short.david@ensco.com, or Mr. Lane at 321-783-9735 Ext. 245 or lane.bob@ensco.com for more information on this work.

INSTRUMENTATION AND MEASUREMENT

I&M and RSA Support (Dr. Bauman and Mr. Wheeler)

Mr. Wheeler tested several different screen configurations and application tools on the RSA Advanced Weather Interactive Processing System (AWIPS) to address reports that the system slowed down after certain applications had been installed. He noticed no slow down. He discussed his results with the 45 WS and then sent them to the Space and Missile Center and Lockheed Martin for their review. He also worked with the 45 WS on their AWIPS terminal. Finally, Mr. Wheeler requested clarification from Lockheed Martin on how to access weather data on the AWIPS system. The AMU has two upcoming tasks that require the data.

MESOSCALE MODELING

ARPS Optimization and Training Extension (Mr. Case)

As the Advanced Regional Prediction System (ARPS) prognostics and ARPS Data Analysis System (ADAS) diagnostics mature for increased operational use, the NWS at Melbourne, FL (NWS MLB) and the Spaceflight Meteorology Group (SMG) require increased accessibility to AMU resources to ensure the most beneficial evolution of these systems. The NWS MLB plans to ingest several new data sets into ADAS, and the operational configuration will be ported to a Linux workstation. In addition, the NWS MLB requires assistance to upgrade the ARPS system to the latest version. The NWS MLB also desires to switch from the Rapid Update Cycle (RUC) 40-km hybrid coordinate fields to the RUC 20-km pressure coordinate fields to use as background fields for ARPS simulations. Finally, a limited examination of several ARPS warm-season convective cases will be necessary to offer suggestions for adaptable parameter modifications leading to improved forecasts of convective initiation and coverage. Therefore, the AMU was tasked to develop routines for incorporating new observational data sets into the operational ADAS and provide the NWS MLB with assistance in making the upgrades and improvements described above.

Mr. Case focused on configuring the newest version of ARPS (5.1.2), obtained from Weather Decision Technologies Inc. He incorporated modifications he had made to the current operational version 4.5.2 at NWS MLB. Mr. Case also compiled all primary and utility programs that may be used within the operational ARPS/ADAS cycles. He is currently modifying the operational scripts and testing each program within the operational cycle.

One of the benefits of upgrading to ARPS 5.1.2 is that, beginning with version 5.0, the ARPS source code was translated from the FORTRAN-77 language to FORTRAN-90. The FORTRAN-90 code construct has dynamic memory allocation within all ARPS programs, making re-compilation of the code unnecessary when changing model grid dimensions. This new feature of ARPS 5.1.2 results in easier maintenance and more flexibility for running different model domains in the future at NWS MLB.

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

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

The integrity of real-time, continuous diagnostic grids from the operational 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. Keen developed an interactive map of Florida surface observation sites. This map will serve as a foundation for interactive quality control features at each site. Also, map backgrounds and observation labels can be modified based on customer feedback and requirements. Examples of the dynamic map are shown in Figures 11 and 12. All surface observations, including standard METAR, the Florida Automated Weather Network (FAWN), and Automatic Position Reporting System cooperative observations will be plotted on the map (Fig. 11). The user can then perform a simple “mouse-over” of any of the plotted observation points to examine the raw data being analyzed by ADAS (Fig. 12).

Future development will include a capability for the user to click on any observation site and manipulate the quality-control flags for any of the primary meteorological variables (pressure, temperature, dewpoint, and wind speed/direction). In addition, a capability will be developed to modify the quality-control flags for groups of observations (e.g. exclude all FAWN dewpoint observations).

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.

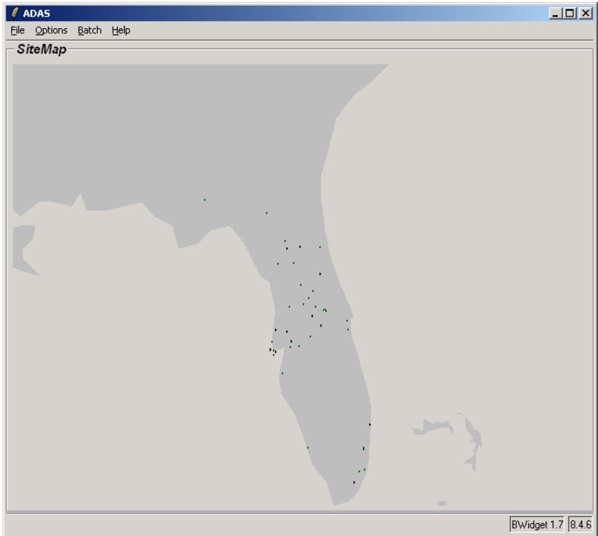

Figure 11. A plot of stations across the Florida peninsula for interactive quality control.

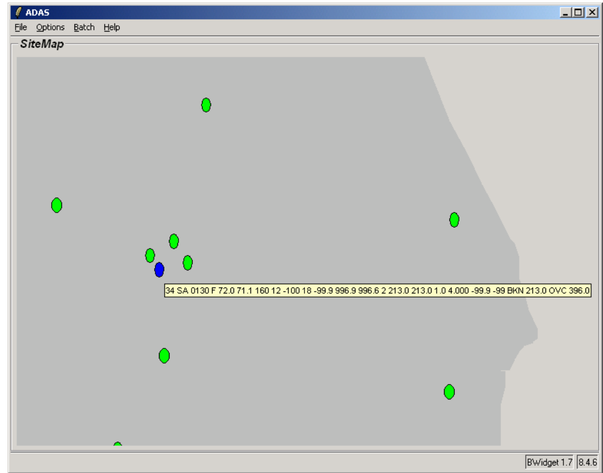

Figure 12. An example of a "mouse-over" on one of the observations near Orlando, FL (station ID#34). The mouse-over results in a display box showing the raw, un-translated observational data.

AMU CHIEF'S TECHNICAL ACTIVITIES (Dr. Merceret)

Dr. Merceret and Ms. Ward completed an analysis of how the electric field and radar reflectivity decay with distance from the edge of anvil and debris clouds. They also co-authored a NASA technical memorandum describing the results (Ward and Merceret, 2004). The analysis used merged data sets from the Airborne Field Mill project, the goal of which is to permit safe relaxation of standoff distances in the lightning LCC.

Dr. Merceret used high-resolution AMPS rawinsonde data to identify a systematic error in the altitude reported by the newly-modified 50 MHz Doppler radar wind profiler. He speculated that this error was due to failure to account for the beam elevation in the revised software. A detailed examination of the software by CTI, Inc. personnel confirmed that speculation. He spent most of September working hurricane-related issues, including advising on post-storm engineering analyses of wind damage to KSC structures.

Dr. James Glover of Oral Roberts University arrived in May and departed in July. He was a KSC Summer Fellow and worked on lightning cessation research under the AMU Visiting Scientist Program. He completed his initial research on statistical forecasting of lightning cessation and presented his findings to the local weather community on 30 July. Dr. Glover hopes to return again as a summer faculty fellow next year to continue this research.

Ms. Angel Bennett, a junior in the Pennsylvania State University (PSU) meteorology program, arrived in June and departed in August. She was a summer intern in PSU's KSC Internship Development Program. Her project involved statistical analysis of CGLSS data. Ms. Bennett completed working on lightning probabilities based on flow regimes for the areas 20 n mi surrounding CCAFS and 5 n mi surrounding PAFB. She also wrote her final report and gave her final presentation.

AMU OPERATIONS

The AMU work schedule was disrupted by two major hurricanes in September. KSC was closed 1 – 12 September due to evacuations and damage from Hurricane Frances. However, most AMU team members returned to work on 9 September when CCAFS opened. KSC was also closed 24 - 27 September for Hurricane Jeanne. Prior to closure, the AMU team spent time preparing the office according to the Hurricane Plan. The AMU lost 8 of the 22 business days in the period, just over one third of the time. As a result, work on some of the tasks was delayed.

Mr. Wheeler worked with the NASA procurement office to update and finalize AMU purchase requests and prepared several pieces of equipment to turn in as excess hardware. He updated the software on some workstations and began the transition from UNIX to LINUX on the AMU's data servers. He also updated the AMU backup hardware and software after one of the backup tape drives failed.

Mr. Case traveled to SMG from 26 – 29 July for technical interchange, and to present final results from the Anvil Transparency and Mesonet Temperature and Wind Climatology tasks. Dr. Bauman traveled to the Short-term Prediction Research and Transition Center (SPoRT) at Marshall Space Flight Center in Huntsville, AL from 9-10 August for a technical interchange meeting to better understand SPoRT's mission and how the AMU and SPoRT can work together.

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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
AMU	Applied Meteorology Unit
ARPS	Advanced Regional Prediction System
AWIPS	Advanced Weather Interactive Processing System
BS	Brier Score
CAIB	Columbia Accident Investigation Board
CCAFS	Cape Canaveral Air Force Station
CGLSS	Cloud-to-Ground Lightning Surveillance System
CSI	Critical Success Index
CSR	Computer Sciences Raytheon
CT	Cross Totals
EDT	Eastern Daylight Time
FAR	False Alarm Ratio
FSL	Forecast Systems Laboratory
FSU	Florida State University
FY	Fiscal Year
GUI	Graphical User Interface
HR	Hit Rate
HSS	Heidke Skill Score
ISS	International Space Station
JSC	Johnson Space Center
KI	K-Index
KSC	Kennedy Space Center
KSS	Kuipers Skill Score
LCC	Launch Commit Criteria
LI	Lifted Index
LOS	Line-Of-Site
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NOAA	National Oceanic and Atmospheric Administration
NSSL	National Severe Storms Laboratory
NW	Northwest
NWS MLB	National Weather Service in Melbourne, FL
PAFB	Patrick Air Force Base
PC	Personal Computer
POD	Probability of Detection
PSU	Pennsylvania State University
PW	Precipitable Water
QC	Quality Control
RSA	Range Standardization and Automation
SE	Southeast
SLF	Shuttle Landing Facility
SMC	Space and Missile Center
SMG	Spaceflight Meteorology Group
SRB	Solid Rocket Booster
SRH	NWS Southern Region Headquarters
SS	Brier Skill Score
SSI	Showalter Stability Index
SPoRT	Short-term Prediction Research and Transition Center
SWEAT	Severe WEAther Threat
T500	Temperature at 500 mb
TI	Thompson Index
TT	Total Totals
USAF	United States Air Force
UTC	Universal Coordinated Time
WSR-88D	Weather Surveillance Radar 1988 Doppler
WWW	World Wide Web
XMR	CCAFS Sounding Identifier

Appendix A

AMU Project Schedule 31 October 2004				
AMU Projects	Milestones	Scheduled Begin Date	Scheduled End Date	Notes/Status
Objective Lightning Probability Phase I	Literature review and data collection/QC	Feb 03	Jun 03	Completed
	Statistical formulation and method selection	Jun 03	Oct 03	Completed, but delayed due to errors found in COTS software
	Equation development, tests with verification data and other forecast methods	Aug 03	Nov 03	Completed, but delayed as above
	Develop operational products	Nov 03	Jan 04	Delayed as above
	Prepare products, final report for distribution	Jan 04	Mar 04	Delayed as above
Mesonet Temperature and Wind Climatology	Process data and calculate climatology of biases/deviations	Jul 03	Feb 04	Completed
	Develop tabular and geographical displays	Feb 04	Apr 04	Completed
	Final Report	Apr 04	Jun 04	Completed
	Assistance in transitioning product into operations	Jul 04	Jul 04	Delayed, Waiting to schedule training sessions with customers
Severe Weather Forecast Tool	Local and national NWS research, discussions with local weather offices on forecasting techniques	Apr 03	Sep 03	Completed
	Develop database, develop decision aid, fine tune	Oct 03	Apr 04	Delayed due to higher priority Shuttle Ascent Camera Cloud Obstruction Forecast Task
	Final report	May 04	Jun 04	Delayed as above
Hail Index	Evaluate Current Techniques	Aug 04	Feb 05	On Schedule
	Memorandum	Mar 05	May 05	On Schedule

AMU Project Schedule
31 October 2004

AMU Projects	Milestones	Scheduled Begin Date	Scheduled End Date	Notes/Status
Expanded Statistics Towers Task for Edwards AFB and Northrup Strip	Deliver wind tower QC FORTRAN code to personnel at MSFC	Jun 04	Jun 04	Completed
	Deliver MS Excel file containing wind tower statistics GUI and associated VBA scripts to personnel at MSFC	Jun 04	Jun 04	Completed
	Provide consultation on QC code and Excel VBA scripts	Jun 04	Sep 04	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	Jun 04	Delayed to provide support for Program Requirements Control Board Briefings
Anvil Transparency Relationship to Radar Reflectivity	Literature search and identification of days with anvil cloud over weather station B near the SLF	Nov 03	Dec 03	Completed
	Analysis of WSR-88D and satellite data for anvil days	Jan 04	May 04	Completed
	Memorandum	Jun 04	Jul 04	Completed
Mesoscale Model Phenomenological Verification Evaluation	Literature search for studies in which phenomenological or event-based verification methods have been developed	Jun 04	Jan 05	On Schedule
	Determine operational feasibility of techniques found in the literature	Jul 04	Jan 05	On Schedule
	Final Report	Jan 05	Mar 05	On Schedule

AMU Project Schedule 31 October 2004				
AMU Projects	Milestones	Scheduled Begin Date	Scheduled End Date	Notes/Status
ARPS/ADAS Optimization and Training Extension	Provide the NWS Melbourne with assistance in upgrading to ARPS version 5.x.	Aug 04	Oct 04	On Schedule
	Provide the NWS Melbourne with assistance in porting the operational ADAS to a Linux workstation	Oct 04	Dec 04	On Schedule
	Assist the NWS Melbourne in upgrading to the 20-km RUC pressure coordinate background fields	Oct 04	Dec 04	On Schedule
	Develop routines for incorporating new data sets into ADAS	Dec 04	May 05	On Schedule
	Examine a limited number of warm-season convective cases	May 05	Jul 05	On Schedule
User Control Interface for ADAS Data Ingest	Develop control graphical user interface (GUI)	Apr 04	Jan 05	On Schedule
	Installation assistance and documentation	Jan 05	Mar 05	On Schedule

NOTICE