ENSCO, Inc. 1980 North Atlantic Avenue • Suite 230 • Cocoa Beach, FL 32931 • 321-783-9735 • www.ensco.com

Applied Meteorology Unit (AMU)

Quarterly Report

Fourth Quarter FY-03

Contract NAS10-01052

31 October 2003

Distribution

NASA HQ/M/F. Gregory
NASA KSC/AA/J. Kennedy
NASA KSC/MK/M. Wetmore
NASA KSC/PH/ M. Wetmore
NASA KSC/PH-A2/D. Lyons
NASA KSC/PH/M. Leinbach
NASA KSC/PH/S. Minute
NASA KSC/PH-A/J. Guidi
NASA KSC/YA/J. Heald
NASA KSC/YA-C/D. Bartine
NASA KSC/YA-D/H. Delgado
NASA KSC/YA-D/J. Madura
NASA KSC/YA-D/F. Merceret
NASA JSC/MA/W. Parsons
NASA JSC/MS2/C. Boykin
NASA JSC/ZS8/F. Brody
NASA JSC/ZS8/R. Lafosse
NASA MSFC/ED03/S. Pearson
NASA MSFC/ED41/W. Vaughan
NASA MSFC/ED44/D. Johnson
NASA MSFC/ED44/B. Roberts
NASA MSFC/ED44/S. Deaton
NASA MSFC/MP01/A. McCool
NASA MSFC/MP71/S. Glover
45 WS/CC/R. LaFebre
45 WS/DO/P. Broll
45 WS/DOR/T. McNamara
45 WS/DOR/J. Moffitt
45 WS/DOR/J. Tumbiolo
45 WS/DOR/K. Winters
45 WS/DOR/J. Weems
45 WS/SY/D. Hajek
45 WS/SYA/B. Boyd
45 WS/SYO/F. Flinn
45 WS/SYR/W. Roeder
45 MXG/CC/B. Presley
45 MXG/LGP/R. Fore
45 SW/SESL/D. Berlinrut
45 OG/CC/G. Billman
CSR 4140/H. Herring
CSR 7000/M. Maier
SMC/CWP/G. Deibner
SMC/CWP/T. Knox
SMC/CWP/R. Bailey
SMC/CWP (PRC)/P. Conant
HQ AFSPC/XOSW/A. Gibbs
HQ AFWA/CC/C. Benson
HQ AFWA/DNX/E. Bensman
HQ AFWA/DN/N. Feldman
HQ USAF/XOW/R. Clayton
NOAA “W/NP”/L. Uccellini
NOAA/OAR/SSMC-I/J. Golden
NOAA/NWS/OST12/SSMC2/J. McQueen
NOAA Office of Military Affairs/M. Weadon
NWS Melbourne/B. Hagemeyer
NWS Southern Region HQ/“W/SRH”/X. W. Proenza
NWS Southern Region HQ/“W/SR3”/D. Smith
NWS/“W/OSD5”/B. Saffle
NSSL/D. Forsyth
NSSL/C. Crisp
30 WS/SY/S. Emert
30 WS/CC/C. Keith
30 WS/DO/S. Saul
30 SW/XP/J. Hetrick
NASA DFRC/RA/J. Ehernberger
412 OSS/OSWM/P. Harvey
FSU Department of Meteorology/P. Ray
NCAR/J. Wilson
NCAR/Y. H. Kuo
NOAA/ERL/FSL/J. McGinley
Office of the Federal Coordinator for Meteorological Services and Supporting Research
Boeing Houston/S. Gonzalez
Aerospace Corp/T. Adang
ACTA, Inc./B. Parks
ENSCO, Inc./T. Wilfong
ENSCO, Inc./E. Lambert

EXECUTIVE SUMMARY

This report summarizes the Applied Meteorology Unit (AMU) activities for the Fourth Quarter of Fiscal Year 2003 (July – September 2003). 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	A meeting between the AMU and 45th Weather Squadron (45 WS) defined the data types needed, the period of record, and statistical methods to use for equation development. The data were collected and processed for analysis.
Discussion	The Cloud-to-Ground Lightning Surveillance System (CGLSS) data will determine whether lightning occurred on each day. Values calculated from the Cape Canaveral Air Force Station (CCAFS) and other Florida soundings will be used as predictors of lightning occurrence.

Task	Mesonet Temperature and Wind Climatology
Goal	Identify any sensor or exposure biases, and geographic or meteorological variability that occur across the Kennedy Space Center (KSC)/CCAFS wind tower network. Deviations in the data could adversely affect forecasts and analyses for ground, launch, and landing operations.
Milestones	A manual quality control (QC) procedure was developed that identifies and removes inconsistent and likely erroneous observations from the 6- and 54-ft temperature data.
Discussion	All towers were checked for data availability, and only those with 80% or more availability during 1995 – 2003 will be used. In the manual QC method, temperature frequency distributions are examined for outliers. If any bad data are found, they are set to missing.

Task	Severe Weather Forecast Decision Aid
Goal	Create a new severe weather forecast decision aid to improve the 45 WS severe weather watches and warnings meant for the protection of personnel and property.
Milestones	Technical interchange meetings (TIMs) with the National Weather Service (NWS) offices at Melbourne, Tampa, and Jacksonville focused on local office severe weather event forecast procedures. A database of east-central Florida severe events from 1960 – 2003 was collected.
Discussion	The information gathered from the TIMs will be used to develop the severe weather forecasting tool. The information from previous severe events will help determine indices and thresholds needed for the tool.

Task	Advanced Regional Prediction System (ARPS) Optimization and Training
Goal	Improve the configuration and forecast accuracy of the real-time ARPS model output at the NWS Melbourne, FL (NWS MLB) and Spaceflight Meteorology Group offices.
Milestones	The soil moisture initialization was improved, which dramatically increased the forecast output availability to nearly 100%.
Discussion	To correct a hot and dry bias in the surface forecasts, a new soil moisture initialization procedure was implemented that uses the daily rain gauge measurements across Florida to adjust the soil moisture field in ARPS. The ARPS forecast output availability was improved by correcting a computer networking error on the NWS MLB Linux system that runs the model.

Table of Contents

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/home.html.

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 and/or subtask.

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 (FR), and daily planning for 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 will develop statistical lightning forecast equations that will provide a lightning occurrence probability for the day by 1100 UTC (0700L) during the months May – September. 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.

Personnel from the AMU and the 45 WS met in July to discuss all aspects of this task including data types, period of record (POR), and statistical procedures. The three data types to be used in this task are from the Cloud-to-Ground Lightning Surveillance System (CGLSS), the 1000 UTC CCAFS rawinsonde, and 1200 UTC soundings from synoptic sites in Florida. Since data from the CCAFS rawinsonde are not available before 1989, the POR is 1989 – 2003 for the warm-season months of May – September. The statistical method to calculate daily lightning occurrence probabilities will likely be logistic regression, but will depend on the results found from an exploratory analysis of the data. The equations will produce a probability of lightning occurrence during the day between 0700 – 0000 EDT. All data will be processed and equations developed using the S-PLUS® software package (Insightful Corporation 2000). The following sections discuss each data type and how they will be processed to create the predictors and predictands for the statistical forecast equations.

Cloud-to-Ground Lightning Surveillance System

This data set will be used as the predictand in the equations, determining whether or not lightning occurred on a particular day in the database. A lightning occurrence climatology created from the CGLSS data will also be tested as a possible predictor in the equations, and will be used as a baseline forecast against which the new equations will be tested. These data were provided to the AMU by Mr. Paul Wahner of Computer Sciences Raytheon (CSR).

Before analysis, the CGLSS data were filtered to include only lightning strikes recorded during the warm season between 0700 – 0000 EDT and only in a specific geographic area. This area was determined by the 5 n mi circles surrounding all the locations on KSC, CCAFS, and the Port area that require lightning warnings. It is a rectangle defined by the northern-most point (28.71 N) on the northern-most circle, the southern-most point (28.34 N) on the southern-most circle, the western-most point (80.91 W) on the western-most circle, and the eastern-most point (80.44 W) on the eastern-most circle. The rectangle is shown by the dotted lines in Figure 1.

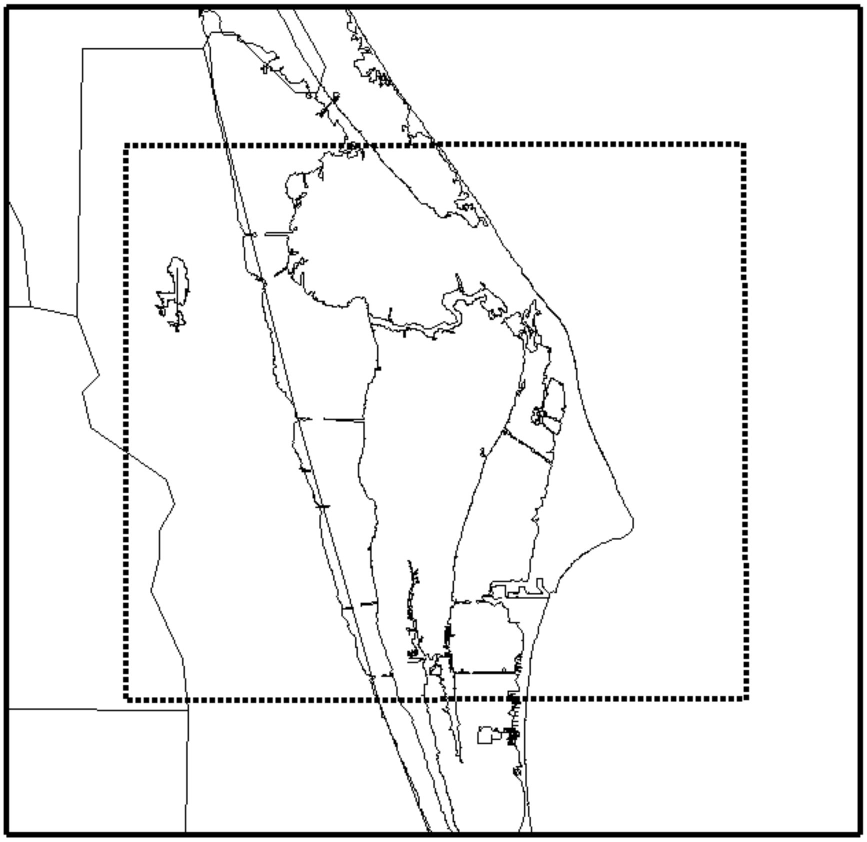

Figure 1. The dotted line outlines the area in which lightning strikes detected by CGLSS will be used to indicate whether or not lightning occurred on the days in May – September, 1989 – 2003 between 0700 – 0000 EDT.

Development of the predictand and climatology involved only whether lightning was observed in the time period and geographic area of interest on each day. The calculations did not consider how many lightning strikes were detected. Calculation of the predictand was straightforward: a ‘1’ was assigned as the predictand if lightning was detected within the defined time frame and spatial area on a specific day, otherwise a ‘0’ was assigned. Figure 2 shows the lightning climatology for each day of the warm season in the 14-year POR 1989 – 2002. The 2003 data are still being collected. They were calculated following Everitt (1999) using a 15-day Gaussian-weighted method in which the 7 days before and after each day were used with decreasing weights as the temporal space increased. The last 7 days in April and first 7 days in October were used to calculate the probabilities at the beginning of May and end of September, respectively. The probabilities for this POR are small at the beginning and end of the season, but approach 70% in June and July. The significance and cause of the fluctuations in the climatology curve in Figure 2 are not known. A similar pattern also appears in the climatology calculated by Everitt (1999). The fluctuations seen in the probability increase from May to the end of June and the decrease seen from the end of August through September might reflect yearly differences in the onset and conclusion of the convective season, respectively.

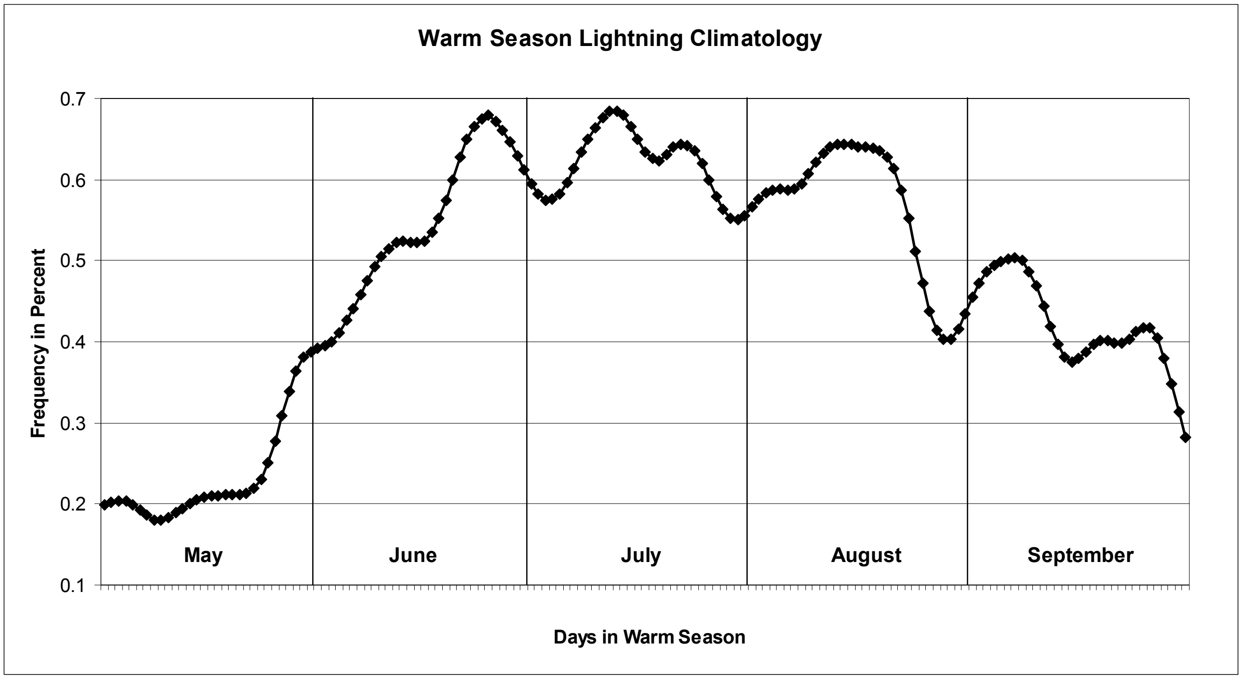

Figure 2. The climatological probability values of lightning occurrence for the warm-season months in the POR 1989 – 2002.

The CGLSS data will also be used to calculate persistence predictors and benchmark forecasts. One predictor will be similar to the predictand in which a '1' will be assigned to a particular day if lightning was detected the previous day, otherwise a '0' will be assigned. The probability of lightning occurring on a specific day if lightning occurred the previous day will also be calculated.

Florida Rawinsondes

These data were collected based on a request by the 45 WS that flow regimes similar to those derived in Lericos et al. (2002) be used as predictors in the equations. Rawinsonde data for the period 1989 – 1997 were available on the CD-ROMs "Radiosonde Data of North America 1946 – 1996" and "Radiosonde Data of North America 1994 – 1997". Data from 1998 – present were downloaded from the Forecast Systems Laboratory (FSL) web site http://www.fsl.noaa.gov/docs/data/fsl-data.html. Following the procedure in Lericos et al. (2002), the 1200 UTC soundings from Miami (MIA), Tampa (TPA), and Jacksonville (JAX) were used to determine the large scale flow regime for the day from the average wind direction in the 1000 – 700 mb layer. Prior to 1995, data from MIA and JAX were not available. As in Lericos et al. (2002), data from West Palm Beach and Waycross, Georgia, respectively, were used as proxies for these sites. Figure 3 shows the number of days in each flow regime for July in the POR 1989 – 2002. There are seven flow regime categories and two other categories for missing data and other wind directions:

- Southeast flow (SE) occurs when the ridge associated with high pressure over the Atlantic Ocean is north of the Florida Peninsula and the wind direction at all three stations is 90° - 180°.
- Southwest flow (SW) occurs when the ridge associated with high pressure over the Atlantic Ocean is south of the Florida Peninsula the wind direction at all three stations is 180° - 270°.
- The ridge is considered north of KSC/CCAFS (RN) when the wind direction at JAX is 180° - 270° and the directions at MIA and TPA are 90° - 180°.
- The ridge is considered south of KSC/CCAFS (RS) when the wind directions at JAX and TPA are 180° - 270° and the direction at MIA is 90° - 180°.
- Northwest flow (NW) occurs when the wind direction at all three stations is 270° - 360°.

- Northeast flow (NE) occurs when the wind direction at all three stations is 0° - 90°.
- When the flow at all three stations did not fit any of the above criteria, it is given the designation 'None'.
- When one or more soundings are missing or do not have adequate data to calculate an average layer wind, the flow is designated as 'Missing'.

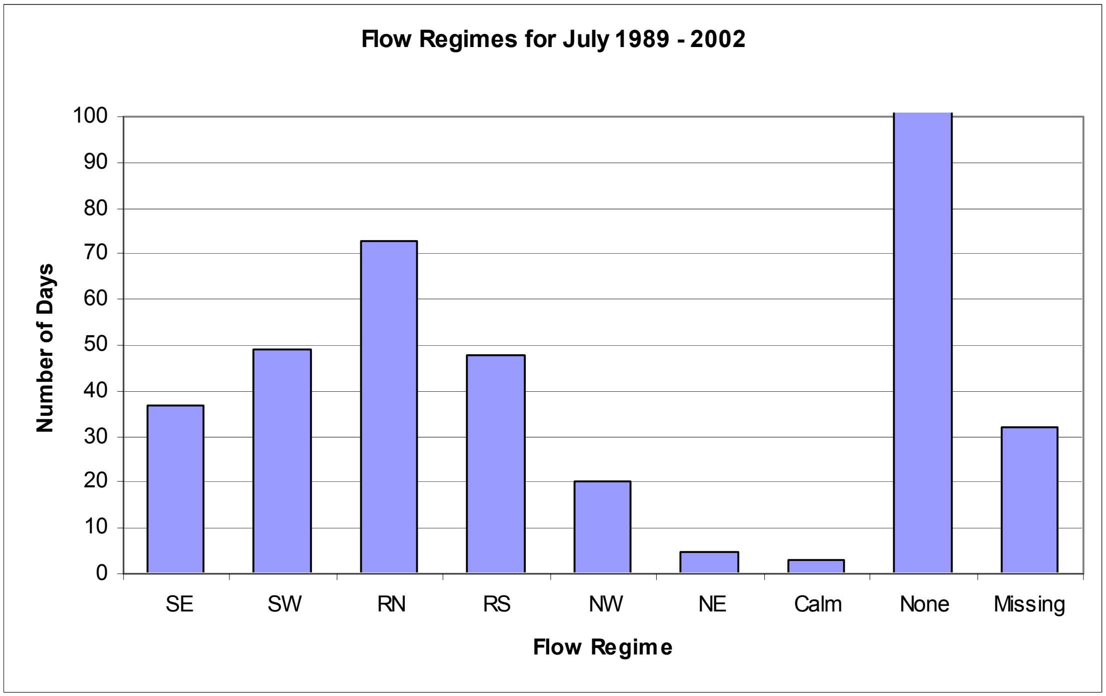

Figure 3. Histogram of the number of days for each flow regime observed in July 1989 – 2002. The flow regimes are southeast (SE), southwest (SW), ridge north of KSC/CCAFS (RN), ridge south of KSC/CCAFS (RS), northwest (NE), northeast (NE), wind speeds < 4 kts (Calm), and days with missing observations (Missing). The value of the None category is 167. The y-axis range was truncated to emphasize the other flow regimes.

CCAFS 1000 UTC Sounding

These data will be used to calculate the stability parameters normally available to the forecasters through the Meteorological Interactive Data Display System (MIDDS). All stability parameters, e.g. the K and Lifted Indices, convective available potential energy, convective inhibition and others, will be calculated and their usefulness as predictors in the forecast equations will be determined. In order to calculate the same values that would be available to the forecasters, the same equations used in the MIDDS code will be used. Mr. Paul Wahner of CSR provided all the necessary code, as well as all the CCAFS rawinsonde data. Work on this part of the task will take place in the next quarter.

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

MESONET TEMPERATURE AND WIND CLIMATOLOGY (MR. CASE)

Forecasters at the 45 WS use the wind and temperature data from the KSC/CCAFS tower network to evaluate LCC and to issue and verify temperature and wind advisories, watches, and warnings for ground operations. The Spaceflight Meteorology Group (SMG) also uses these data when evaluating FR for Shuttle landings at the KSC Shuttle Landing Facility (SLF). Unidentified sensor and/or exposure biases in these measurements at any of the towers could adversely affect an analysis, forecast, or verification for all of these operations. In addition, substantial variations in temperature and wind speed can occur due to geographic location or prevailing wind direction. Forecasters need to know if any towers exhibit a consistent bias in temperature and/or wind speed, and the typical geographical and diurnal variations of temperature and wind speed throughout the tower network. Therefore, the AMU was tasked to identify any systematic biases, geographical variability, or meteorological discrepancies that occur within the tower network by analyzing archived 5-minute tower observations over the past nine years. The task will also result in a tool that forecasters can use to view the results.

Mr. Case focused on the quality control (QC) of 6-ft and 54-ft temperature data during the months of January – June, for the nine years 1995 – 2003. Ms. Lambert ran an automated QC algorithm (Lambert 2002) on the nine-year database of tower data on a month-by-month basis as new data became available from Mr. Paul Wahner of CSR. The dataset for the mesonet climatology task will be complete once December 2003 data are delivered. An initial examination of the quality-controlled data indicated that manual QC was also required for the temperature observations. This section describes the methodology developed for manual QC of the 5-minute temperature observations prior to analysis for systematic biases and geographical variability under specific wind regimes.

The methodology for manual QC of the 6-ft and 54-ft temperatures contains the following steps:

1. Determine the availability of data in percent at each individual tower location,
2. Generate frequency distributions of temperatures at towers with at least 80% data availability,
3. Identify the towers that have data outliers, then generate two-dimensional (2D) frequency diagrams of the temperature distributions versus UTC hour and years to determine if these outliers are bad data, and
4. Using the combined information in the 2D frequency diagrams, along with climate data, and adjacent tower information (as necessary), identify the exact times and years with bad data, and set these data to missing in the database.

This manual QC process is illustrated in an example for Tower 1 data from March, as shown in Figures 4 – 7. The data availability in percent for each tower during March is shown in Figure 4. About 90% of the 5-minute data at Tower 1 (0001 in Fig. 4) were available from the March 1995 to 2003 period of record. Several towers inland of KSC (i.e. Towers 1500 to 2202) had poor data availability at only 40 to 70%. Towers with such poor data availability will be excluded from the climatology in order to obtain representative means and standard deviations of temperatures and wind speeds when categorizing the data into UTC hour and wind-direction bins.

Since Tower 1 showed an adequate amount of data during March, the frequency distribution was plotted to determine if any outliers were present in the database (Fig. 5). By comparing the frequency distributions of several different towers from the same month on one chart, it is easier to identify anomalies. According to Figure 5, Tower 1 measured anomalously high temperatures in the 90s and 100s °F, compared to the other towers plotted on the chart.

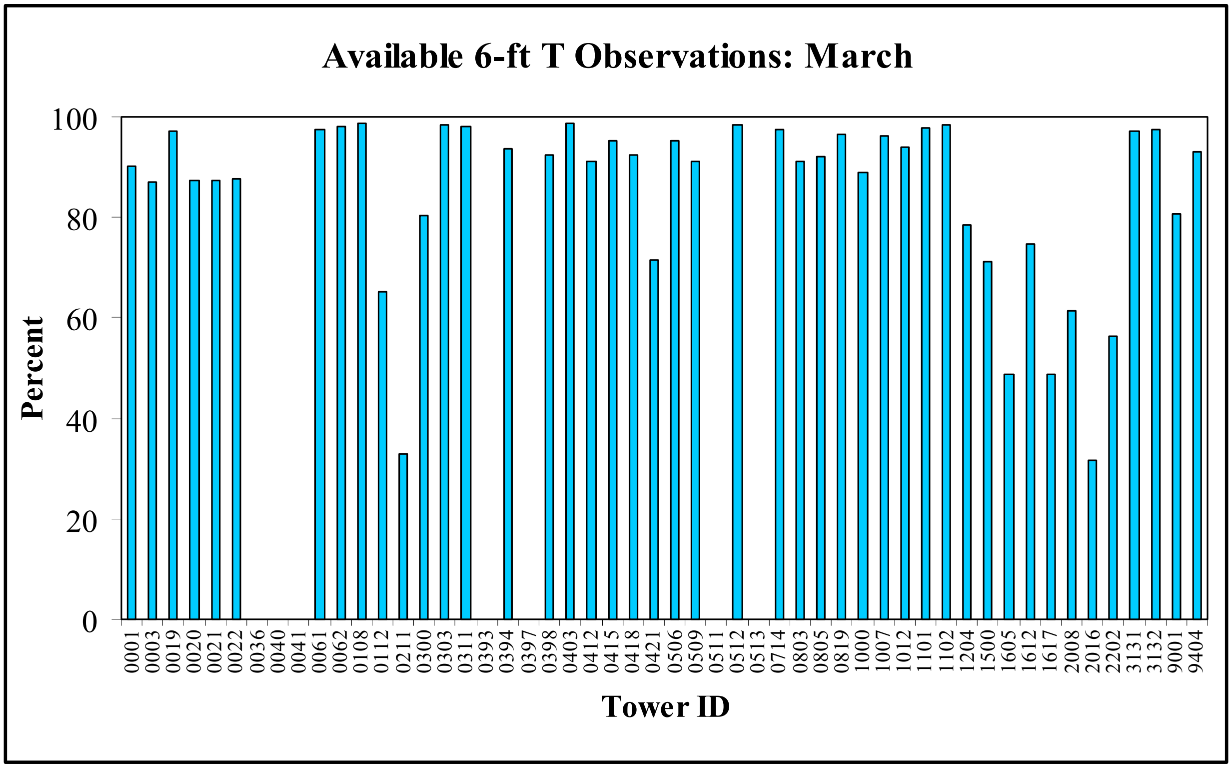

Figure 4. The percent availability of archived 5-minute, 6-ft temperature observations for all towers during March for the years 1995 – 2003. Towers with data availability greater than 80% will be quality controlled and included in the climatology, whereas towers with percentages less than 80% will be excluded due to insufficient data availability.

With the likely outliers identified, the next step is to isolate the UTC time(s) and year(s) during which the potentially bad data occurred. Figures 6 and 7 depict the 2D frequency distribution of temperatures versus UTC time and year, respectively, for Tower 1. Similar diagrams are prepared for all other towers exhibiting questionable frequency distributions. According to Figure 6, the anomalously high temperatures were observed between 1500 and 1700 UTC, since this cluster of occurrences are clearly separate from the smoother diurnal extremes in temperatures. Based on Figure 7, the anomalous data occurred in 1995 since a portion of the distribution is separated from the remainder of the frequency diagram, suggesting that these data are erroneous. These temperature data are determined to be erroneous or valid by examining Melbourne, FL climate data for the day in question, as well as the temporal variations of the 5-minute data, tower winds, and adjacent tower data (as necessary). If the readings are highly unrealistic relative to other meteorological data, then the measurements are determined to be erroneous.

These erroneous data are identified in the database using commands available in the S-PLUS® software package (Insightful Corporation 2000) that quickly isolate the locations in the spreadsheet based on the information obtained from Figures 6 and 7. The bad data are set to a missing flag to indicate that the data have been manually quality controlled. This QC process will continue after each month, as the new 2003 data become available.

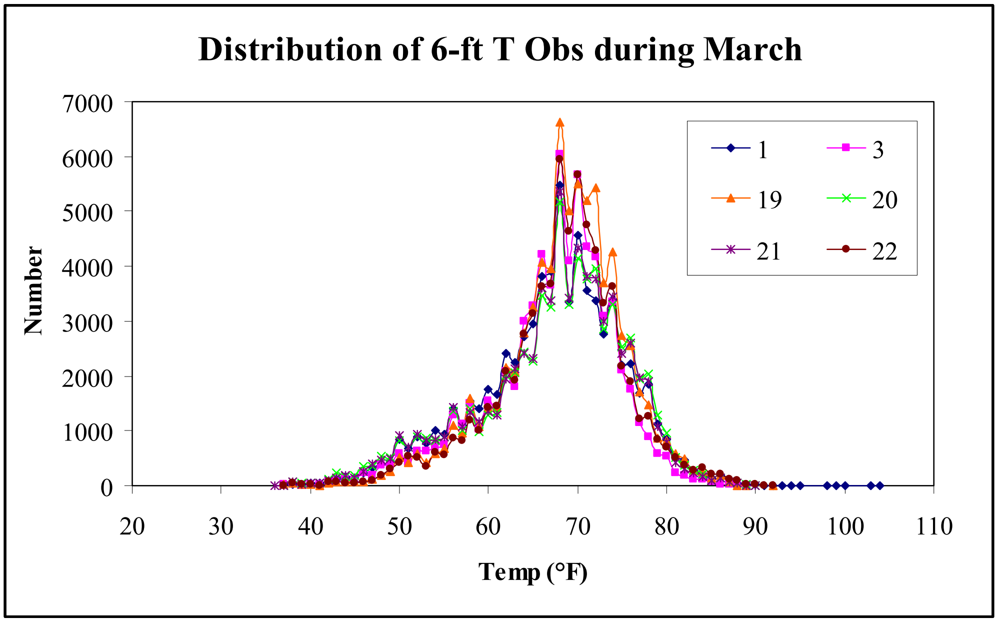

Figure 5. These curves show the frequency distribution in number of observations of the 5-minute, 6-ft temperatures during March (1995 - 2003) at Towers 1, 3, 19, 20, 21, and 22. Note the outliers at Tower 1 with temperatures in the 90s and 100s °F.

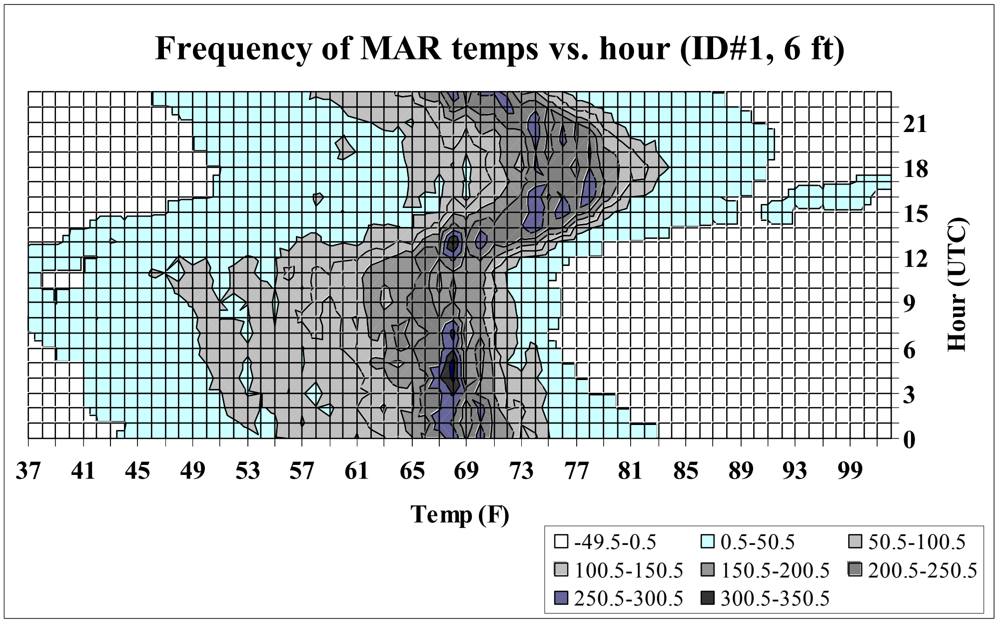

Figure 6. This contour diagram shows 2D frequency distribution of 5-minute, 6-ft temperatures at Tower 1 during March (1995 - 2003) as a function of hour. Note that the high-temperature outliers in Figure 5 occurred between 1500 and 1700 UTC. Frequencies are contoured every 50 units beginning at -49.5, in order to depict one or more occurrences with shading.

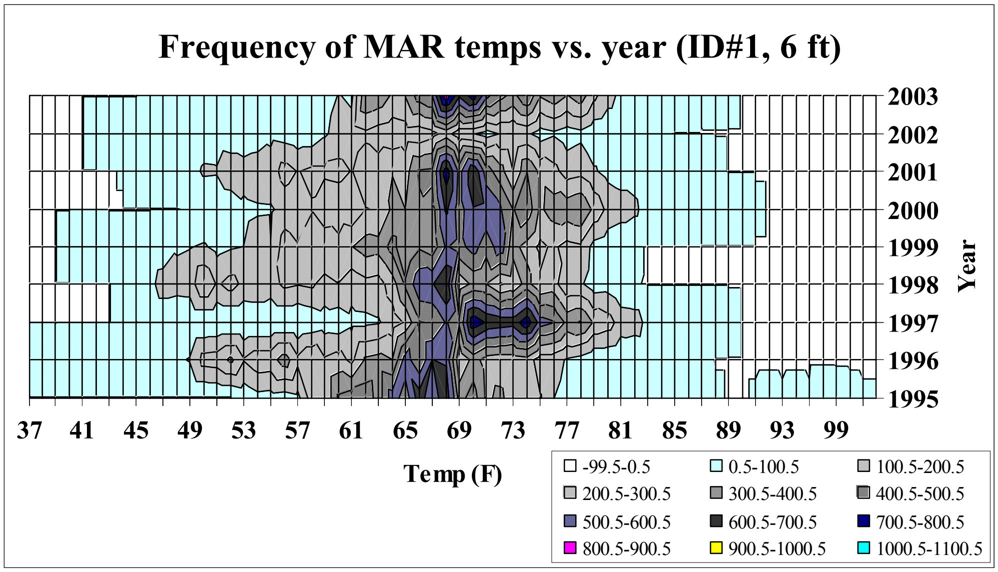

Figure 7. This contour diagram shows the 2D frequency distribution of 5-minute, 6-ft temperatures at Tower 1 during March (1995 to 2003) as a function of year. Note that the high-temperature outliers of Figure 5 occurred in 1995. Frequencies are contoured every 100 units beginning at -99.5, in order to depict one or more occurrences with shading.

For more information on this work, contact Mr. Case at 321-853-8264 or case.jonathan@ensco.com.

SEVERE WEATHER FORECAST DECISION AID (MR. WHEELER AND DR. SHORT)

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).

Mr. Wheeler and Dr. Short visited the National Weather Service (NWS) offices at Melbourne (NWS MLB), NWS TPA, and NWS JAX for technical interchange meetings (TIMs) with their respective Science and Operations Officers, Dave Sharp (NWS MLB), Charlie Paxton (NWS TPA), and Pat Welsh (NWS JAX). The technical interchange at each location consisted of an overview of local procedures for assessing the daily risk of severe weather, a review of locally-generated reports and databases of severe weather events, and a discussion of future plans for integrating improved modeling and analysis capabilities into the operational forecasting environment.

In an effort to identify historical and climatological patterns of severe weather events that may be helpful in the development of local forecast tools, Dr. Short downloaded Storm Event data from the National Climatic Data Center website (http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms) for six counties in east-central Florida: Brevard, Volusia, Indian River, St. Lucie, Orange and Seminole. Storm events were defined as tornadoes, wind gusts ≥ 50 kts and hail with diameters ≥ 0.75 in for the period January 1960 to May 2003. The date, time and location of 1433 events were identified.

Figure 8 shows the annual cycle of the severe weather events. Severe hail events have a distinct annual variation, falling to zero in November and December with a maximum of 106 in the month of May. A secondary peak in March was most pronounced for the inland counties (Orange and Seminole), but was also present for the coastal counties (Volusia, Brevard, Indian River and St. Lucie). Tornado events were most common during the warm season (May through September) but occurred in all months of the year.

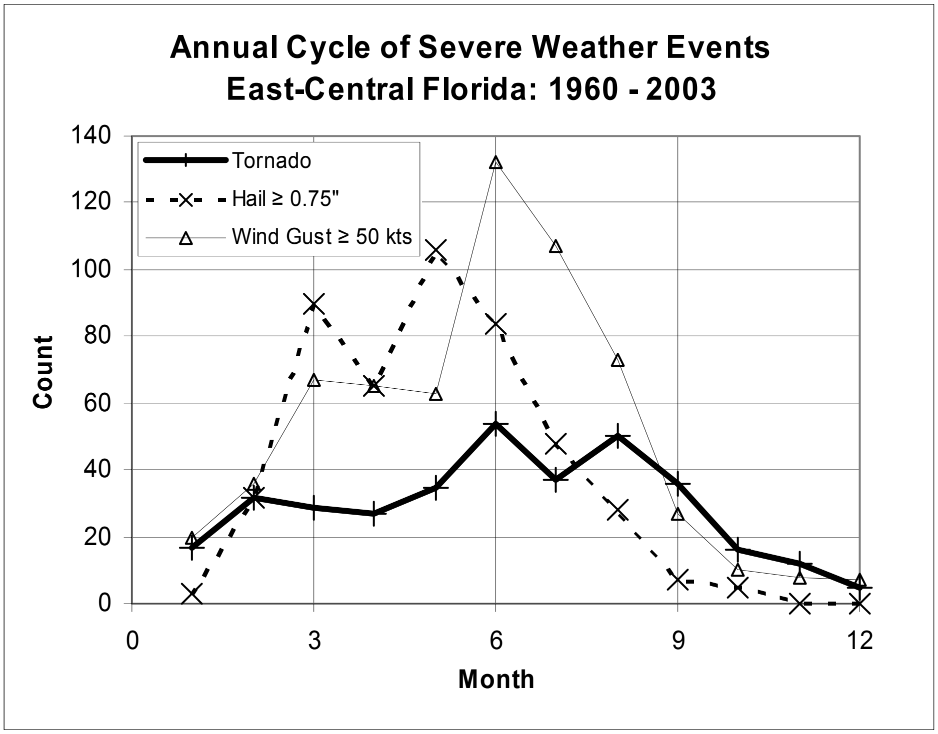

Figure 8. This chart shows the annual cycle of east-central Florida severe weather events from 1960 - 2003.

Figure 9 shows the diurnal cycle of the severe weather events. Severe hail events are rare during the late night and early morning hours, and maximized during the late afternoon. Thunderstorm wind gusts ≥ 50 kts show a similar diurnal cycle, although they are relatively more common than hail during the early morning hours. Tornadoes also show a distinct diurnal variation, but are more frequent than hail and as frequent as thunderstorm wind gusts during the early morning hours.

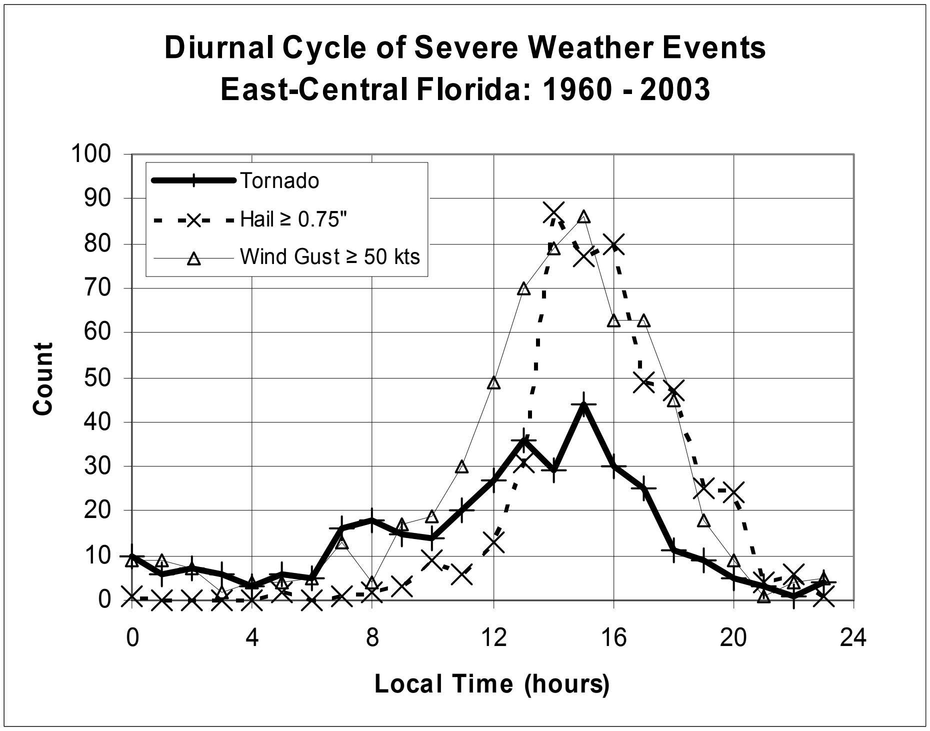

Figure 9. Diurnal cycle of east-central Florida severe weather events from 1960 – 2003.

The annual and diurnal cycles of severe weather events shown in Figures 8 and 9 indicate that the afternoon hours of the warm season are the most likely time for the occurrence of tornadoes, hail ≥ 0.75" in diameter and thunderstorm wind gusts ≥ 50 kts. It is during these times that maximum surface heating, destabilization of the lower atmosphere and other low level forcing mechanisms, such as sea breeze fronts and outflow boundaries from pre-existing storms, can act as triggers for deep convection and severe weather events. However, the documented history of severe weather events at all times of day and through all seasons indicates that the role of large scale forcing mechanisms such as fronts, pre-frontal squall lines and the outer bands of tropical storms should be important elements to be considered by operational forecasters.

For more information on this work, contact Mr. Wheeler at 321-853-8205 or wheeler.mark@ensco.com, or Dr. Short at 321-853-8105 or short.david@ensco.com.

INSTRUMENTATION AND MEASUREMENT

I&M AND RSA SUPPORT (DR. BAUMAN AND MR. WHEELER)

The AMU weather display equipment console was removed and replaced by a new Range Standardization and Automation (RSA) 3-bay console. All government equipment along with the new RSA Advanced Weather Interactive Processing System (AWIPS) hardware was installed into the new console. Lockheed Martin personnel performed the installation of the AWIPS hardware and software. The new equipment was signed over to the Eastern Range by the end of July. Mr. Wheeler attended a RSA TIM in Boulder, CO, where the latest version the AWIPS software was reviewed and discrepancies noted. The final release should be delivered to the Eastern Range by the end of November 2003.

Table 1. AMU hours used in support of the I&M and RSA task in the Fourth Quarter of FY 2003 and total hours since July 1996.

Quarterly Task Support (hours)	***Total Task Support (hours)***
70	583

MINISODAR EVALUATION (DR. SHORT AND MR. WHEELER)

The Doppler miniSODAR™ System (DmSS) is an acoustic wind profiler from AeroVironment, Inc., that provides vertical profiles of wind speed and direction with high temporal and spatial resolution. The DmSS in this evaluation is a model 4000 system presently configured to provide 1-minute wind estimates at 23 vertical levels from 49.2 to 410.1 ft (15 to 125 m) every 16.4 ft (5 m). It is a phased array system with 32 speakers that are used to form an electronically steered beam for measuring orthogonal components of the wind field, 2 horizontal and 1 vertical. The Boeing Company installed a DmSS near Space Launch Complex 37 (SLC-37) as a substitute for a tall wind tower. It will be used to evaluate the launch pad winds for the new Evolved Expendable Launch Vehicle during ground operations and to evaluate LCC during launch operations. In order to make critical Go/No Go launch decisions the 45 WS Launch Weather Officers and forecasters need to know the quality and reliability of DmSS data.

The AMU was tasked to perform an objective comparison between the DmSS wind observations near SLC-37 and those from the nearest tall (≥ 204 ft) wind tower. The tall wind tower nearest to SLC-37 is Tower 6, at a distance of 0.95 n mi to the south-southeast. Tower 6 has wind speed and direction instruments at 4 levels: 12, 54, 162, and 204 ft. Tower 108 is closer, a distance of 0.6 n mi to the NW, but its wind sensors are only at 12 and 54 ft, the latter being close to the lowest level from the DmSS at 49.2 ft. In addition to these nearby wind towers there is a sonic anemometer at the DmSS site mounted on a 33 ft (10 m) pole, about 100 ft southwest of the DmSS. Wind data from the sonic anemometer is integrated into the DmSS data stream and reported at the 33-ft level.

Analysis of July 2003 Data

July 2003 marked the end of the data collection and analysis portion of the MiniSODAR Evaluation task. Mr. Wheeler archived the July DmSS data onto the AMU computer system and Dr. Short obtained the quality-controlled 5-minute tower data from Ms. Lambert. Dr. Short then averaged the DmSS data into 5-minute intervals for comparison with the tower data.

Figure 10a shows the diurnal cycles of average and peak wind speeds for July 2003 from 162 ft on Tower 6 and 164 ft of the DmSS, the level closest to 162 ft. The daily averaged wind speeds from the DmSS and Tower 6 are 7.3 and 7.5 kts, respectively, with the DmSS showing slightly lower values during the nighttime hours and slightly higher values during the daytime hours. The daily averages of peak wind speed from the DmSS and Tower 6 are 13.4 and 9.3 respectively, representing a positive bias of 44%. These results are consistent with those presented in the previous AMU Quarterly Report and with other analyses of average and peak wind speed data throughout the course of this evaluation.

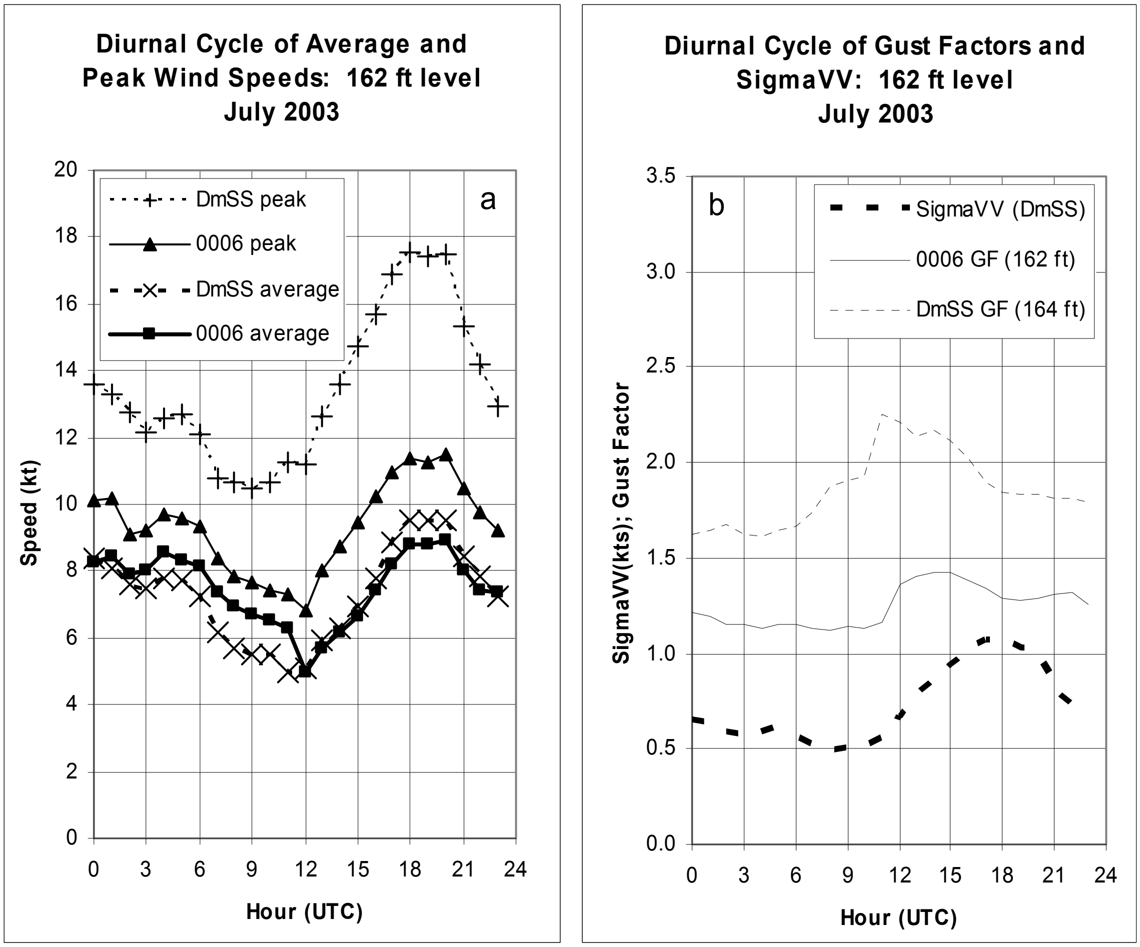

Figure 10. a) Diurnal cycle of average and peak wind speed from Tower 6 (0006) at 162 ft and from the DmSS at the closest corresponding level, 164 ft. b) Diurnal cycle of gust factors from 1a and the standard deviation of vertical velocities from the DmSS at 164 ft.

Figure 10b shows the diurnal cycles of gust factors from Figure 10a, where the gust factor is the ratio of the peak to average wind speeds. DmSS gust factors were systematically higher than those observed at Tower 6, because the DmSS peak speeds are systematically higher while the average speeds of the two sensors are nearly the same. Figure 10b also shows the standard deviation of vertical velocities (SigmaVV) from the DmSS at 164 ft. The diurnal cycle in SigmaVV was consistent with a more turbulent atmosphere during the daytime hours due to effects of surface heating. The mathematical Doppler profiler model developed by Dr. Short, and documented in detail in the final report, suggests that rapid spatial and temporal variations in vertical velocity can cause peak wind speeds from a phased array profiler to be biased high while average wind speeds from the same profiler are unbiased.

Dr. Short and Mr. Wheeler began preparation of the final report during this quarter. They completed a first draft that was reviewed internally and revised accordingly. This revised version has been submitted for external review by customers at 45 WS, SMG, and NWS MLB.

For more information on this work, contact Dr. Short at 321-853-8105 or short.david@ensco.com, or Mr. Wheeler at 321-853-8205 or wheeler.mark@ensco.com.

MESOSCALE MODELING

ARPS OPTIMIZATION AND TRAINING (MR. CASE)

Accurate guidance from the Advanced Regional Prediction System (ARPS) numerical weather prediction model is necessary to continue improvements to operational short-range forecasts (< 12 hours) of local atmospheric fields across East-Central Florida. Realistic depictions of the short-range prognostic state of meteorological phenomena such as sea breezes and convection will assist forecasters with critical short-term forecasts and severe weather outlooks/warnings at NWS MLB. In addition to these types of forecasts, SMG will also use the ARPS in FR evaluation. Recommendations for future improvements, along with documentation of local configurations, will facilitate the transfer of routine ARPS maintenance responsibilities to NWS MLB and SMG personnel. The AMU was tasked to assist with testing, optimizing, and adjusting as necessary the ARPS forecast cycle configuration at NWS MLB, and provide documentation and training for the transfer of ARPS maintenance to NWS MLB and SMG.

Mr. Case and NWS MLB representatives changed the soil moisture initialization procedure in the real-time ARPS, and dramatically improved the forecast output reliability on the NWS MLB Linux cluster. The following sub-sections provide details regarding these two major accomplishments this past quarter.

Improvements to the Soil Moisture Initialization

When the system first became operational at NWS MLB, the ARPS soil moisture and soil temperatures were interpolated from the RUC 2-h forecast grids. During the early summer months, the AMU and NWS MLB noticed that the ARPS model output had a consistently hot, dry bias near the surface. This bias resulted from unrealistically dry soil moisture values in the RUC forecast grids across much of the Florida peninsula. To fix this problem, the AMU implemented and fine-tuned the Antecedent Precipitation Index (API) that is currently available in the ARPS model. The API initialized soil moisture is based on a first-guess value, and a long-term integration of daily rain-gauge measurements from the National Centers for Environmental Prediction (NCEP). The NCEP rain gauge data consists of a single daily reading of rainfall at a large number of gauge stations across the United States. The locations of the gauges across the Florida peninsula are shown in Figure 11.

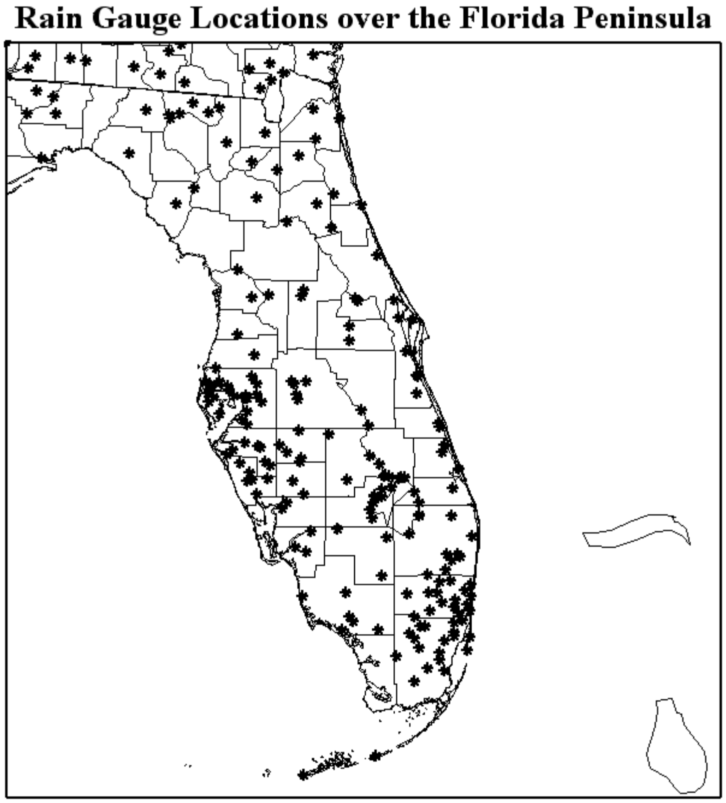

Figure 11. Locations of the NCEP daily rain gauge measurements used to initialize soil moisture in the real-time ARPS at NWS MLB.

The ARPS initial soil moisture is determined at each grid point by adjusting the ratio between the wilting and saturation points for each soil type, using the rain gauge measurements from each observation. The first-guess field at t – 150 days is set to 50% of the saturation value for a particular soil type, and then adjusted each day according to the rainfall amounts from nearby gauges and the evapo-transpiration rate based on the time of year (evapo-transpiration follows a sinusoidal function peaking on 15 July and reaching a minimum on 15 January). The API is run for 150 days in order to lose all memory of the initial guess of 50% of the saturation point, since this value could be substantially in error depending on the time of year and recent rainfall patterns. With some tuning by the AMU, the API resulted in a robust initialization of soil moisture, which resulted in much more accurate low-level temperature and moisture forecasts in the model, particularly during the daytime.

Improvements in the Forecast Reliability

Throughout the summer, the real-time ARPS at NWS MLB frequently failed due to hardware and network issues on their Linux cluster. Through a combination of assistance from the NWS MLB's vendor and a suggestion by the AMU, the forecast reliability was improved to nearly 100% in late August. The primary source of failures on the NWS MLB cluster was related to the intra-network between the compute nodes and the master node while the model ran in parallel on several different processors. In the original configuration, the ARPS model wrote all data files across the cluster's network from each separate processor to the master node disk. The modification suggested by the AMU was to write all ARPS data files from each separate processor onto the local compute node disk, rather than write each file across the network. This modification resulted in the improvement to the model output reliability. In addition, the vendor's assistance resulted in improving the run-time performance of the ARPS simulations by about 10%.

For more information on this work, contact Mr. Case at 321-853-8264 or case.jonathan@ensco.com.

AMU CHIEF'S TECHNICAL ACTIVITIES (DR. MERCERET)

Dr. Merceret and Ms. Ward submitted a note to the American Meteorological Society Journal of Atmospheric and Oceanic Technology documenting their automated cloud edge detection algorithm. Dr. Merceret participated in several Lightning Advisory Panel teleconferences and a Titan Day-of-Launch Working Group regarding the structure of proposed new lightning LCC. Dr. Merceret upgraded the software he used to process data from the Airborne Field Mill project. He also addressed several concerns to the Shuttle program concerning their exclusive use of high-resolution wind observations for Shuttle loads analyses, and began an analysis of the correlation and spectra of filtered and unfiltered Jimsphere pairs for presentation at a November meeting of the Shuttle Natural Environments Panel.

AMU OPERATIONS

Mr. Wheeler finished his work on a 45 WS Option Hours task to analyze wind tower and other data from a severe weather event that occurred near the SLF on 4 March 2003. His report was reviewed internally and will be published next quarter. Mr. Wheeler also worked with Mr. Tim Wilcox of Linux-Force on upgrading the hardware and software on the AMU Linux cluster. He submitted all Fiscal Year 2003 AMU equipment and software purchase requests through the KSC Procurement office. All but two pieces of hardware that have been ordered have been delivered to the AMU.

Dr. Bill Bauman became the AMU Program Manager on 4 August, taking the place of Dr. John Manobianco who began work on the new ENSCO Global Environmental MicroElectroMechanical Systems (MEMS) Sensors (GEMS) contract. Dr. Bauman received training on program manager duties from Dr. Manobianco in August. Dr. Bauman also worked on a KSC Weather Office Option Hours task to prepare a Shuttle Imaging Weather Evaluation Concept Study. The AMU was tasked to identify and evaluate alternative methods for determining whether or not a sufficient number of Shuttle launch imaging cameras will have a field of view unobstructed by weather. His memorandum was completed in October.

REFERENCES

Everitt, J. A., 1999: An Improved Thunderstorm Forecast Index for Cape Canaveral, Florida. M.S. Thesis, AFIT/GM/ENP/99M-06, Department of Engineering Physics, Air Force Institute of Technology, 98 pp. [Available from the Air Force Institute of Technology, Wright-Patterson Air Force Base, OH 45433].

FSL and NCDC, 1996: *Radiosonde Data of North America 1946 – 1996*. CD-ROM. [Available from the NCDC Online Store at http:\\www.ncdc.noaa.gov.]

FSL and NCDC, 1997: *Radiosonde Data of North America 1994 – 1997*. CD-ROM. [Available from the NCDC Online Store at http:\\www.ncdc.noaa.gov.]

Insightful Corporation, 2000: *S-PLUS® 6 User's Guide*, Insightful Corp., Seattle, WA, 470 pp.

Lambert, W. C., 2002: Statistical Short-range Guidance for Peak Wind Speed Forecasts on Kennedy Space Center/Cape Canaveral Air Force Station: Phase I Results. NASA Contractor Report CR-2002-211180, Kennedy Space Center, FL, 39 pp. [Available from ENSCO, Inc., 1980 N. Atlantic Ave., Suite 230, Cocoa Beach, FL, 32931.]

Lericos, T. P., H. E. Fuelberg, A. I. Watson, and R. L. Holle, 2002: Warm season lightning distributions over the Florida Peninsula as related to synoptic patterns. *Wea. Forecasting*, **17**, 83 – 98.

List of Acronyms

2D	Two Dimensional
30 SW	30th Space Wing
30 WS	30th Weather Squadron
45 RMS	45th Range Management Squadron
45 OG	45th Operations Group
45 SW	45th Space Wing
45 SW/SE	45th Space Wing/Range Safety
45 WS	45th Weather Squadron
ADAS	ARPS Data Analysis System
AFSPC	Air Force Space Command
AFWA	Air Force Weather Agency
AMU	Applied Meteorology Unit
API	Antecedent Precipitation Index
ARPS	Advanced Regional Prediction System
AWIPS	Advanced Weather Interactive Processing System
CCAFS	Cape Canaveral Air Force Station
CGLSS	Cloud-to-Ground Lightning Surveillance System
CSR	Computer Sciences Raytheon
DmSS	Doppler miniSODAR System
EDT	Eastern Daylight Time
FR	Flight Rules
FSL	Forecast Systems Laboratory
FSU	Florida State University
FY	Fiscal Year
JAX	Jacksonville, FL 3-Letter Identifier
JSC	Johnson Space Center
KSC	Kennedy Space Center
LCC	Launch Commit Criteria
MIA	Miami, FL 3-Letter Identifier
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NOAA	National Oceanic and Atmospheric Administration
NSSL	National Severe Storms Laboratory
NWS MLB	National Weather Service in Melbourne, FL
PC	Personal Computer
POR	Period of Record
QC	Quality Control
RSA	Range Standardization and Automation
SLC-37	Space Launch Complex 37
SLF	Shuttle Landing Facility
SMC	Space and Missile Center
SMG	Spaceflight Meteorology Group
SRH	NWS Southern Region Headquarters
TIM	Technical Interchange Meeting
TPA	Tampa, FL 3-Letter Identifier
USAF	United States Air Force

UTC	Universal Coordinated Time
WWW	World Wide Web

Appendix A

AMU Project Schedule

31 October 2003

AMU Projects	Milestones	Scheduled Begin Date	Scheduled End Date	Notes/Status
Objective Lightning Probability Phase I	Literature review and data collection/QC	Feb 03	Oct 03	Ongoing for 2003 Data
	Statistical formulation and method selection	Jun 03	Oct 03	Delayed Due to Data Collection and McIDAS Code Interpretation
	Equation development, tests with verification data and other forecast methods	Aug 03	Nov 03	Delayed as stated above
	Develop operational products	Nov 03	Jan 04	On Schedule
	Prepare products, final report for distribution	Jan 04	Mar 04	On Schedule
Mesonet Temperature and Wind Climatology	Process data and calculate climatology of biases/deviations	Jul 03	Jan 04	On Schedule
	Develop tabular and geographical displays	Feb 04	Apr 04	On Schedule
	Final Report	Apr 04	Jun 04	On Schedule
	Assistance in transitioning product into operations	Jul 04	Jul 04	On Schedule
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	Feb 04	On Schedule
	Final report	Feb 04	Mar 04	On Schedule

AMU Project Schedule

31 October 2003

AMU Projects	Milestones	Scheduled Begin Date	Scheduled End Date	Notes/Status
MiniSODAR Evaluation	Data collection, data reduction, and QC	Aug 02	Jul 03	Completed
	Comparative analysis of miniSODAR and nearby wind tower observations	Sep 02	Jul 03	Completed
	Final Report	Jul 03	Oct 03	On Schedule
Updating ADAS/ARPS Software	Document detailing the AMU changes made to ARPS version 4.5.2	Apr 03	Jul 03	Completed
	Remote / verbal assistance for incorporating AMU code modifications	Jun 03	Jul 03	Completed
	Final memorandum	Jul 03	Jul 03	Completed
ARPS Optimization and Training	Assistance for testing and optimizing the real-time ARPS configuration	Jul 03	Dec 03	On Schedule
	Final task memorandum and training/maintenance manual	Dec 03	Dec 03	On Schedule

NOTICE