Applied Meteorology Unit (AMU)

Quarterly Report

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Executive Summary

This report summarizes AMU activities for the third quarter of FY 97 (April-June). A detailed AMU project schedule is included in the Appendix.

On 6 May 1997, NASA (KSC, JSC, MSFC, and HQ), USAF (45WS, SMC/CWP, 45MX), and the National Weather Service (SMG and Melbourne) met to select and prioritize AMU taskings for next year. This annual tasking meeting reached consensus in less than six hours due to extensive pre-meeting coordination and negotiation. The following tasks were selected.

Task Name	Primary Advocate	Product Sought	Operational Need	Target Begin Date	Target Completion Date
Data Integration Model / Data Deficiency	SMG	Prototype analysis system Final report identifying mesoscale data sources and describing proof-of-concept analysis system	Data integration of all available mesoscale data Gridded data set for nowcasting algorithms; integrated upper air wind analyses	Jun 97	Jul 98
Extend 29-km Eta Model Evaluation	SMG 45WS NWS MLB	Final report on intra- and interseason comparisons	Increase sample size for direction-based stratification Assess model utility for users given anticipated upgrades	Jun 97	Apr 98
Extend WDSS Evaluation	NWS MLB	Final report on operational effectiveness of WDSS and its algorithms	Tune algorithms for FL Increase detection/lead time for severe weather events	Jul 97	Mar 98
GVAR Sounder Products Evaluation	SMG	Final report on data availability and utility of satellite sounder products POC for accessing data	Determine utility of GOES satellite data for weather support	Apr 98	Dec 98

On 5 June, AMU personnel attended the Local Weather Technical Interchange Meeting at Patrick Air Force Base which was designed to facilitate the exchange of applied research results, techniques, tools, and training aids among personnel who perform and/or support operational weather forecasting for central Florida. Dr. Manobianco and Mr. Nutter assessed the utility of the NCEP's meso-eta model for local weather forecasting in support of 45WS, SMG, and NWS MLB operations. Mr. Wheeler explained (1) discrepancies between cloud tops determined by radar versus aircraft during two recent unmanned launches and (2) causes for the severe weather case of 13 August 1996 which produced considerable, yet extremely localized damage at Patrick Air Force Base and areas of west Melbourne.

Dr. Taylor and Ms. Lambert distributed a preliminary work plan for the 915 MHz boundary layer profiler task in April 1997. After a discussion between SMG, 45 WS, and NWS MLB in May 1997, the AMU was assigned the data quality and thunderstorm forecasting objectives. The data quality objective will enable operational forecasters to determine the reliability of the data for critical launch and landing decisions. It will be done before the thunderstorm forecasting objective because the methods developed will be used to ensure only reliable data are used for that objective. The results from both objectives will be presented in a single final report in early FY 99.

Dr. Manobianco and Mr. Nutter completed the first draft of the meso-eta model evaluation final report to be distributed to RWO, SMG, and NWS MLB for review shortly. As the primary deliverable for the AMU's meso-eta model evaluation task, the report presents both objective and subjective verification results. Objective verification results demonstrate that forecasts of selected parameters are reliable over the course of an entire season; however, they do not indicate whether the model is more accurate overall during either the warm or cool season.

Results from the subjective verification suggest that the model forecasts over central Florida may be more useful during the cool season and demonstrate that model forecasts of developing weather events such as thunderstorms, sea breezes, cold fronts, etc. are not always as accurate as implied by the seasonal error statistics.

In order to increase the sample size and track possible changes in model accuracy, the objective component of the meso-eta evaluation is being extended. A comparison between results from the 1996/1997 and 1997/1998 seasons will highlight any changes in the error characteristics at selected stations which may occur in response to updates in the meso-eta model configuration. This analysis will improve utility for model users since the 1997/1998 results will be more representative of the meso-eta model's current capabilities.

In April, Dr. Merceret's paper "On the distribution of Rapid Temporal Changes in Mid-tropospheric Winds" was accepted for publication in the *Journal of Applied Meteorology* (*JAM*). During the quarter, Dr. Merceret used the results of the work accepted by *JAM* to examine the operational risk assessment consequences of using Gaussian assumptions when the actual distribution is lognormal. The results show the Gaussian assumption to be extremely non-conservative. His analysis was presented to Shuttle and Titan program personnel.

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If anyone on the current distribution would like to be removed and instead rely on the WWW for information regarding the AMU's progress and accomplishments, please respond to Frank Merceret (407-853-8200, francis.merceret-1@ksc.nasa.gov) or Ann Yersavich (407-853-8217, anny@fl.ensco.com).

1. BACKGROUND

The AMU has been in operation since September 1991. Brief descriptions of the current tasks are contained within Attachment 1 to this report. The progress being made in each task is discussed in Section 2.

2. AMU ACCOMPLISHMENTS DURING THE PAST QUARTER

The primary AMU point of contact is reflected on each task and/or subtask.

2.1 TASK 001 AMU OPERATIONS

During April, SMG, RWO, and NWS MLB submitted proposed tasks for the annual AMU tasking meeting to be held at KSC on 6-7 May 1997. AMU personnel exchanged electronic mail and participated in numerous teleconferences with SMG, RWO, and NWS MLB to discuss and clarify both proposed and existing tasks in order to develop accurate resource requirement estimates. These estimates will be used by representatives from SMG, RWO, and NWS MLB at the meeting to prioritize and select AMU tasks for the next six to twelve months.

AMU personnel attended the annual AMU Tasking and Prioritization Meeting held at Kennedy Space Center on 6 May. Since Dr. Taylor was not able to attend the meeting due to illness, Dr. Manobianco presented the current status and resources estimates for proposed taskings. Ms. Lambert and Mr. Nutter recorded minutes from the meeting. The minutes were sent to the appropriate representatives from NASA KSC, 45 WS, SMG, and NWS MLB for review, and then to Dr. Jack Ernst for approval and distribution.

AMU personnel attended the 2nd annual Local Weather (LW) Technical Interchange Meeting (TIM) held at Patrick Air Force Base (AFB) on 5 June. The goal of the LW TIM was to facilitate the exchange of applied research results, techniques, tools, training aids, etc. among meteorologists and others who perform and/or support operational weather forecasting for the central Florida Atlantic coast. Participants included personnel from the 45 WS, SMG, NWS MLB, KSC Weather Office, AMU, National Severe Storms Laboratory, and Cooperative program for Operational Meteorology, Education and Training (COMET). Dr. Manobianco and Mr. Nutter briefed selected portions of the AMU's meso-eta model evaluation. In addition, Mr. Wheeler presented results from recent AMU studies on the Radar/PIREP cloud top discrepancy study and severe weather case of 13 August 1996.

2.2 *TASK 004 INSTRUMENTATION AND MEASUREMENT*

SUBTASK 2 915 MHZ BOUNDARY LAYER PROFILERS (DR. TAYLOR)

Dr. Taylor and Ms. Lambert determined the work required to complete the task objectives suggested by SMG, 45 WS, and NWS MLB and distributed a preliminary work plan for the objectives in April. After a discussion between the organizations in May, the AMU was assigned the data quality and thunderstorm forecasting objectives.

The Data Quality Objective (QC)

The data quality objective will provide a method for operational forecasters to determine the reliability of the data when making critical launch and landing decisions. It will be done before the thunderstorm forecasting objective because the methods developed will be used to ensure only reliable data are used in the development of thunderstorm forecasting tools.

Specific cases in which the quality of the data appear suspect will be identified as the data are being collected. These will be subjectively analyzed to initially define possible criteria for identifying questionable consensus data. Other possible criteria will be determined through discussions with experts and subjective analyses of additional data. Dr. Frank Merceret has subjectively and objectively analyzed the 50 MHz DRWP for quality. His criteria for flagging bad data will be included in the subjective analysis. The data to be used in defining the criteria include, but are not limited to, the consensus values, spectrum width, signal-to-noise ratio, noise power, and number of samples used in the consensus.

Once the criteria have been determined, software to automatically detect suspect consensus data must be identified, and modified if necessary, or developed. One of the existing tools to be examined is the Weber-Wuertz QC algorithm. Dr. Merceret has also developed an algorithm to automatically check the 50 MHz profiler data for quality. Both of these tools will be examined for their utility in this objective. The routines will be evaluated for their usefulness in flagging questionable data when developing the thunderstorm forecasting methods. In addition, the possibility of using any of the routines in real-time for operational use will be examined. One of the routines will then be applied in the thunderstorm forecasting objective. If a routine is identified that is suitable for real-time data QC, it will be recommended for use in operations.

Work on this task is expected to be complete in November 1997. Much of the work will be done during the data collection period from 1 May to 1 September 1997. The Pert chart below provides the expected timelines for each part of this objective.

Data Quality Objective	1997						
	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Data Collection	▼		▲				
ID Cases	▼			▲			
Subjective Analysis		▼		▲			
Develop Routines			▼		▲		
Apply Routines						▼	

The Thunderstorm Forecasting Objective

This objective will provide forecasters with a method or methods to use that will aid in forecasting the timing and location of thunderstorm development over KSC/CCAS. Fifteen thunderstorm cases will be identified as the data are being collected. Five of the days will have thunderstorms that form over the Cape area, five will have thunderstorms that advect into the Cape area, and five will not have any thunderstorms that advect into or form over the Cape area. The wind tower network data will be used to confirm the existence of a sea breeze and the WSR-88D/KMLB and satellite data will be used to confirm the existence of storms over the Cape area. All days must indicate a high probability of thunderstorm formation through indices derived from the morning rawinsonde.

The data from the chosen cases will be first checked for quality using the routine developed in the data quality objective and the unreliable data will be removed. A subjective analysis will be done with these data. This analysis on a limited number of cases is necessary to identify any parameters and products that could be used as thunderstorm forecasting tools. To facilitate this subjective analysis, display routines in GEMPAK, VIS5D, NTRANS, or NCAR Graphics will be developed to display the parameters. The products to be examined are:

- Area average divergence
- RASS T_v profiles
- Divergence contours
- Depth of the convergence layer
- Vertical velocity
- Vertical velocity at the top of the boundary layer
- Consensus wind observations of the sea breeze, river breeze, and Merritt Island convergence in
    - Horizontal cross sections
    - Vertical cross sections
    - Perturbation wind field

An objective analysis will then be done with the parameters and products identified in the subjective analysis using the data from all thunderstorm days in the collection period. This analysis will determine which of the parameters and products are useful in forecasting thunderstorms.

Hardware problems occurred with some of the profilers in May and June, and by mid-June only two profilers were operating. Dr. Taylor and Ms. Lambert determined that at least four of the profilers must be operating 90% of the time daily between 1400 and 0000 UTC from 1 July through 1 September 1997 to effectively evaluate the profiler network for its use in thunderstorm forecasting. NWS MLB, SMG, and the 45 WS were notified and advised that this objective may have to be replaced by another. An update of the profiler network status will be distributed at the beginning of July 1997.

If this objective is executed, the work is expected to be complete by June 1998. The Pert chart below provides the expected timelines for each part of this objective.

Thunderstorm Forecasting Objective	1997							1998					
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Data Collection	▼		▲										
ID Storm Cases	▼		▲				▼						
Data Quality Check							▼	▲					
Display Software								▼	▲				
Subjective Analysis									▼	▲			
Objective Analysis										▼			▲

Final Report

The results found from both objectives will be given in a single final report to be distributed in October 1998. The data quality objective section will describe the techniques developed for checking the data. This will include descriptions of both manual and automatic techniques, how they were developed, and whether they can be automatically implemented in real-time operations. The thunderstorm forecasting objective section will identify the most suitable parameters and their thresholds for use in thunderstorm initiation forecasting.

SUBTASK 5 I&M AND RSA SUPPORT

In April, Mr. Wheeler attended an Advanced MIDDS meeting to discuss the System Acceptance Test. A 12-page listing of MIDDS requirements was categorized and prioritized prior to the meeting. Factory Acceptance that was scheduled for early June 1997 has been delayed until October 1997.

In June, Mr. Wheeler had discussions with Mr. Weems (45 WS), CSR, and PRC concerning the current functionality of MIDDS compared to the Advanced McIDAS system.

SUBTASK 7 LDAR DATA AND DISPLAY (MS. LAMBERT)

Only a few minor revisions to the final report were needed after internal and external reviews. The report was distributed at the end of May. A summary of the results from this study can be found in the AMU's Quarterly Report for the Second Quarter FY 1997.

SUBTASK 8 RADAR / PIREP INVESTIGATION

Mr. Wheeler finished his analysis and writing on the radar and pilot report cloud top inconsistencies report in April and the final version of the Radar/PIREP Cloud Top Discrepancy Study was distributed in May. A summary of the results from this study can be found in the AMU's Quarterly Report for the Second Quarter FY 1997. A copy of the final report can be obtained from Mr. Wheeler.

2.3 TASK 005 MESOSCALE MODELING

SUBTASK 2 29 KM ETA MODEL EVALUATION (DR. MANOBIANCO)

Dr. Manobianco and Mr. Nutter completed the first draft of the meso-eta model evaluation final report. A copy of the report will be distributed to RWO, SMG, and NWS MLB for review before the end of July 1997. The report concludes with a section that summarizes results from the objective verification of meso-eta model point forecasts and the subjective verification of sea breezes, thunderstorms, easterly waves, and cold fronts. This section also provides a general summary and lessons learned from the year-long meso-eta model evaluation. The text of that concluding section is as follows.

Summary of Objective Verification

The objective verification of the meso-eta model focuses on the overall accuracy of wind, temperature, and moisture forecasts at XMR, TBW, and EDW for the warm and cool seasons. The statistical measures used to quantify model forecast errors are the bias, RMS error, standard deviation, and consistency. Using these statistics, point forecasts from the 0300 UTC and 1500 UTC meso-eta model cycles are verified against standard surface and rawinsonde observations. Convective parameters and 850 to 500-mb layer-averaged wind and relative humidity are derived from the forecast soundings and verified against corresponding values from observed soundings. As specified in the evaluation protocol, results were stratified by the 950 to 600-mb layer-averaged wind direction. However, examination of results for every parameter indicates that error characteristics are qualitatively similar under both westerly and easterly flow regimes. For this reason, all available data are combined and final results are not stratified by wind regime.

Surface Parameters

Results of the surface verification indicate that forecast errors for most parameters follow a diurnal cycle. Overall, results of the surface parameter verification reveal that forecast errors are on average reasonably small. However, there are a few identifiable biases which include overestimation of dew point temperature and wind speed during the cool season at XMR and large diurnal changes in warm season temperature, wind speed, and mean sea-level pressure (MSLP) at EDW.

The only benchmark specified in the evaluation protocol is a comparison of 10-m winds with 1- to 6-h persistence. Results of this benchmark reveal that 1- to 3-h persistence forecasts of wind speed and direction usually have smaller RMS errors than the corresponding meso-eta model forecasts. However, the model forecasts of these variables are occasionally more accurate than 6-h persistence.

In general, RMS error trends for most parameters reveal that the model exhibits minimal error growth throughout the 33-h forecast period. The error variance often comprises a large portion of the total error. This suggests that errors in surface parameters are commonly due to more random, non-systematic variations in the forecasts and/or observations. Consistency results indicate that subsequent model runs tend to agree more closely with one another than with observations. Since the magnitude of errors depends on parameter, location, and season, it is difficult to specify whether the model is generally more accurate in forecasting surface parameters during the warm or cool season.

Upper Air Parameters

Examination of results for all upper air parameters reveals that errors are qualitatively similar for both the 0300 and 1500 UTC forecast cycles. Therefore, sounding data from both model cycles are combined while performing the verification of upper air parameters. As with surface variables, forecast errors for upper air parameters are on average reasonably small. RMS error trends among each of the three available verification periods indicate that the model exhibits minimal error growth. Consistency results again suggest that subsequent model runs tend to agree more closely with one another than with observations.

For many parameters, a large portion of error standard deviations may be explained, in part, by rawinsonde measurement uncertainty. As with surface forecasts, error variances provide large contributions to the total error. There are a few identifiable biases which include difficulties in resolving tropopause heights and cool season lower tropospheric temperature inversion heights at XMR and TBW.

In addition, warm season forecast errors at XMR and TBW indicate a cool, dry bias which suggests that forecast soundings are on average more stable than observed.

Convective Indices and 850-500 mb Layer-Averages

During the warm season, negative biases in precipitable water (PWAT) and convective available potential energy (CAPE) and positive biases in the lifted index (LIFT) suggest that forecast soundings are typically drier and more stable than observed. These errors are consistent with lower tropospheric warm season biases in mixing ratio and temperature at XMR which indicate that forecasts tend to be thermodynamically more stable than observed. During the cool season, positive biases in CAPE and the K index (KINX) and negative biases in LIFT suggest that cool season forecasts are more unstable than observed. These results are also consistent with the low-level warm bias in temperature and moist bias in mixing ratio found during the cool season at XMR. In general, the results of both convective parameter and 850-500 mb layer-average verifications are consistent with characteristic biases identified in the upper air statistics.

Errors in forecast convective parameters on any given day may actually be large enough to provide misleading information regarding the likelihood for thunderstorm development. In particular, errors in any given convective index result from errors in moisture, temperature or wind variables which are used to compute the index and may be cumulative especially for integrated quantities such as CAPE. Therefore, it is important to understand the accuracy and relationships of all variables which are used to derive each index.

Summary of Subjective Verification

The subjective verification of sea breezes, thunderstorms, easterly waves, and cold fronts is designed to assess the added value of the meso-eta model in forecasting selected aspects of these phenomena. The evaluation strategy consists of limited cases and seasonal verification. Seasonal verification quantifies the added value and is important because conclusions drawn about model limitations and capabilities in forecasting the aforementioned phenomena are limited by examining only a few cases.

Sea Breezes

The analysis of the forecast and observed sea-breeze development from 7 June 1996 demonstrates that the meso-eta model forecasts a sea breeze that is characterized by a peninsula-scale thermally direct circulation. The thermally direct circulation is driven by differential heating across the land/sea boundaries along the Florida peninsula. The features associated with the forecast sea breeze identified from 3-h model output include a thermal trough in sea-level pressure over the peninsula, shift in 10-m level wind direction from offshore to onshore flow, and low-level convergence and vertical motion patterns oriented parallel to the coastlines. Based on the results from this single case, the meso-eta model appears to depict an evolution of the sea breeze that is dynamically realistic although at a larger scale than observed. It is important to note that the 29-km horizontal resolution of the model is not sufficient to resolve the individual circulations associated with east or west coast sea breezes. Instead, the model generates a single low-level convergence zone and an associated circulation that generally lies parallel to the coastlines.

The sea-breeze verification is also designed to determine how reliably the meso-eta model forecasts the occurrence of east or west coast sea breezes anywhere along the Florida peninsula during the entire warm season. This portion of the analysis is important because previous studies have shown that the timing and location of convection over Florida is modulated by interactions between the sea-breeze circulations and synoptic-scale flow. The results indicate that the 0300 UTC model runs correctly forecast the occurrence of sea breezes about 50% of the time they are observed during the warm season. The utility of sea-breeze forecasts may be limited for this reason and the fact that the meso-eta model resolves only the larger-scale aspects of the observed sea breeze. In some cases, the failure of the model to forecast the occurrence of the sea breeze is likely due to larger-scale forecast errors over a significant portion of Florida.

Thunderstorms

Two cases are presented of forecast and observed thunderstorm development on 1 – 2 August 1996 (case 1) and 9 – 10 August 1996 (case 2). The first example shows a best-case scenario when the meso-eta model depicts a remarkably accurate forecast of developing convection in the late-afternoon and early evening across the Florida peninsula. The second case illustrates an alternative scenario when the model forecasts excessive precipitation along much of Florida's east coast during the same time period. The results from these and other warm season cases (not shown) suggest that the model generates broader areas of organized convection which, on occasion, are remarkably accurate. In contrast, there are a number of instances during the warm season when the model did not forecast areas of organized convection or the evolution of individual thunderstorms that produced significant weather. This result is expected because the 29-km horizontal resolution of the meso-eta model is too coarse to resolve convection at those scales.

Since a wide variety of scenarios for the development of forecast and observed convection were observed during warm season forecast exercises, a verification of precipitation occurrence is required in order to quantify the utility of the model in forecasting warm season convection. Given the limitations in resolving small-scale convection, traditional precipitation verification using point-to-point comparison at selected thresholds was not done. Instead, verification of precipitation over 3-h periods in zones on the order of 100 km x 200 km is performed for all available warm season days. The technique does not specifically address precipitation verification within 25 miles of XMR as specified in the original evaluation protocol. However, it does provide a means to quantify the accuracy of the model in forecasting the occurrence of larger areas of organized convection without requiring that the model produce the correct amount of precipitation at exactly the location where it is observed.

The bias in all zones over Florida from 1500 – 1800 UTC ranges from 1.69 to 2.44 indicating that the meso-eta model forecasts precipitation to occur more often than observed. During later time periods from 1800 to 2100 UTC and 2100 to 0000 UTC, the bias, POD, and FAR in all zones indicate that the meso-eta model shows more utility than in the earlier period (1500 – 1800 UTC) in successfully delineating whether precipitation will occur in a specific zone. The statistical scores such as bias for zone 5 improve with time in part due to an increase in frequency of observed precipitation within that zone. Since observed precipitation is counted in the contingency tables regardless of scale, the statistics may improve further by excluding observed precipitation events such as isolated thunderstorms which can not be resolved by the model.

The verification of warm season precipitation occurrence indicates that the model generates excessive precipitation from 1500 to 1800 UTC despite the fact that biases in convective parameters such as CAPE and LIFT show that 1000 UTC forecast soundings are on average typically drier and more stable than observed. At least 95% of the warm season forecast precipitation over Florida is produced by the convective scheme in the meso-eta model. It is possible that forecast soundings destabilize too rapidly after 1000 UTC thereby triggering the convective parameterization which eventually produces precipitation more often than it is actually observed. For example, the erroneous precipitation forecast in case 2 may be related to excessive moisture convergence and instability as documented by a comparison of forecast and observed soundings at XMR along the east coast. However, more comprehensive analyses of model output and additional observations are required to diagnose the reasons for both accurate and inaccurate forecasts of convective precipitation throughout the warm season.

Easterly Waves

Only one easterly wave developed during the warm season period which entered the model domain used for this study. A single case is too limiting to draw conclusions about model forecasts of easterly wave timing, development, and motion. However, examination of the case does point out that persistence of cyclonic shear in lower tropospheric winds and/or weak surface troughs are important for the classification of potential easterly waves. These features should persist between subsequent 0300 UTC and 1500 UTC forecast cycles for at least 2 to 3 days. Small scale vorticies on the order of 100's km are common in the meso-eta model and should not be interpreted as easterly waves due to their small size and lack of persistence.

Cold Fronts

The analysis of a cold front which passed through central Florida on 8 – 9 November 1996 demonstrates some of the meso-eta model's capabilities and limitations in depicting the timing and motion of cold frontal passages. The case reveals that although the model is not able to predict the small-scale details, it is capable of forecasting the larger-scale areas covered by clouds and precipitation with remarkable accuracy. Moreover, the location of the leading edge of the frontal zone near the surface is in agreement with observations of winds and dew point temperatures. Although the model appears to forecast the location of the frontal zone quite accurately across central Florida, the 29-km grid point resolution is not adequate to capture the sharpness of the observed cold front.

Hourly plots of 2-m dew point temperature and 10-m wind direction for this case reveal that the leading edge of both forecast and observed frontal zones pass through XMR within the same hour. It is interesting to note that shifts in forecasts of surface parameters are more gradual than corresponding shifts in observed data as the front passes XMR. This result supports the idea that the meso-eta model does not resolve the sharp gradients of surface temperature, moisture, wind, etc. at the scales which are characteristic of observed frontal zones. Forecasts of most parameters for this case of frontal passage are generally quite accurate, a result which is consistent with the relatively small biases noted earlier for the entire cool season. In fact, a verification of cold front timing at XMR over the entire cool season reveals that the model is accurate to within the nearest hour for a majority of documented cold frontal events.

Overall Evaluation Summary and Lessons Learned

The meso-eta evaluation is designed to assess the utility of the model for local weather forecasting in support of 45WS, SMG, and NWS MLB operational requirements. The following points summarize overall results from the AMU's year-long evaluation.

- In general, objective verification results reveal that meso-eta model point forecasts at XMR, TBW, and EDW are reasonably unbiased. This result suggests that the model has few substantial systematic errors and on average, can be used reliably. However, there are some exceptions identified in this evaluation as indicated by the following list of model biases.

    2-m dew point temperatures and 10-m wind speeds are typically overestimated at XMR during the cool season.

    Large diurnal changes exist in the average forecast errors for 2-m temperature, 10-m wind speed and MSLP at EDW.

    At XMR and TBW, warm (cool) season forecast soundings are typically drier and more stable (unstable) than observed.

The height of the lower tropospheric inversion at XMR and TBW is misrepresented during the cool season.

Tropopause heights are misrepresented by the model at all three stations.

- Objective verification results also indicate minimal error growth with time based on RMS errors. This means that, on average, forecast accuracy does not vary substantially throughout the 33-h forecast period.

- The error variance for many variables comprises a large portion of the total RMS error. In these instances, total model error over the course of an entire season is dominated by the day-to-day variability in forecasts and/or observations.

Subjective verification of sea breezes, thunderstorms, easterly waves, and cold fronts is very important to quantify added value of the model forecasts for these specific phenomena which can not be readily inferred from statistics over many cases (i.e. from objective verification). Moreover, subjective and objective verification are complimentary and results from each component of the evaluation are generally consistent. Some results from the subjective evaluation which can be important for operational forecast concerns include the following.

- The forecast sea breeze is characterized by a peninsula-scale, thermally direct circulation that forms in response to differential heating across the land/sea boundaries along the Florida peninsula. The occurrence of sea breezes are correctly forecast about 50% of the time they are observed during the warm season. The 29-km grid point resolution of the model is not sufficient to resolve the individual circulations associated with the observed west and/or east coast sea breezes.

- Two case studies demonstrate different situations where the model generates both accurate and inaccurate forecasts of larger scale, organized convection. The model's 29-km grid point resolution is not sufficient to accurately forecast the development of small scale, isolated thunderstorms.

- Cold frontal passages through XMR are often forecast to within the nearest hour of observed passages. The spatial and temporal evolution of weather associated with frontal passages is also depicted well by animation of the 3-h forecast gridded products. However, the ability of the model to represent small scale details such as the width of the surface frontal zone is limited by the model's 29-km resolution.

- Results from the objective verification do not indicate whether the model is more accurate overall during either the warm or cool season. However, results from the subjective verification suggest that the model forecasts over central Florida may be more useful during the cool season. This statement is based on the fact that the meso-eta model resolution is not yet sufficient to resolve the small-scale details of sea and river/lake breeze circulations, thunderstorm outflow boundaries, and other phenomena which play a dominant role in determining the short-term evolution of weather over east central Florida during the warm season.

- Objective verification results also demonstrate that forecasts of selected parameters are reliable over the course of an entire season. On the other hand, results from the subjective verification demonstrate that model forecasts of developing weather events such as thunderstorms, sea breezes, cold fronts, etc. are not always as accurate as implied by the seasonal error statistics.

The AMU's daily real-time warm season forecast exercise proved to be a valuable component of the overall subjective verification because it revealed how operational forecasters could use the 0300 UTC cycle of the meso-eta model for local forecasting. Lessons learned from these daily weather discussions are as follows.

- Animation of 3-h model output with color enhancements and overlay of multiple fields (winds, temperature, etc.) is useful to identify features and trends that could become important for developing weather (as illustrated with sea breeze, thunderstorm, and cold front case examples).
- Availability of digital gridded model output at 3-h intervals is important because it gives users the flexibility to select variables, cross sections, overlay options, contour intervals etc. and it provides the temporal resolution needed to track specific aspects of forecast weather events such as the timing of cold frontal passage, onset of sea breeze, etc.
- The model often generates small scale vortices that are difficult to confirm with observations. Many times, these vortices are not realistic and lead to fluctuations in point forecast variables such as wind direction and convective parameters (as demonstrated in the large error standard deviations of these variables).
- In order to exploit the four-dimensional capability of the meso-eta and other models in forecasting possible realizations of the atmosphere, sufficient communication bandwidth and computer processing power are necessary to retrieve, process, and examine output data. This requirement will become more important in the future as NCEP increases the number of meso-eta model runs per day, the model resolution, and potentially the frequency of model output.

SUBTASK 4 DELTA EXPLOSION ANALYSIS

The Delta Explosion Analysis project, which is being funded by KSC under AMU options hours, began on 1 June. The primary goal of the project is to analyze the plume resulting from the Delta 2 explosion on 17 January 1997. Mr. Evans will use models and observations for the analysis with the principal models being REEDM, RAMS, and HYPACT and the principal observations being the WSR-88D radar observations.

During June, Mr. Evans ran RAMS for 17 January on PROWESS. PROWESS runs RAMS with 1.5 km horizontal grid spacing with the microphysics option turned on. He also changed some input parameter settings in RAMS and reran RAMS on ERDAS for 17 January. ERDAS runs RAMS with 3 km horizontal grid spacing and microphysics turned off.

During June Mr. Evans was able to get HYPACT running on PROWESS and produced some preliminary results. Previously PROWESS only ran on ERDAS. Several software modifications had to be made to get HYPACT running on PROWESS.

In July, Mr. Evans will make some additional RAMS and HYPACT runs and will begin looking at the WSR-88D data from 17 January. He will also be meeting with Mr. Bud Parks of ACTA who will be assisting in the model and plume analysis.

2.4 AMU CHIEF'S TECHNICAL ACTIVITIES (DR. MERCERET)

In April, Dr. Merceret's paper "On the distribution of Rapid Temporal Changes in Mid-tropospheric Winds" was accepted for publication in the *Journal of Applied Meteorology (JAM*). During the quarter, Dr. Merceret used the results of the work accepted by *JAM* to examine the risk assessment consequences of using Gaussian assumptions when the actual distribution is lognormal. The results show the Gaussian assumption to be extremely non-conservative. His analysis was presented to Shuttle and Titan program personnel for review and comment. A note entitled "Risk Assessment Consequences of the Lognormal Distribution of Mid-tropospheric Wind Changes" was submitted to the *Journal of Spacecraft and Rockets*.

NOTICE