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Applied Meteorology Unit (AMU)

Quarterly Report

Third Quarter FY-02

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EXECUTIVE SUMMARY

This report summarizes the Applied Meteorology Unit (AMU) activities for the third quarter of Fiscal Year 2002 (April – June 2002). A detailed project schedule is included in the Appendix. Significant progress was made on four main AMU tasks this quarter.

<u>Task</u>	<u>Statistical Short-Range Forecast Tools</u>
Goal	Develop a short-range peak winds forecast tool to use in launch and landing support operations.
Milestones	Developed a model to estimate distribution parameters for higher wind speeds so that the probability of exceeding specified peak wind values at these higher speeds can be determined.
Discussion	The model is a polynomial fit to the parameters of the peak wind speed Weibull distributions associated with the average wind speeds. This model estimates the distribution parameters for higher wind speeds that had few or no observations. This allows forecasters to estimate probabilities of exceeding peak speed values that are significant to operations.
<u>Task</u>	<u>Land Breeze Forecasting</u>
Goal	Develop rules of thumb that will improve the reliability of the land-breeze occurrence forecasts and help determine land-breeze timing, direction, and strength.
Milestones	Examined the large-scale flow, sea-breeze occurrence, and temperature fields for 171 land-breeze events to determine if they could serve as predictors for the land-breeze onset time, strength, and movement.
Discussion	The parameters examined so far do not correlate well with the land-breeze onset time and movement. The most substantial relationship found is when the prevailing large-scale flow is offshore, land breezes preceded by a sea breeze the previous afternoon typically move through the KSC/CCAFS area before 0400 UTC (around midnight local time).
<u>Task</u>	<u>AMPS Moisture Profiles</u>
Goal	Evaluate differences in moisture profiles between the Automated Meteorological Profiling System (AMPS) and the Meteorological Sounding System (MSS), and determine the impact of those differences on thunderstorm forecasting indices.
Milestones	Completed the analysis of 26 dual-sensor AMPS/MSS profiles and wrote first draft of memorandum describing results.
Discussion	The AMU comparison of AMPS and MSS RH profiles shows a bias pattern between MSS, the current operational system, and AMPS, its planned replacement. The bias pattern enhances the contrast between low level moisture and upper level dryness, making the atmosphere appear less stable when diagnosed using thunderstorm forecasting indices based on AMPS data.
<u>Task</u>	<u>Verification of Numerical Weather Prediction Models</u>
Goal	Develop an automated method that will verify specific weather phenomena in high-resolution models in order to improve upon traditional verification techniques.
Milestones	Developed an objective method that identifies sea-breeze boundaries from fields of wind direction, and verifies the forecast sea-breeze boundary against the observed location.
Discussion	The verification algorithm identifies significant gradients in wind direction along a wind-shift boundary. Preliminary tests were done to see how well the algorithm identifies and verifies sea breezes. The output from these tests shows the horizontal variation in the model timing errors of the sea-breeze front, and regions where the model erroneously predicted a sea breeze or failed to predict its occurrence.

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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.merceret-1@ksc.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

STATISTICAL SHORT-RANGE FORECAST TOOLS (MS. LAMBERT)

The peak winds near the surface are an important forecast element for both the Space Shuttle and Expendable Launch Vehicle (ELV) programs. As defined in the Shuttle Flight Rules (FR) and the Launch Commit Criteria (LCC), each vehicle has certain peak wind thresholds that cannot be exceeded in order to ensure the safety of that vehicle during launch and landing operations. The 45th Weather Squadron (45 WS) and the Spaceflight Meteorology Group (SMG) indicate that peak winds are a challenging parameter to forecast. The goal of this task is to develop short-range peak-wind forecast tools to be used in support of ELV/Shuttle launches and Shuttle landings. Ms. Lambert is using seven years (January 1995 – December 2001) of 5-minute data from the Kennedy Space Center/Cape Canaveral Air Force Station (KSC/CCAFS) wind tower network and any other appropriate data sets to develop a statistical short-term forecast method for peak winds at the specific tower sites shown in Table 1.

Table 1. The towers and heights at which peak winds forecasts will be made, and their associated launch or landing operation.

Launch Operation	***Tower(s)***	***Primary Height (ft)***	***Backup Height (ft)***
Shuttle	0393/94, 0397/98	60	N/A
Shuttle (*landing*)	511 / 512 / 513	30	N/A
	313	492	N/A
Atlas	36	90	N/A
Delta	20 / 21	90	54
Titan	1101 / 1102	162	54

Modeled Peak Wind Distributions

As stated in the previous AMU Quarterly Report (Second Quarter FY-02), results of several tests indicated that the probability density functions (PDFs) of the observed peak winds resembled the Weibull distribution (Wilks 1995). The mu, shape, and scale parameters describe a Weibull distribution. The mu parameter is analogous to the mean of the distribution. The shape parameter determines the location of the maximum probability in the distribution. As the shape value increases, the location of the maximum shifts to the right. The effect of the scale parameter is to stretch/compress the PDF horizontally, thereby also compressing/stretching it vertically.

Ms. Lambert developed a model that estimated the Weibull parameters for the distributions of 5-minute peak wind speed based on the 5-minute average wind speeds. The results of testing linear and polynomial regression techniques indicated that a quadratic polynomial regression calculated the best estimate of the Weibull scale and mu parameters. The amount of variance in the parameter values explained by these polynomial equations exceeded 98%. Equations were developed using the polynomial regression function in S-PLUS® (Insightful Corp. 2000) for each tower/height combination, each month in the cool season (October – April), and both the scale and mu parameters for a total of 252 equations of the form

$$\text{Parameter} = Ax^2 + Bx + C,$$

where x is the 5-minute average wind speed for every knot from 1 – 30 knots and A, B, and C are constants. Since there were very few wind observations above 25 knots for most of the towers, it was unclear whether the stronger wind speeds exhibited the same Weibull characteristics as the lower speeds. Stronger winds caused by phenomena such as frontal passages, convective gust fronts, and high momentum air penetrating from above the inversion level may have distributions other than Weibull, but the sample sizes were too small to determine the actual distribution. Therefore, the parameters were only estimated for speeds up to 30 knots.

In order to create new PDFs, the shape parameter had to be known. The shape parameter was difficult to model, but it could be estimated from scale and mu through the equation

$$\text{mu} = \text{scale} * \Gamma[(\text{shape}+1)/\text{shape}].$$

The gamma function ($\Gamma[]$) in the equation above is an integral of the form (Wilks 1995)

$$\Gamma(\alpha) = \int_0^\infty t^{\alpha-1} e^{-t}\, dt \ .$$

A function for this integral exists in S-PLUS and was used to estimate the shape parameter from the modeled mu and scale parameters.

The results of the calculations for Tower 0397 in January are shown in Figure 1. Tower 0397 is located just northwest of Shuttle launch complex 39B and has a wind sensor at 60 ft. As reported in the previous AMU Quarterly Report (Second Quarter FY-02), the only 5-minute average wind speeds used to create the equations were those that had at least 600 observations in the monthly stratifications. For the particular case in Figure 1, the number of observations decreased below 600 at 19 knots and continued to decrease quickly as speed increased. While the modeled trends of all three parameters are smooth up to 30 knots, the observed trends begin to deviate from the modeled trends at 19 knots.

The underlying assumption is that the modeled trend beyond 18 knots represents what the true trend would be if there were enough observations to define the PDFs. To test this assumption, the standard errors of the Weibull parameters for observed peak wind distributions associated with 5-minute average wind speeds were calculated. The modeled parameter values associated with most of the average wind speeds were well within the standard error of the observed parameters. However, the standard errors associated with average wind speeds > 26 knots were not large enough to encompass the modeled parameter values. This result raises questions about the validity of the underlying assumption at these speeds. On the other hand, the modeled parameters at all average wind speeds in Figure 1 produce mean peak speeds consistent with known and accepted gust factors (McVehil and Camnitz 1969; Hsu 2001). This contradiction will be explored more fully in the next quarter.

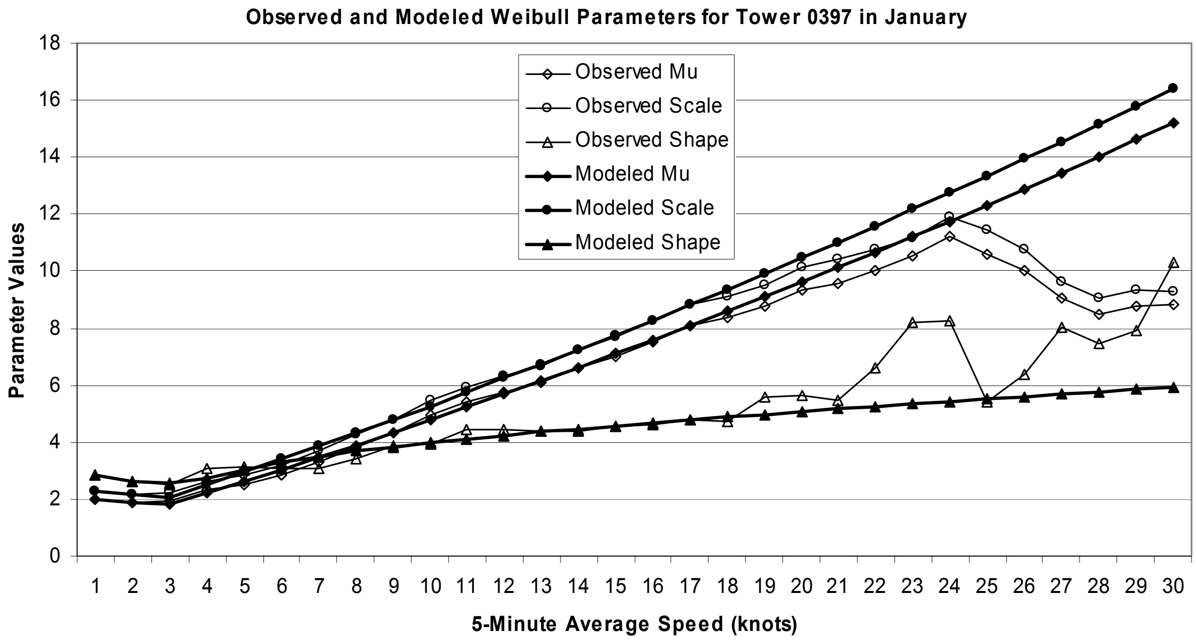


Figure 1. The observed (thin lines) and modeled (thick lines) Weibull scale, mu, and shape parameter values for the peak wind speed PDFs based on the January 5-min average wind speeds from 1-30 knots at Tower 0397.

The new modeled shape and scale parameters were used to create PDFs from which probabilities of exceeding certain peak wind values could be extracted. Once again, S-PLUS contained a function which produced new PDFs given a range of speed values and the shape and scale parameters. A comparison of the observed and modeled PDFs for Tower 0397 in January is shown by Figures 2 and 3, respectively. In Figure 2 the height and width of the PDFs decrease and increase, respectively, with increasing average speed in a consistent manner. When average speed reaches 19 knots, however, the PDFs no longer have a continuous shape nor continue the height/width trend of the previous PDFs. The number of observations used to calculate these PDFs was less than 600 (gray curves). All PDFs in Figure 3 were created using the modeled scale and shape parameters. The trend of the PDFs in Figure 3 is almost identical to that in Figure 2, except for the PDFs at 19 knots and beyond that follow a smooth trend of decreasing height and increasing width. Also, the widths and peak PDF values are similar for the observed PDFs created from more than 600 observations and the corresponding modeled PDFs (black solid and dashed lines in Figures 2 and 3).

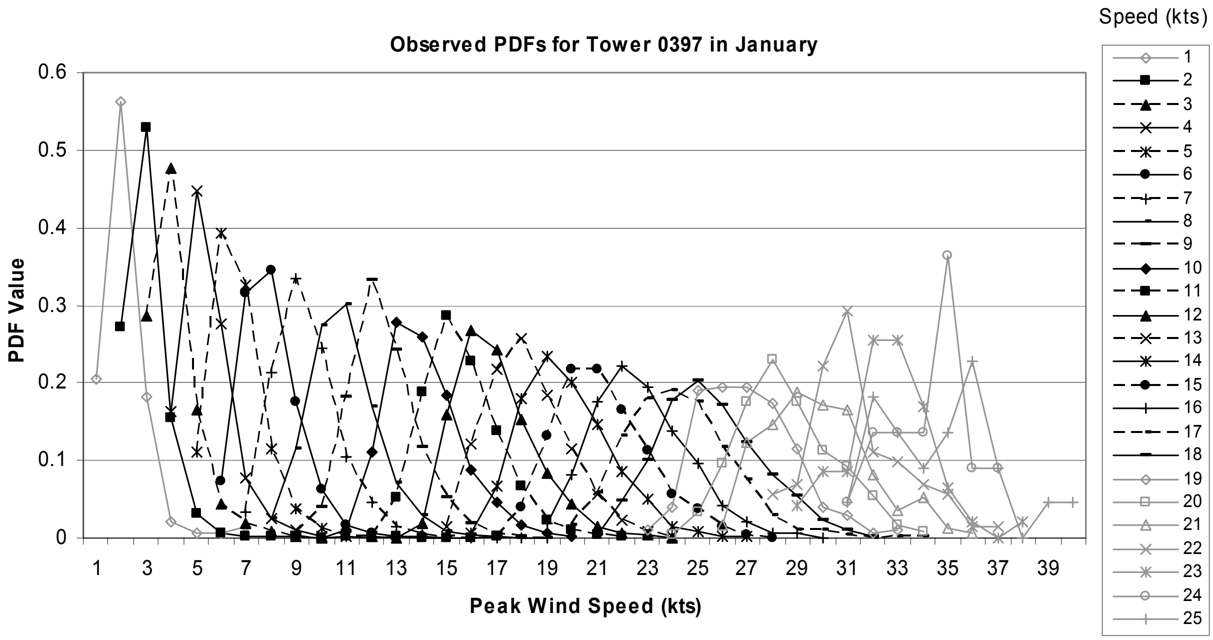


Figure 2. Observed PDFs of the January peak wind speed distributions associated with each 5-minute average wind speed from 1-25 knots at Tower 0397. The gray PDFs were calculated from distributions with less than 600 observations. The legend shows the 5-minute average speeds associated with each PDF. The black PDFs alternate solid and dashed lines to make them easier to distinguish.

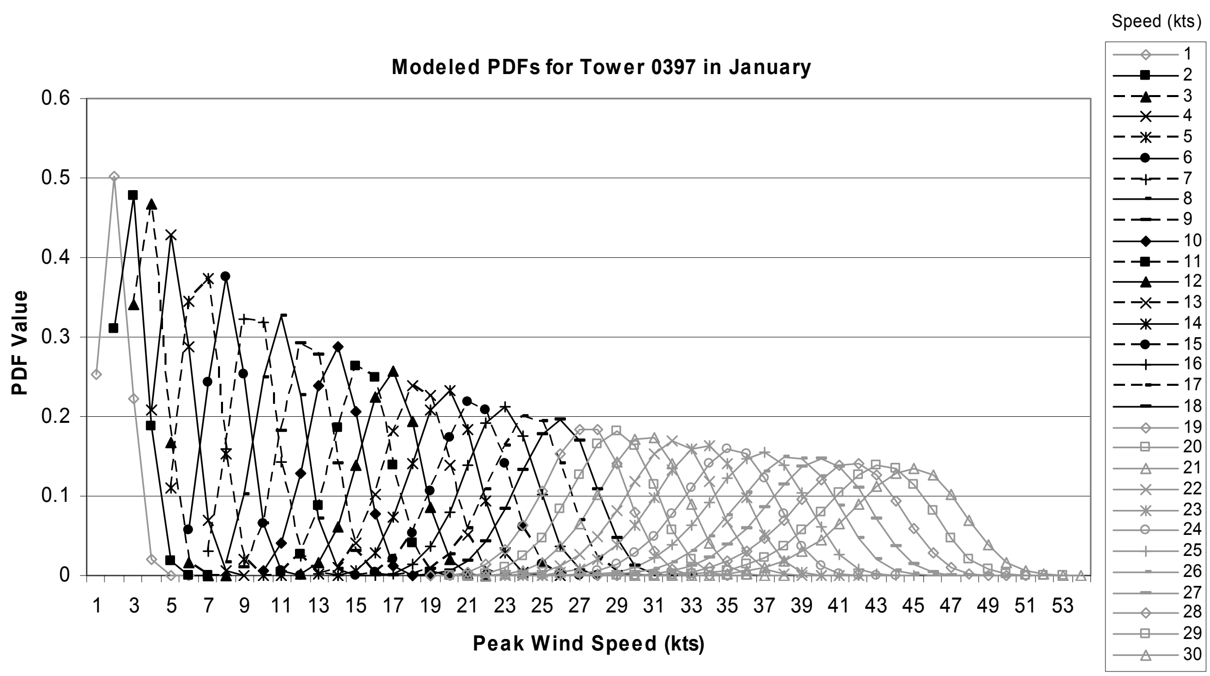


Figure 3. Modeled PDFs of the January peak wind speed distributions associated with each 5-minute average wind speed from 1-30 knots at Tower 0397. The gray lines indicate the PDFs whose parameters were not used to determine polynomial regression equations. The legend shows the 5-minute average speeds associated with each PDF. The black PDFs alternate solid and dashed lines to make them easier to distinguish.

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

Improved Anvil Forecasting Phase II (Dr. Short and Mr. Wheeler)

The 45 WS Launch Weather Officers (LWOs) have identified anvil forecasting as one of their most challenging tasks when attempting to predict the probability of an LCC violation due to the threat of natural and triggered lightning. SMG forecasters have reiterated this difficulty when evaluating Space Shuttle FR. Phase I of this task established the technical feasibility of developing an observations-based forecasting technique, given the promising relationships found by the 45 WS between anvil length and lifetime and the average wind speed/direction and moisture content in the anvil layer (Lambert 2000). The goals of Phase II are to 1) build upon the results of Phase I with data collection and analysis to increase the sample size of anvil cases and improve the reliability of resulting statistics, and 2) develop objective graphical tools for forecasting the occurrence of anvil clouds over the KSC/CCAFS area with lead times of 36 hours or less.

Delivery and Implementation of Forecast Tool for Operational Use

Dr. Short and Mr. Wheeler completed development of a graphical tool for short-term forecasting of anvil clouds. The tool overlays an anvil threat sector on a satellite image, indicating the direction and distance from which anvil clouds could threaten the station within the next three hours. Dr. Short and Mr. Wheeler delivered the tool to the 45 WS and it has been implemented in the Range Weather Operations (RWO) on the Meteorological Interactive Data Display System (MIDDS). Two minor updates were made to the forecast tool in May, at the request of the Shuttle LWO: addition of a 10 n mi circle and a command line option to input any radiosonde time of interest.

The Phase II Final Report was completed and distributed to customers.

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.

Land Breeze Forecasting (Mr. Case and Mr. Wheeler)

The onset of a nocturnal land breeze at KSC, CCAFS, and Patrick Air Force Base is an operationally significant event. The occurrence and timing of the land breeze at night affects low-temperature and fog forecasts, and is critical for toxic material dispersion forecasts during hazardous operations. With current tools, 45 WS forecasters are able to predict the occurrence of a land breeze for a particular night reasonably well, but find it challenging to forecast the timing. As a result, the 45 WS has tasked the AMU to develop forecast rules that will improve the reliability of the occurrence forecasts, and help determine the timing of land-breeze occurrences. These rules will include guidance on the duration, speed, and approximate direction of the winds associated with the land breeze.

In the last AMU Quarterly Report (Second Quarter FY-02), some preliminary results were presented from the AMU's objective land-breeze climatology for the months of October - May in the years 1995 - 2002. This climatology yielded 257 land-breeze events. Mr. Case and Mr. Wheeler used these events to begin developing forecast rules that can be applied to daily forecasts of land breezes and their characteristics. The following sections describe the methodology used to analyze and categorize the conditions associated with the land-breeze events, and present some preliminary results from a cluster analysis of selected land-breeze events.

Methodology for Developing Possible Forecast Rules

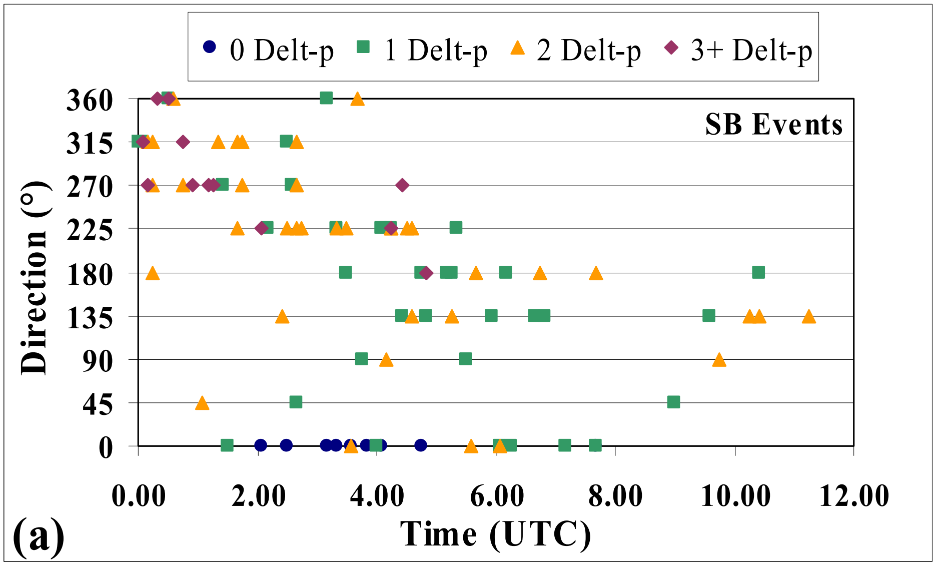
Mr. Case removed those events that were weak or subtle, focusing on only the most substantial land-breeze days in the land-breeze climatology database. He then performed a subjective classification of the synoptic flow for the remaining 171 events by examining mean sea-level pressure (MSLP) fields from the National Centers for Environmental Prediction (NCEP)/National Center for Atmospheric Research (NCAR) reanalysis archive. The NCEP/NCAR reanalysis maps of MSLP were examined at 0000 UTC for each land-breeze day to discern both the large-scale flow and MSLP gradient across the Florida Peninsula. The 171 events were then categorized according to the large-scale flow, magnitude of the MSLP gradient, and occurrence/non-occurrence of a sea breeze during the previous afternoon. Mr. Wheeler also examined the temperature contrasts as a function of time from Orlando, across selected KSC/CCAFS wind towers, and out to buoy 41009 offshore of Cape Canaveral.

Preliminary Results of Analysis

Out of the 171 distinctive land-breeze days, 95 events had a sea breeze (SB) occur during the previous afternoon (SB events) and 76 did not have a sea breeze occur (non-SB events). The greatest number of "sharp" land breezes with distinct frontal boundaries occurred within the SB events database. Fifty (50) of the 95 SB events (52%) were considered sharp through a subjective analysis, whereas only 23 of 76 non-SB events (30%) were denoted as sharp.

An examination of the distribution of land-breeze onset times versus the prevailing synoptic flow direction revealed that the most significant clustering of the data occurred in the northerly and offshore synoptic flow directions (Figure 4). In Figure 4a (SB events), the land-breeze onset time always occurred before 0300 UTC when the prevailing synoptic flow was from the northwest (315°) or west (270°), with the exception of one outlier. Under southwest flow (225°), all land-breeze onset times fell between 0200 and 0600 UTC in Figure 4a. These results suggest that the land breezes associated with a sea breeze the previous afternoon could be a retreating sea-breeze front during the early nighttime hours. In the non-SB events (Figure 4b), few land-breeze events occurred with offshore synoptic flow (225°, 270°, and 315°); however, all of these events also had an early land-breeze onset time (before 0400 UTC).

For synoptic flow from the south (180°), onshore (135°, 90°, and 45°), and light and variable (0°), there was a large spread among land-breeze onset times for both SB and non-SB events. Most of these flow regimes experienced a range of land-breeze onset times of at least 6 hours. The magnitude of the MSLP gradient did not provide guidance in explaining this large variance. Therefore, it appears that land breezes occurring within onshore synoptic flow may have relatively low predictability based on the direction and magnitude of the large-scale flow. Further investigation is required to determine the best predictors of the land-breeze onset time with prevailing onshore flow.



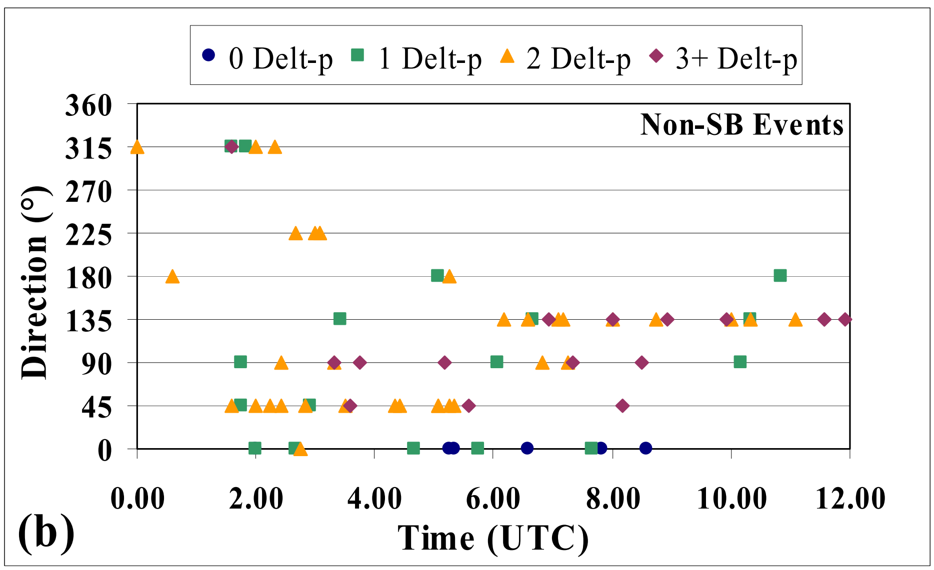


Figure 4. The distribution of land-breeze onset times as a function of prevailing synoptic flow direction and mean sea-level pressure gradient (Delt-p) in mb across the Florida Peninsula for (a) SB events, and (b) non-SB events. The direction on the y-axis represents the quadrant of the synoptic flow (e.g. 360° = northerly, 315° = northwest, etc.), where 0° denotes light and variable flow.

Mr. Case and Mr. Wheeler examined other parameters such as land-sea temperature contrasts, land-breeze direction as a function of synoptic flow, and diurnal temperature contrasts in order to construct land-breeze forecast rules. Unfortunately, these parameters yielded very weak or no discernable relationships to the land-breeze onset time and direction of movement. Based on the relatively weak signatures and relationships seen thus far, further investigation such as numerical modeling experiments may be necessary to understand the physical mechanisms driving the circulation, and to improve the ability to forecast the land-breeze phenomena.

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

INSTRUMENTATION AND MEASUREMENT

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

Mr. Wheeler met with Mr. Russ Bolton of Lockheed Martin to discuss the configuration of the AMU RSA console setup and equipment layout. He also met with Mr. Madura and Dr. Merceret of the KSC Weather Office and Mr. Tim Wilfong of Lockheed Martin for more discussions concerning the AMU console setup and hardware configuration for the AMU.

Table 2. AMU hours used in support of the I&M and RSA task in the third quarter of FY 2002 and total hours since July 1996.

Quarterly Task Support (hours)	***Total Task Support (hours)***
3.5	334.5

AMPS MOISTURE PROFILES (DR. SHORT AND MR. WHEELER)

The 45 WS utilizes vertical profiles of humidity and temperature from balloon-borne radiosonde observations (RAOBs) to assess atmospheric stability and the potential for thunderstorm activity. Operational RAOBs from the Meteorological Sounding System (MSS) will be replaced by the Low Resolution Flight Element (LRFE) of the Automated Meteorological Profiling System (AMPS) at the balloon facility (XMR) in the near future. Testing of the AMPS LRFE (hereafter AMPS) and earlier comparisons with MSS revealed significant differences in relative humidity (RH) between the two systems (Leahy 2002). Because local experience and thunderstorm forecast rules of thumb are based on a long history of stability indices computed from MSS RAOBs, and because the vertical profile of RH is a sensitive indicator of atmospheric stability, it is important that forecasters become familiar with any changes in the humidity data that accompany the transition to AMPS RAOBs. The AMU was tasked to examine the RH differences in detail to evaluate the impact of the humidity differences on the diagnosis of atmospheric stability and thunderstorm indices.

A special data collection campaign was conducted at XMR during January, February and April 2002, obtaining 26 pairs of humidity and temperature profiles from balloon flights that carried both AMPS and MSS sensors. The AMU conducted a study of the 26 dual-sensor profiles and determined that the humidity differences are systematic, causing the atmosphere to appear less stable when diagnosed with AMPS data. The AMU also evaluated the impact of the humidity differences on thunderstorm forecasting indices used operationally by the 45 WS, SMG, and the National Weather Service Office at Melbourne, FL (NWS MLB).

Background

The MSS humidity sensor was produced by VIZ Manufacturing (VIZ) before VIZ was acquired by Sippican, Inc., the AMPS vendor, in 1998. Sippican, Inc. uses the VIZ RH sensor in its AMPS. Therefore, the two RH sensors compared in this study were based on the same design and produced using the same basic manufacturing process. However, research on the algorithms for retrieving RH from the VIZ-type sensor has resulted in several recommended changes over the past decade. Some of these changes have been incorporated in the AMPS, whereas the MSS RH retrieval algorithms have remained unchanged (Phipps 1986).

Wade (1994) studied problems affecting the measurement of low humidity in the VIZ carbon film hygristor and recommended a change in the VIZ RH algorithm that would result in a significant increase in the frequency of relative humidity readings below 10%, consistent with VIZ calibration data. In addition to the algorithm changes recommended by Wade (1994) and adopted by the NWS (Blackmore and Lukes 1998), Sippican, Inc. introduced three new coefficients or "H-factors" to help improve the accuracy of RH measurements. The H1 calibration coefficient was added to the high end of the RH range (> 33%), and the H2 calibration coefficient was added to the low end of the RH range (< 33%). A low-temperature adjustment factor, H3, was also added. The NWS adopted the H1 and H2 coefficients in 1999 (WMO 1999).

A review of literature on the VIZ RH sensor suggests that RH algorithms in MSS and AMPS are different. The MSS RH algorithm predates changes referred to above, whereas the AMPS RH algorithm appears to have incorporated them in addition to other changes. Although quantitative differences between the MSS and AMPS RH algorithms were not determined in this study, some characteristics of the RH differences are consistent with the algorithm changes.

Marshall Space Flight Center Study

The 45 WS and Computer Sciences Raytheon (CSR) tested the AMPS RAOBs during an Operational Utility Evaluation (OUE) from August 1999 to June 2000. OUE testing included five dual-sensor test flights with AMPS and MSS sensors carried aloft on the same balloon from XMR. Mr. Stewart Deaton of the Environments Group at Marshall Space Flight Center (MSFC) requested additional dual-sensor test flights on behalf of the MSFC Shuttle Integration Office. The purpose of the additional test flights was to build a statistically significant sample set of comparison data to determine if the AMPS thermodynamic data met the weather instrumentation accuracy requirements of the Space Shuttle Program (Leahy 2002). During 2001, six additional dual-sensor flights were made and a preliminary analysis suggested that the AMPS RH was much lower that the MSS RH at low temperatures. The AMPS low temperature adjustment factor (H3; see Leahy 2002) was turned off and 26 more dual-sensor flights were made in January, February and April 2002.

The MSFC Environments Group conducted an evaluation of thermodynamic data measured by the AMPS prior to March 2002 for the Space Shuttle Program (Leahy 2002). The MSFC study focused on air pressure and density which were derived from measurements of temperature, RH, and height from MSS and AMPS dual-sensor profiles. Leahy (2002) reported that the derived quantities of density and air pressure were relatively insensitive to the systematic differences in RH found between the two systems. The AMU study focused on atmospheric stability and the potential for thunderstorm development, which were found to be sensitive to the RH differences. The AMU coordinated its analysis activities with Mr. Frank Leahy of Raytheon Information Technology and Scientific Services (ITSS) at MSFC, obtaining data and sharing preliminary analysis results during the course of this investigation. The AMU and MSFC studies have 16 dual-sensor profiles in common. Minor differences in requirements on the minimum acceptable profile height, quality control procedures and the cut-off date for inclusion account for the fact that the profiles included in the AMU and MSFC studies are not identical.

AMU Analysis of AMPS vs. MSS Humidity Differences

Individual MSS and AMPS profiles of humidity and temperature were merged by matching times within each sounding. The MSS reports time every 6 seconds in integer values, while the AMPS data is reported every second with a precision of 0.1 seconds. The AMPS times were rounded to integer values and matched to the MSS times. Intermediate data points were not used. The 6-second temporal interval results in approximately 100 ft vertical intervals between data points. Pressure and height information for each dual-sensor profile were obtained from the AMPS data. Six of the dual-sensor profiles were excluded from the comparison on the basis of a subjective quality control procedure. The data in the remaining 20 dual-sensor profiles were filtered by excluding levels with a pressure less than 100 mb and by excluding data pairs where the temperature difference between the two temperature sensors was more than 1°C. The quality control and filtering process resulted in 20 profiles containing 8598 pairs of points for comparison.

Figure 5 shows average MSS RH versus average AMPS RH for 10% intervals of MSS RH from 10% to 100%. The vertical bars represent the standard deviation of AMPS RH values within each interval of MSS RH. A fourth order polynomial fit to the average data points is shown by the thick black line. This polynomial was used to simulate AMPS RH from climatological and historical MSS RH profiles.

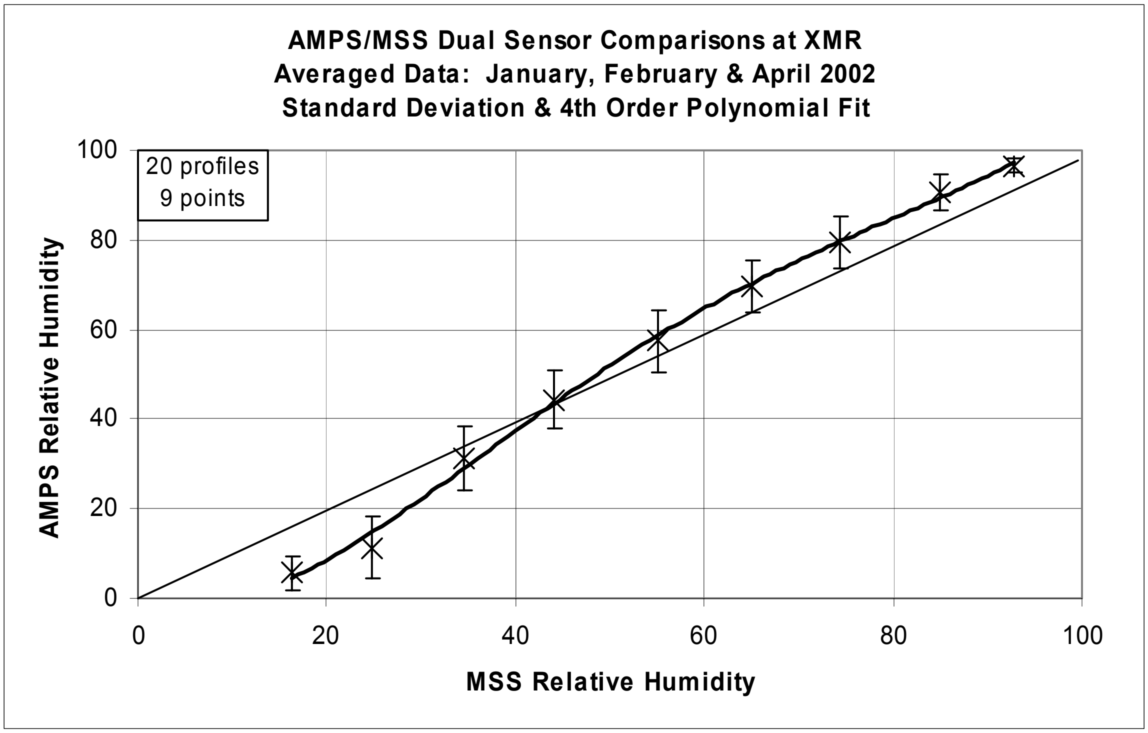


Figure 5. Average MSS RH versus average AMPS RH for 10% intervals of MSS RH from 10% to 100%. The standard deviations of AMPS RH values for each MSS RH interval are indicated by the vertical bars. A fourth-order polynomial fit to the 9 average data points is shown by the heavy solid line and has the equation: $Y= -1.2383 - 0.50915 X + 0.065987 X^2 - 0.00088056 X^3 + 0.0000037915 X^4$.

Impact on Stability

Individual profiles of temperature, pressure and humidity from the AMPS and MSS sensors were formatted for analysis by the Generalized Meteorological Package (GEMPAK). The AMPS pressure was used for both profiles. Four stability indices were computed for each profile: Showalter Index, Lifted Index, K-Index and Total Totals. Figure 6 shows scatter diagrams of the stability indices computed from the MSS and AMPS profiles of temperature and humidity.

The solid circles show stability index values computed from the August climatological profiles of temperature and humidity, assumed to represent an average MSS RAOB, and from a simulated AMPS RH profile, using the polynomial shown in Figure 5. The data for the August climatological profile covers approximately 28 years, from January 1973 to November 2000, having been updated by the Air Force Combat Climatology Center in 2001 at the request of the Range Commanders Council Meteorology Group.

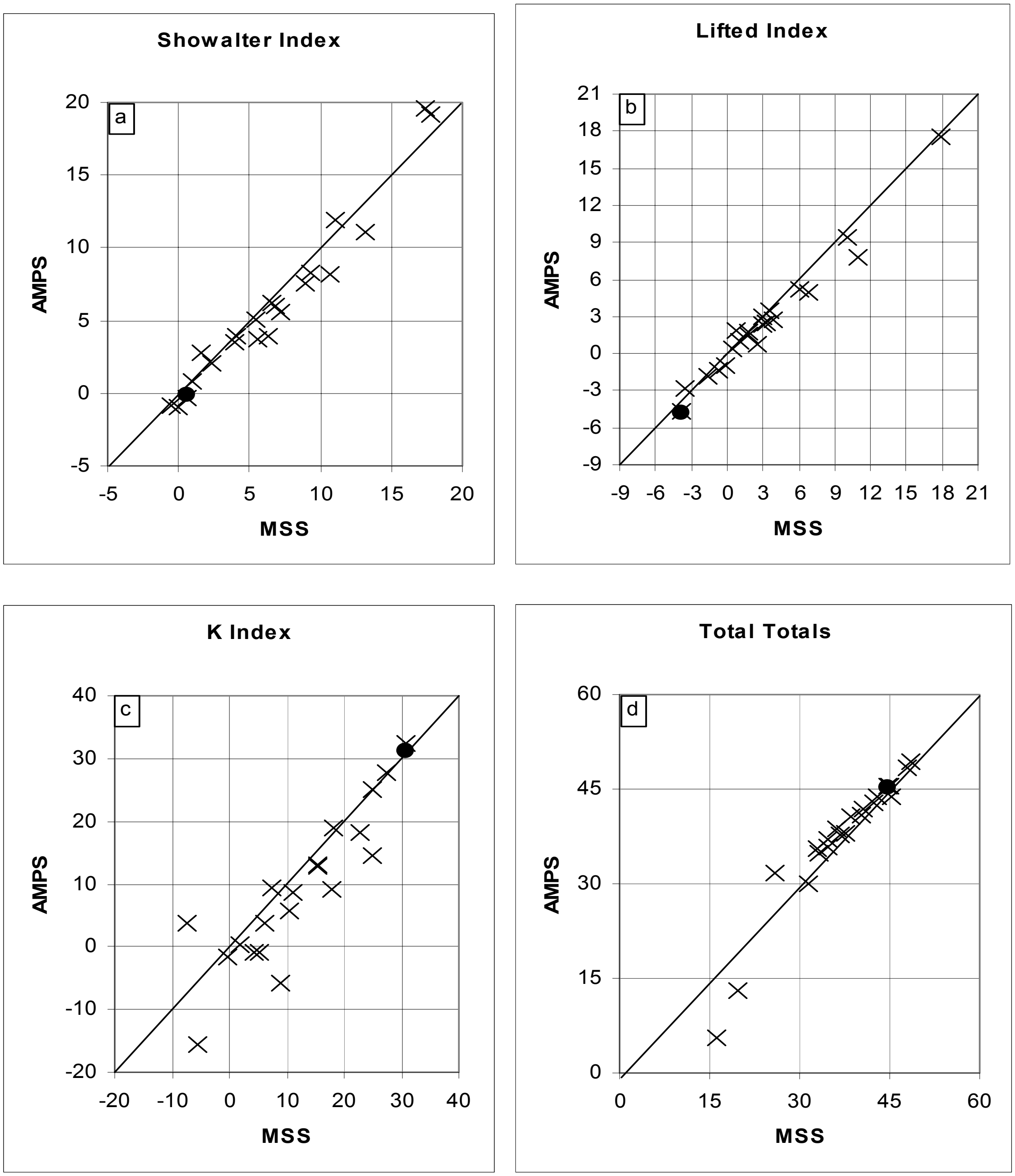


Figure 6. MSS thunderstorm forecasting indices versus AMPS indices for twenty dual-sensor profiles (×) and for the August climatological profile (•): a) Showalter Index; b) Lifted Index; c) K-Index; and d) Total Totals. The AMPS profile for August was simulated by applying the polynomial fit shown in Figure 5 to the August climatological profile of RH.

- The Showalter Index (Figure 6a) indicates stable conditions when positive and unstable when negative, less than –6 indicating very unstable (Showalter 1953). The majority of profiles indicate stable conditions, and in most cases the AMPS profile is less stable than the MSS profile. The few that are near zero on the scale clearly show the AMPS profile to be less stable than the MSS profile.

- The Lifted Index (Figure 6b) also indicates stable conditions when positive and unstable conditions when negative, less than –9 indicating very unstable (Galway 1956). The majority of profiles indicate stable conditions. As in Figure 6a, the majority of AMPS profiles are less stable than the MSS profiles.
- The K-Index (Figure 6c) indicates a < 20% probability of thunderstorms when less than 20, and a near 100% probability when greater than 40 (George 1960). The highest, least stable values in this sample, just above 30, show that the AMPS profile is less stable than the MSS profile, indicating a higher probability of thunderstorms.
- The Total Totals index (Figure 6d) indicates that thunderstorms are possible with values from 45 to 50, and severe thunderstorms are likely when the index is greater than 55 (Miller 1972). The majority of data pairs indicate that the AMPS profiles are less stable than the MSS profiles.

Table 3 provides numerical values for the August climatological stability indices plotted in Figure 6, and for four additional parameters including Convective Available Potential Energy (CAPE), Precipitable Water, Level of Free Convection (LFC) and the Microburst Day Potential Index (MDPI). Parameters in the MSS August Climatology column were computed by GEMPAK from the August climatological profile of temperature and humidity. The parameters in the AMPS Simulated August Climatology column were computed in GEMPAK by first simulating a profile of AMPS RH from the August climatological RH profile with the polynomial model shown in Figure 5.

The parameters in the MSS August 2000 Soundings column were computed by GEMPAK from an average of five soundings in the month of August 2000 with very dry air near 600 mb overlying very moist air to emphasize conditions with enhanced convective instability. These conditions were chosen to illustrate the potential for the AMPS bias pattern to amplify the diagnosis of convective instability, relative to the MSS. The AMPS Simulated August 2000 parameters in were computed by first simulating a profile of AMPS RH from the MSS August 2000 Soundings RH profile with the polynomial model shown in Figure 5.

Table 3. Stability parameters computed from the MSS and AMPS. The first two columns contain the stability parameters calculated from the August climatological profiles, and the last 2 columns contain the stability parameters calculated from an average of the five August 2000 profiles with enhanced convective instability.

Parameter	MSS August Climatology	AMPS Simulated August Climatology	MSS August 2000 Soundings	AMPS Simulated August 2000 Soundings
Showalter Index	+0.5	-0.3	+3.7	+2.7
Lifted Index	-3.9	-4.7	-1.3	-2.3
K Index	30.7	32.5	21.8	22.4
Total Totals	44.6	45.5	40.0	41.1
CAPE	2031	2531	3086	4016
Precipitable Water (in)	1.94	2.04	1.46	1.47
LFC (mb)	878	903	881	909
MDPI	0.77	0.83	0.99	1.15

Note the impact on the MDPI, which is an indicator of the potential for microbursts to develop within thunderstorms. The MDPI utilizes the vertical profile of equivalent potential temperature taking the difference between the largest value below 850 mb and the smallest value between 660 and 500 mb (Wheeler and Roeder 1996). The difference is divided by a local tuning constant (30 K for the KSC/CCAFS area) to produce the index. An MDPI value ≥ 1 indicates that microbursts are likely in the event that thunderstorms occur.

Conclusions

This AMU analysis of dual-sensor atmospheric RH profiles has shown a systematic bias pattern between the current operational system, the MSS, and its planned replacement system, the AMPS. The AMU database of 26 dual-sensor profiles taken at XMR during the months of January, February and April 2002, yielded 20 profiles suitable for an objective comparison. The following systematic pattern was found:

- AMPS RH was ~ 5% higher than the MSS RH when the MSS RH was > 50%, and
- AMPS RH was ~ 10% lower than the MSS RH when the MSS RH was < 30%.

The pattern of RH differences when the MSS is < 30% is consistent with RH algorithm changes that have occurred with the RH sensor, the VIZ carbon film hygristor, over the past several years. The changes appear to have been incorporated after the operational MSS was established at XMR. The cause for the RH differences at the high end of the RH scale is not known at this time.

The impact of the systematic RH differences on stability indices made the atmosphere appear less stable when diagnosed with the AMPS RH profile:

- Typical values for the K-Index and Total Totals were about 1 unit higher,
- Typical values for the Showalter Index and Lifted Index were about 1 unit lower, and
- The MDPI appeared to be most sensitive to the RH bias pattern, with values 10-15% greater when low RH values occur between 660 - 500 mb, and high RH values between the surface and 850 mb.

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

LOCAL DATA INTEGRATION SYSTEM PHASE V (MR. CASE)

The Local Data Integration System (LDIS) task emerged out of the need to simplify short-term weather forecasting in support of launch, landing, and ground operations. The complexity of creating short-term forecasts has increased due to the variety and disparate characteristics of available weather observations. Therefore, the goal of the LDIS task is to generate high-resolution weather analysis products that will enhance the operational forecasters' understanding of the current state of the atmosphere, resulting in improved short-term forecasts.

Four phases of this task have been completed by the AMU. In Phase I, the AMU configured a prototype LDIS using the Advanced Regional Prediction System (ARPS) Data Analysis System (ADAS). In Phase II, the AMU simulated a real-time LDIS configuration using two weeks of archived data. In Phase III, the AMU provided assistance to SMG and NWS MLB to install a working real-time LDIS that routinely generates high-resolution products for operational guidance. In Phase IV, the AMU improved data ingest by including additional data sources, fine-tuned the analysis configuration, and assisted SMG and NWS MLB in improving real-time graphics capabilities. The Phase V portion of the LDIS task involves AMU assistance for SMG in upgrading the analysis software when version 5.0 of ARPS is officially released. Once SMG has fully upgraded and tested ARPS version 5.0, then the NWS MLB will upgrade their software as well.

Only limited consultation was provided during this past quarter since the ARPS version 5.0 has not been officially released to the public. Furthermore, the recent AMU tasking meeting in early July resulted in this task being dropped since the official release date of the ARPS version 5.0 is still unknown. This task will be re-visited at next year's AMU tasking meeting, contingent upon the release of ARPS version 5.0.

LOCAL DATA INTEGRATION SYSTEM OPTIMIZATION AND TRAINING (MR. CASE)

SMG and NWS MLB are running a real-time version of ADAS to integrate a wide-variety of national- and local-scale observational data. While the analyses have become more robust through the inclusion of additional local data sets as well as the modification of several adaptable parameters, further improvements are highly desired prior to configuring and initializing the ARPS model with ADAS analyses in future AMU tasks. In addition, limited training would facilitate the transfer of the ARPS/ADAS software configuration and maintenance responsibilities to the NWS MLB and SMG. As a result, the AMU is tasked to improve the real-time data ingest by including additional data sets and modifying the ingestion of selected data sets. The AMU will also investigate and recommend the steps required to implement additional features of ADAS that are not currently utilized, or features that are unavailable within the software. Finally, the AMU will provide limited training to NWS MLB and SMG forecasters regarding the maintenance of data-ingest programs and adjustments to the local ADAS configuration.

During this past quarter, Mr. Case provided assistance in upgrading the analysis software when the 20-km version of the Rapid Update Cycle (RUC) model was released. He helped the NWS MLB and SMG re-configure the ARPS/ADAS software to incorporate the new 20-km RUC data, which has the same areal coverage as the 40-km version of the RUC model, but contains more vertical levels and twice as many horizontal points. Both SMG and NWS MLB use the RUC model forecasts as a background field for the 10-km ADAS analysis every 15 minutes. Mr. Case also provided limited consultation to NWS MLB this past quarter on miscellaneous issues regarding future grid configurations of ADAS when providing initial conditions for the ARPS numerical weather prediction model.

VERIFICATION OF NUMERICAL WEATHER PREDICTION MODELS (DR. MANOBIANCO AND MR. CASE)

This project is an option-hours task funded by KSC under the Center Director's Discretionary Fund. It is a joint effort between the KSC Engineering Support Contractor, Dynacs, Inc., and the AMU. A key to improving mesoscale numerical weather prediction (NWP) models is the ability to evaluate the performance of high-resolution model configurations. Traditional objective evaluation methodologies developed for large-scale models cannot adequately verify phenomenological forecasts from mesoscale models, and subjective manual alternatives are lengthy and expensive. New objective quantitative techniques are required for evaluating high-resolution, mesoscale NWP models. Therefore, in coordination with personnel from Dynacs, Inc., the AMU was tasked to develop advanced techniques for the objective evaluation of mesoscale NWP models currently employed or under development for Range use. Archived Regional Atmospheric Modeling System (RAMS) forecasts and KSC/CCAFS wind-tower observations will be used to develop the objective verification algorithms for the sea-breeze phenomenon. The verification of sea breezes was chosen because this phenomenon is predicted fairly well by RAMS and the sea-breeze boundary is often nearly linear and narrow in width, making the geometry simple.

Dynacs examined two objective techniques to identify and compare forecast versus observed sea-breeze boundaries using gridded observed and RAMS forecast data from 6 July 2000. Dynacs initially pursued a technique that utilizes image-processing methods to identify gradients in wind direction and wind speed. The algorithm underwent extensive tuning, but the boundaries identified by the algorithm were often discontinuous and noisy. Dynacs then pursued a much simpler technique that uses a binary threshold to distinguish between easterly (onshore) and westerly (offshore) wind directions. To ensure focus on the sea-breeze boundary only, Dynacs built an erosion technique that removes extraneous boundaries not associated with the primary sea-breeze front.

In order to conduct a comparison between the observed and forecast fields, the gridded RAMS forecasts were first interpolated to the location and height of the wind-tower observations. Then, the observed and point forecast winds were analyzed objectively onto the 1.25-km RAMS forecast grid using identical tuning parameters of the Barnes (1964) algorithm. As a result, the objective analysis grid of observations and forecasts has coverage only within the domain of the KSC/CCAFS wind-tower network. The following sub-sections describe the observed and forecast sea-breeze development for 6 July 2000, and present some preliminary results of the Dynacs binary-threshold verification technique.

6 July 2000 Sea Breeze

The 6 July 2000 sea-breeze event occurred during a common summer regime across east-central Florida. Light offshore flow was prevalent during the morning hours through 1600 and 1700 UTC (Figures. 7a and b). By 1800 UTC, the sea-breeze front developed across the northeastern and southeastern portions of the analysis domain, with post-sea breeze flow consisting of northeast winds to the north, and southeast winds to the south (Figure 7c). The sea-breeze front pushed further inland by 1900 UTC, with mostly east and southeast winds on the seaward side of the front (Figure 7d).

The corresponding high-resolution RAMS forecast, initialized at 1200 UTC from the east-central Florida domain with 1.25-km grid spacing, is shown in Figure 8. The RAMS 4-h forecast wind field (Figure 8a) is slightly south of west compared to observations at 1600 UTC, but shows all offshore winds at this time. By 1700 UTC, the RAMS forecast showed the sea breeze starting over the extreme southeastern corner of the domain (Figure 8b), earlier than the corresponding observed sea-breeze front in this part of the domain. By 1800 UTC, RAMS advanced the sea-breeze front northwestward into the center part of the domain (Figure 8c), slightly faster than the observations (Figure 7c). However, by 1900 UTC, the RAMS forecast placed the sea-breeze front well inland and further west than the observed position.

Preliminary Results of the Objective Comparison Technique

The first comparison that Dynacs and the AMU examined for the objective sea-breeze verification was the spatial distribution of the RAMS timing bias. The algorithm determines the portions of the observed and forecast grid that experienced the sea-breeze passage at each hour. The time of the sea-breeze passage is recorded at each grid point to the nearest hour, yielding a temporal resolution of one hour for the verification. The algorithm subtracts the observed times from the forecast times to denote the model's bias across the domain. The algorithm also accounts for areas where the model either erroneously predicted (false alarm) or failed to forecast a sea-breeze passage. The capability to visualize the spatial distribution of the model contingency skill and the quantitative verification statistics simultaneously is a major strength of this automated technique. It would be difficult and time-consuming to produce similar plots using a subjective evaluation at each individual observation location.

It is important to note that an output temporal resolution of model forecast fields higher than once per hour could greatly improve the quality of the verification plots for the sea-breeze timing and other parameters not yet explored. Therefore, the AMU plans to re-run selected RAMS forecasts to generate output at a much high temporal frequency, such as every 5 or 15 minutes. This high-frequency output would allow for a more precise validation of the forecast sea-breeze timing and position, as well as less uncertainty in the verification fields.

Figure 9 shows the spatial distribution of the RAMS sea-breeze timing biases during 1600 - 1900 UTC on 6 July. This plot shows that RAMS had an early bias of about 1 hour over the southeastern portion of the domain, consistent with the subjective comparison in Figures 7 and 8. Figure 9 also shows that RAMS predicted a sea-breeze passage across the western portion of the analysis region where none was observed. Again, these results are consistent with a subjective comparison between Figures 7 and 8.

These preliminary results represent the initial efforts towards developing new methods for verifying phenomenological features such as the sea breeze. Dynacs and the AMU will continue to explore new ways to verify the forecast sea breeze, such as validating the orientation angle of the front and the post sea-breeze winds and developing probability density functions of the spatial timing biases under specific weather regimes.

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

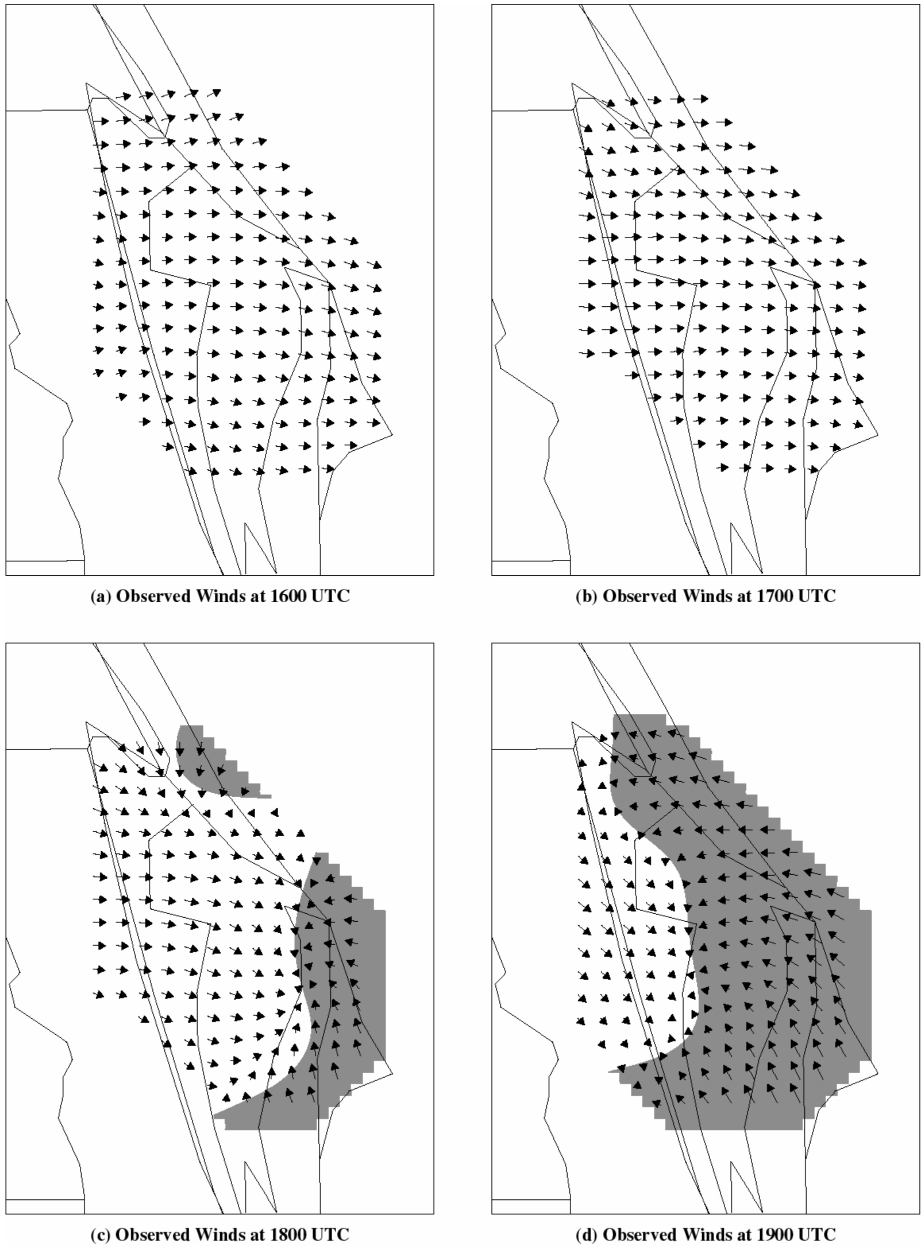


Figure 7. Objective analysis of KSC/CCAFS tower observations of 54-ft winds for 6 July 2000, valid at (a) 1600 UTC, (b) 1700 UTC, (c) 1800 UTC, and (d) 1900 UTC. The winds are given by arrows and wind direction is contoured every 60 degrees. Shading indicates an easterly wind component.

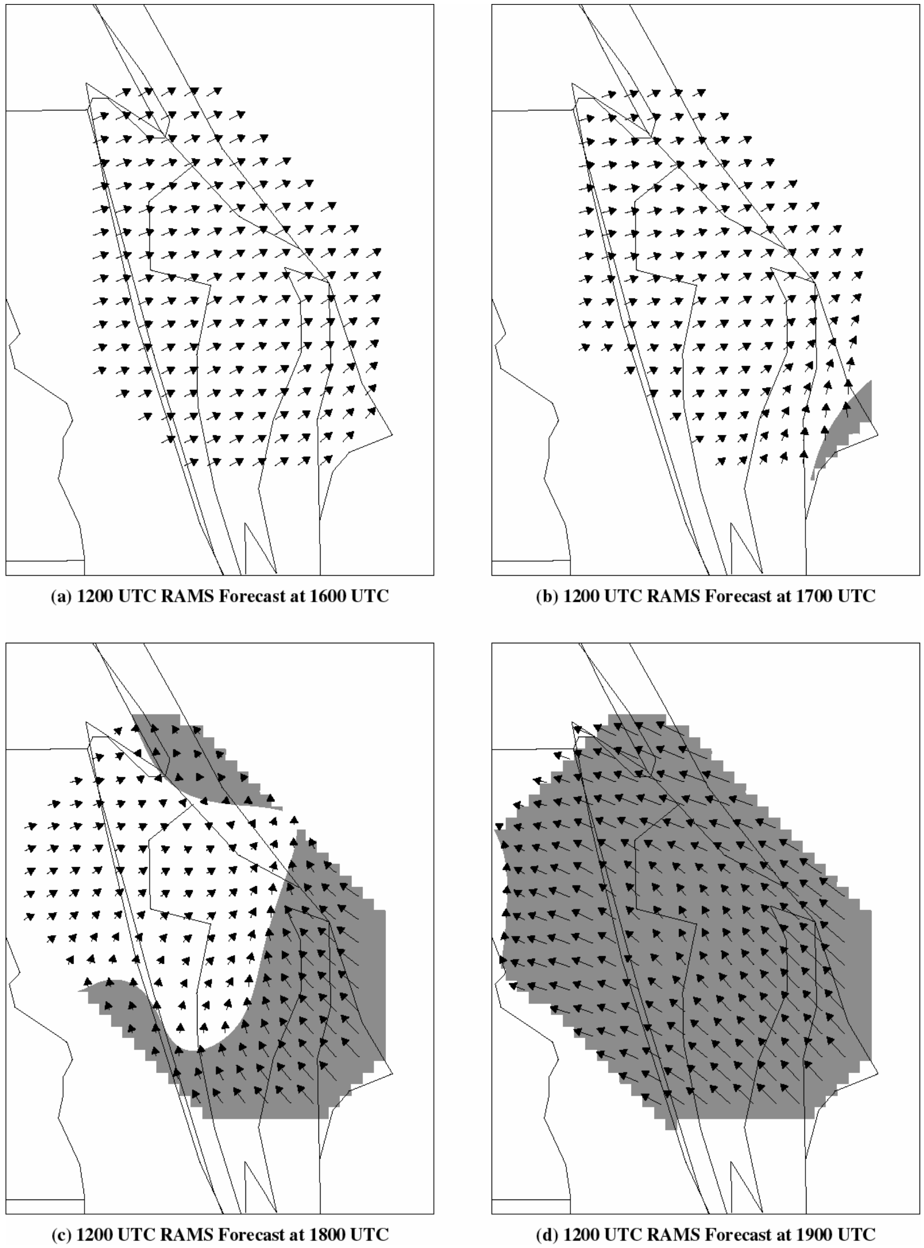


Figure 8. Objective analysis of 1200 UTC RAMS point forecasts at the KSC/CCAFS tower locations, interpolated to 54-ft heights. Valid times for 6 July 2000 are (a) 1600 UTC (4-h forecast), (b) 1700 UTC (5-h forecast), (c) 1800 UTC (6-h forecast), and (d) 1900 UTC (7-h forecast). The winds are given by arrows and wind direction is contoured every 60 degrees. Shading indicates an easterly wind component.

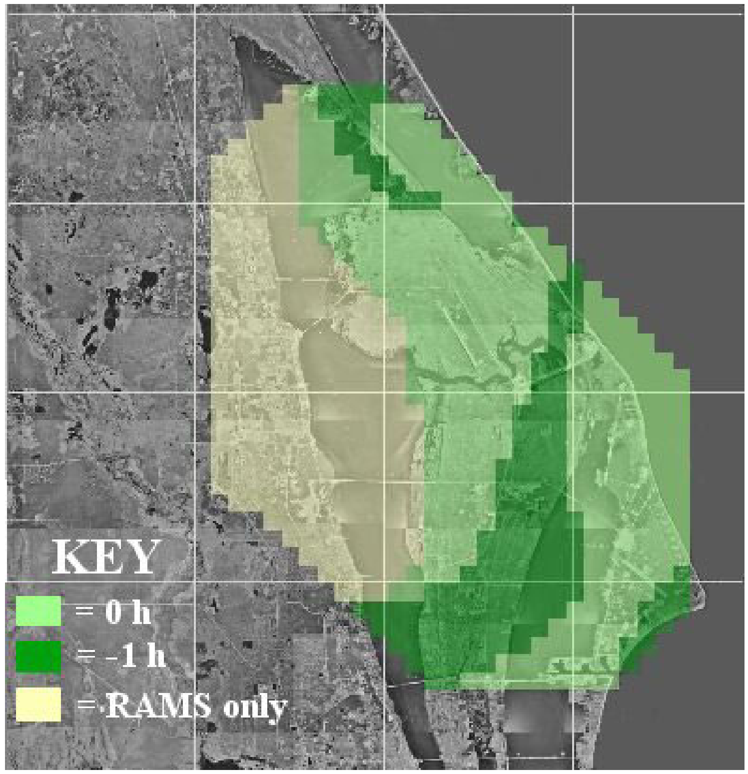


Figure 9. The spatial distribution of the timing bias in the RAMS forecast position of the sea-breeze front within the domain of the KSC/CCAFS wind-tower network during the 1600–1900 UTC time frame. The convention is forecast timing minus observed timing, thus negative numbers indicate an early bias whereas positive numbers indicate a late bias in the forecast sea-breeze front.

AMU CHIEF'S TECHNICAL ACTIVITIES (DR. MERCERET)

Dr. Merceret and Ms. Ward published the results of the radar attenuation study done for the Airborne Field Mill (ABFM) program as a NASA technical memorandum (Merceret and Ward, 2002). They also presented the results of their analysis of the 4 June 2000 case at the bi-weekly ABFM project teleconference on 30 May.

Dr. Merceret and Ms. Ward completed manual quality control of the 1999 and 2000 data from the 915 MHz profilers. The data from 2001 will be completed in July. Dr. Merceret provided consultation to the Eastern Range and SLRS-C regarding specifications for a replacement for the Patrick WSR-74C weather radar. He also provided consultation regarding the transfer of the KSC 50 MHz tropospheric wind profiler to the Range.

AMU OPERATIONS

Mr. Wheeler worked with NASA Procurement on the delivery of several purchase requests. All requests, except some software packages, have been received. A dual-processor Dell system was received and setup. It will used on some of the intense statistical work. The AMU did not spend all allotted equipment funds for this year and the balance was transferred to the KSC Weather Office.

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NOTICE

List of Acronyms

30 SW	30th Space Wing
30 WS	30th Weather Squadron
45 LG	45th Logistics Group
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
AMPS	Automated Meteorological Profiling System
AMU	Applied Meteorology Unit
ARPS	Advanced Regional Prediction System
CAPE	Convective Available Potential Energy
CCAFS	Cape Canaveral Air Force Station
CSR	Computer Sciences Raytheon
ELV	Expendable Launch Vehicle
FR	Flight Rules
FSL	Forecast Systems Laboratory
FSU	Florida State University
FY	Fiscal Year
GEMPAK	Generalized Meteorological Package
ITSS	Information Technology and Scientific Services
JSC	Johnson Space Center
KSC	Kennedy Space Center
LCC	Launch Commit Criteria
LDIS	Local Data Integration System
LFC	Level of Free Convection
LRFE	Low Resolution Flight Element
LWO	Launch Weather Officer
MDPI	Microburst Day Potential Index
MIDDS	Meteorological Interactive Data Display System
MSFC	Marshall Space Flight Center
MSLP	Mean Sea Level Pressure
MSS	Meteorological Sounding System
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
NWP	Numerical Weather Prediction
NWS MLB	National Weather Service in Melbourne, FL
OUE	Operational Utility Evaluation
PDF	Probability Density Function
QC	Quality Control
RAMS	Regional Atmospheric Modeling System
RAOB	Rawinsonde Observation

RH	Relative Humidity
RSA	Range Standardization and Automation
RUC	Rapid Update Cycle
RWO	Range Weather Operations
SB	Sea Breeze
SMC	Space and Missile Center
SMG	Spaceflight Meteorology Group
SRH	NWS Southern Region Headquarters
USAF	United States Air Force
UTC	Universal Coordinated Time
VIZ	VIZ Manufacturing
WMO	World Meteorological Organization
WWW	World Wide Web
XMR	CCAFS 3-letter identifier

Appendix A

AMU Project Schedule 31 July 2002				
AMU Projects	Milestones	Scheduled Begin Date	Scheduled End Date	Notes/Status
Statistical Forecast Guidance (Peak Winds)	Determine predictand(s)	Aug 01	Aug 01	Completed
	Data reduction, formulation and method selection	Sep 01	Mar 02	Completed
	Equation development, tests with independent data and individual cases	Mar 02	May 02	Delay 1 Month due to Customer Request for Further Analysis
	Prepare products, final report for distribution	Apr 02	Jul 02	Delay 1 Month due to Customer Request for Further Analysis
Improved Anvil Forecasting Phase II	Collection and processing of data	May 01	Jan 02	Completed
	Algorithm formulation and testing	Aug 01	Feb 02	Completed
	Final report	Feb 02	Apr 02	Completed
Land Breeze Forecasting	Data collection, data reduction, and QC	Aug 01	Nov 01	Completed
	Identification and analysis of case studies	Sep 01	Nov 01	Completed
	Development of land-breeze climatology	Dec 01	Apr 02	Completed
	Development of forecast rules of thumb / automated tool	Apr 02	Jul 02	On Schedule
	Final report with forecasting rules of thumb	Jul 02	Sep 02	On Schedule
AMPS Moisture Profiles	Data collection, data reduction, and QC	Mar 02	Apr 02	Completed
	Analysis of humidity differences and impact on thunderstorm forecasting indices	Apr 02	May 02	Completed
	Memorandum	May 02	Jun 02	Delayed: Incorporating April 2002 profiles
KSC-Funded Verification of Mesoscale NWP Models	Literature review	Mar 02	Mar 02	Completed
	Develop objective sea-breeze boundary detection algorithm	Apr 02	Aug 02	On Schedule

AMU Project Schedule 31 July 2002				
AMU Projects	Milestones	Scheduled Begin Date	Scheduled End Date	Notes/Status
Verification of NWP Models (continued)	Objective verification of RAMS sea-breeze boundaries	May 02	Dec 02	On Schedule
	Final report/Journal publications	Jan 03	Mar 03	On Schedule
LDIS Extension: Phase V	Assistance in upgrading ADAS/ARPS to version 5.0 at SMG	Jan 02	Mar 02	Delayed: waiting release of ARPS 5.0
	Memorandum	Mar 02	Mar 02	Delayed: waiting release of ARPS 5.0
LDIS Optimization and Training	Revise data ingest programs	Jan 02	Sep 02	On Schedule
	Provide recommendations for implementing new features in ADAS	Jan 02	Sep 02	On Schedule
	Training to SMG and NWS MLB personnel	Jul 02	Sep 02	On Schedule
	Memorandum	Sep 02	Sep 02	On Schedule