Applied Meteorology Unit (AMU)

Quarterly Update Report

Fourth Quarter FY-93

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1. Background

The AMU has been in operation since September 1991. A brief description of the current tasks is 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 sub task.

2.1. Task 001 Operation of the AMU (Dr. Taylor)

Shuttle Training Aircraft (STA) Downlink (Mr. Wheeler)

The AMU demonstrated the STA downlink system to NASA Weather Coordinator Mr. Dick Richards and also to Col. Johnson and his staff at the 45th Weather Squadron. The demonstration used archived data to display the aircraft track and aircraft wind estimates on a PC and to display the aircraft track overlaid on several McGill radar products. Future demonstrations/tests of the STA downlink system include deployment of an STA aircraft to Kennedy Space Center for system checkout and demonstration.

Development of Forecaster Applications (Mr. Wheeler)

During this quarter the AMU met with RWO personnel to solicit suggestions and comments regarding the AMU developed Meteorological Interactive Data Display System (MIDDS) utilities on which the RWO received training during the May - June time period. In addition, upon request by the RWO, the AMU developed and demonstrated a utility that highlights surface station reports which include any type of precipitation or fog. Station observations which include thunderstorms are highlighted in red, stations observations which include fog in yellow, and observations which include other types of precipitation in green. This utility facilitates the forecasters' evaluation of current weather conditions in Florida.

2.2. Task 002 Training (Dr. Taylor)

No significant training activities were undertaken this past quarter.

2.3. Task 003 Improvement of 90 Minute Landing Forecast (Dr. Taylor)

Sub Task 1: Two - Tenths Cloud Cover Study (Ms. Schumann)

The AMU began preparing the two tenths cloud cover data base for use in training an artificial neural network (ANN). The neural network is being developed to demonstrate the utility of this technology to cloud cover forecasting at Kennedy Space Center (KSC). If the technology proves useful, the output from the ANN could be used by the forecasters as a tool to facilitate and improve the accuracy of cloud cover forecasting at KSC.

During October, the AMU will discuss the artificial neural network requirements with RWO and SMG and design the input and output portion of the network. The AMU will then begin training and testing the network.

Sub Task 2: Fog and Status at KSC (Mr. Wheeler)

The AMU has completed the draft of the final report for the AMU's evaluation of fog development at the Shuttle Landing Facility (SLF). The draft is being reviewed internally and should be distributed for external review by the middle of November.

In this study, 36 fog events were analyzed which are representative of the challenging EOM fog forecast at KSC (i.e., onset of fog is coincident with the rapid deterioration of visibility). The fog events fell into three categories: advection, pre-frontal, and radiation. The typical advection fog event is characterized by fog developing west of SLF observation site (TTS) sometimes over to Orlando or north toward the Daytona Beach area, generally to the north of a surface ridge line. The fog is advected into TTS by a westerly surface wind that flows from the land area to the Atlantic Ocean. Pre-frontal fog events are very similar to the advection fog events except for the presence of frontal boundary in Florida which passes through the KSC area on the fog event day. The typical radiation fog event forms near sunrise and is associated with significant radiational cooling and very light winds.

During this past quarter, the AMU also completed a false alarm and probability of detection analysis for the AMU developed fog precursor criteria. A brief summary of this analysis is presented in the following paragraphs.

Table 1 is a 2 × 2 contingency table of observed and forecast fog/no fog conditions at the SLF observation site, TTS. The data used in this analysis contain the 36 case study fog events and 222 no fog events extracted from the 5 year SLF data base. The no fog event days satisfy the surface based fog precursor criteria listed below.

- TTS reported offshore surface wind flow (i.e. wind reported 150° to 330°).
- TTS reported surface dew point depression less than 5° F.

The AMU examined data from the no fog event days to determine if one or more of the criteria listed below was satisfied. These criteria are the inverses of the upper air precursor criteria identified in the AMU preliminary SLF fog evaluation report. Satisfying of one or more of these criteria reduces the likelihood of fog development.

1) Lack of 1000 mb moisture (i.e. 1000 mb dew point depression greater than 5°).
2) 1000 mb wind onshore (i.e. 1000 mb wind direction between 330° and 150°).
3) 1000 mb Wind Speed > 20 kt.
4) FSI > 31.

The FSI is an Air Force developed Fog Stability Index (FSI) and is given by

$$FSI = 4 * T_s - 2 * (T_{850} + T_{ds}) + W_{850}$$

where T_s = surface temperature in °C
T_{850} = 850 mb temperature in °C
T_{ds} = surface dew point temperature in °C
W_{850} = 850 mb wind speed in knots.

If one or more of the four criteria were satisfied, then the forecast was for no fog. If none of the four criteria were satisfied, then the forecast was for fog to develop.

The following skill scores were computed from the data in Table 1.:

- Probability of Detection (POD) 78%
- False Alarm Ratio (FAR) 45%

These skill scores are actually quite good considering that the no fog event days satisfied the surfaced based fog precursor criteria (i.e., potential for fog development existed). In addition, not all fog precursors were included in the POD and FAR analysis because time constraints prohibited a detailed analysis of each of the 222 no fog events (e.g., determination of where fog first formed and location of the surface ridge).

Table 1. Precursor Contingency Table

	No Fog Occurred (No)	Fog Occurred (Yes)
Conditions 1, 2, 3, or 4 Occurred (**NO** Fog Forecast)	199	8
Conditions 1, 2, 3, and 4 Did Not Occur (**YES** Fog Forecast)	23	28

The AMU also completed work on a MIDDS utility, FSINGM, to calculate and display the FSI out to 48 hours using the NGM Point Analysis data (see example below). This utility along with the decision trees and the other AMU developed MIDDS utility "TWRFOG" will allow the forecaster to monitor and forecast potential fog events at the SLF.

FSINGM program output example:

```
Fcst Hour = 10000  Wind Dir = 57  FSI =>  55
Fcst Hour = 20000  Wind Dir = 55  FSI =>  53
.......
Fcst Hour = 330000  Wind Dir = 179  FSI => 31
.......
Fcst Hour = 480000  Wind Dir = 178  FSI =>  32

DAY == 93279     TIME == 0

For Potential Fog Formation, Wind Direction needs to be
between 150° - 330°.

Calculated FSI           Risk of Fog Formation
  > 55                        Low
  31 - 55                     Moderate
  < 31                        HIGH
```

Key results from these analyses and other analyses which are described in the draft final report include:

- A high number (33 of 36) of the fog events analyzed show a westerly component to the surface wind. In many events, a westerly shift in the winds is apparent in the wind tower data prior to the fog development.
- For the advection and pre-frontal events, 83% (30 of 36) of the events had fog develop in the Orlando to Daytona Beach area up to 2 hours prior to development at TTS.
- The primary onset time for fog development at TTS is between 0700 to 1200 UTC: Almost 95% (260 of 280) of all fog events had dissipated (visibility improved to 5 miles or greater) by 1600 UTC and in 75% (210 of 280) of the cases visibility had improved to 5 miles or greater by 1400 UTC.
- A low level inversion at or below 500 feet is generally present.
- Fog can develop even in the presence of strong winds at 492 feet above the surface.
- The vast majority (i.e., 34 of 36) of the fog events characterized by rapid deterioration in visibility are either pre-frontal or advection fog events. Only two of the events were associated with radiational cooling.

Based on the enhanced understanding of fog development at the SLF acquired during this investigation, the AMU has developed fog decision trees and MIDDS utility programs to assist SMG and RWO forecasts assess the potential for fog development. A brief description of two of the MIDDS utility programs is presented below.

- TWRFOG displays time series graphs of wind direction, relative humidity, and temperature information from selected towers within the mesonet tower network. In addition, the current surface observations from central Florida and an estimated FSI are displayed.

- FSINGM computes an FSI out to 48 hours using the NGM Point Analysis data.

The fog forecast decision trees are included in the draft of the final report of the AMU's evaluation of fog development at the SLF.

2.4. Task 004 Instrumentation and Measurement (Dr. Taylor)

Sub Task 3: Doppler Radar Wind Profiler

Implementation of MSFC DRWP Wind Algorithm (Ms. Schumann)

The AMU, in conjunction with NASA/KSC Instrumentation and Measurements Branch and the Paramax MIDDS software group at JSC, performed an interface test between the DRWP and the MIDDS on 28 September 1993. Unfortunately, the test failed since some of the data did not make it to the JSC MIDDS. It appeared the software on the DRWP producing the data as well as the decoder software developed by Paramax on the JSC MIDDS worked properly, and the loss of data was occurring in the modem connection between the DRWP and the KSC MIDDS.

The AMU, CSR, KSC, and Paramax jointly performed several more informal tests of the network to ensure the problem was in the modems and not in the new algorithm software or in the new decoder software. The results of these tests indicated the modem at the DRWP site was losing data prior to transferring the data to the MIDDS modem. Consequently, we decreased the speed of the connection between the DRWP MicroVAX computer and the modem so the modem would no longer overflow its buffer. Preliminary test results indicate the problem is solved. Further analysis is required and another formal interface test will be rescheduled after the STS-58 mission.

The original modem configuration at the DRWP worked fine for the DRWP data output in the jimsphere format, since that transmission is very small and only occurs every 30 minutes. The new format is about 10 times larger than the old format and occurs every three to five minutes thus requiring a more robust communications solution.

The Users' and Maintenance Manuals for the MSFC new wind algorithm software were completed and submitted for NASA and Air Force review. The Test Report was reviewed after the formal software testing in July. The report will be updated with the results of the final interface test between the DRWP and MIDDS and then submitted for final review.

The MSFC wind algorithm software has been running continuously on the DRWP MicroVAX since late August. Until late September, however, the program had to be started manually each time the DRWP MicroVAX restarted. During September, the AMU and the KSC Instrumentation and Measurements Branch modified the DRWP MicroVAX's startup file so the MSFC algorithm software would be automatically started each time the MicroVAX rebooted. The MSFC and the consensus algorithms are now running concurrently on the MicroVAX, but only the consensus algorithm's output in the jimsphere format is transmitted to MIDDS. This configuration will continue until the new decoder written by Paramax is in place at all three MIDDS sites. At that time, the configuration will be changed and the MSFC algorithm's output in the new format will be the only data transmitted to MIDDS. The purpose of running both algorithms concurrently is to identify any existing software problems with the MSFC wind algorithm implementation before it is relied upon exclusively.

DRWP Meteorological Evaluation (Dr. Taylor)

The final report on the AMU's implementation and meteorological evaluation of the MSFC wind algorithm was distributed for external review in early September. Although comments and suggestions from most of the reviewers have been received, the AMU is still waiting for comments from a couple of the reviewers. The AMU anticipates revising and completing this document in November.

Sub Task 7: ASOS Evaluation (Ms. Yersavich)

The AMU has completed an evaluation of ASOS. This evaluation has focused on how ASOS, in conjunction with other systems and procedures, could be used at the SLF to satisfy SLF observations requirements. These requirements, which were outlined in the AMU's Quarterly Report for the third quarter of fiscal year 1993, include standard airfield operations requirements, shuttle operations and simulations requirements, and SMG and Flight Director requirements.

During the last quarter, the AMU investigated other means of satisfying the SLF observations requirements which cannot be met by the standard ASOS configuration. In addition, the acquisition of documentation concerning ASOS measurement accuracy and system reliability and maintainability was completed. The documentation contains results of previous investigations of system performance including comparisons of ASOS data to manual observations.

Most of the AMU efforts during the past month have focused on determining the optimum ASOS configuration and potential concepts of operations (i.e., how ASOS could be used in conjunction with other systems and procedures) which would satisfy the SLF surface observation requirements. The recommended ASOS configuration involves modifications to the current ASOS production software and hardware, the use of multiple sensors, and the suggested placement of all sensors.

It is important to note the AMU is not recommending whether to use ASOS at the SLF. However, should the Shuttle Program decide to use ASOS at the SLF, the recommendations made by the AMU regarding ASOS configurations and concept of operations should be considered.

Three meetings were held to discuss the ASOS evaluation and the potential concepts of operations. AMU personnel met with the Landing Aids Control Building (LACB) personnel to discuss their possible involvement in the potential concepts of operations. In addition, meetings were held with the SMG and RWO to present an overview of the material compiled for the evaluation and discuss the potential concepts of operations. The discussions of the concepts of operations were particularly important to ensure these suggestions would satisfy their observation requirements. Overall, SMG and RWO gave a positive response to the completeness of the analysis and the potential concepts of operations. The recommended ASOS configurations and potential concepts of operations including their advantages and disadvantages/deficiencies are presented below.

Recommended ASOS Configuration for use at SLF

The following description is the recommended ASOS configuration for use at the SLF. The recommended ASOS configuration is based on the standard ASOS production unit and includes modifications to enhance its capabilities with respect to SLF observation requirements. In addition, the recommended ASOS configuration contains suggestions for placement of sensors and display terminals.

<u>Standard ASOS Production Units</u>

The ASOS Combined Sensor group consists of the following sensors:

- Temperature
- Dew Point
- Ceilometer
- Visibility sensor
- Wind Direction and Speed
- Precipitation Accumulation and Identification
- Pressure sensors

The ASOS Touchdown Sensor group consists of the following sensors:

- Ceilometer, and
- Visibility sensor

<u>Recommended ASOS Sensor Group</u>

Recommended ASOS sensor group for use at SLF consists of (at a minimum):

- Two ASOS Combined Sensor group units plus one Touchdown Sensor group unit.

- Enhancements include:
  - Modification of the Touchdown Sensor group to include wind instrumentation.

- Modification of the ASOS sky condition algorithm to append tenths of cloud cover to the observation report.
- Replacement of the current ASOS ceilometer (12000 foot capability) with the Belfort ceilometer (25000 foot capability).

This configuration would provide 3 ceilometers, 3 visibility sensors, and 3 wind sensors. One sensor could be used as the primary and two as secondary.

The recommended location for the two ASOS combined sensor group units is one at each of the approach ends of the runway. The recommended location for the ASOS touchdown sensor group unit is to the west of the SLF.

Other possible ASOS sensor groups for use at the SLF include:
- Three Combined Sensor groups.
- One Combined Sensor group and two Touchdown Sensor groups.

Recommended Locations for ASOS Input and Display Terminals

The recommended locations for the input and display terminals are:
- One input terminal at the LACB (south end of SLF runway).
- One input terminal at the SLF Control Tower (midfield on SLF runway).
- One display terminal in the Range Weather Operations (can be a stand-alone display terminal or the data could be integrated into the Meteorological Monitoring System or into another display system).
- One display terminal in the SMG's working location.
- One input terminal in the ASOS CPU rack to be used for maintenance purposes only.

Proposed Concept of Operations #1

The proposed concept of operations is based on having an ASOS system at the SLF and using LACB personnel to augment the ASOS observations. This concept of operations would require the LACB personnel tasked to augment ASOS observations to become certified weather observers through some type of training program (e.g. Air Force, Computer Science Raytheon, NWS). Another key component of this proposed concept of operations is to move the weather instrumentation from Weather Station B to a location at or near the LACB. This instrumentation would then be used as backup in the case of a partial or complete ASOS failure. If this occurred, LACB personnel would be required to take manual observations of the missing weather elements. This proposed concept of operations would not require any weather observers at Weather Station B.

Key components of this concept of operations include:

- Installing the recommended ASOS sensor group at the SLF.
- Installing the ASOS input and display terminals at the recommended locations.
- Moving the weather instrumentation from Weather Station B to a location at or near the LACB.
- Monitoring the data from three SLF wind towers on MIDDS or dedicated equipment. In the current procedure, the data from three SLF wind towers are manually added to the remarks section of the observation during shuttle launch and landing operations.
- Having LACB personnel augment the hourly and special ASOS observations during their normal operating hours (0600 to 2230 local time, 7 days/week) and during shuttle operations to include cloud tenths, type and height, prevailing visibility, present weather, and additive remarks.
- Having the RWO observer gather weather observations from the ROCC, Weather Station A, and Vehicle Assembly Building (VAB) during shuttle launch and landing operations (from the VAB only during launch operations). The observer would then enter the observations into a text file on MIDDS for distribution to SMG and MSFC. An example of the type of data contained in the text file follows:

  - ROCC: cloud tenths, type and height, present weather and additive remarks.
  - VAB: cloud tenths, type and height, present weather and additive remarks.
  - Weather Station A: complete observation including additive remarks.

  A reduction in Air Force weather observers is scheduled and may impact the RWO’s ability to perform this procedure.

Advantages of Concept of Operations #1

- The proposed concept of operations provides a reduction in cost since no weather observers would be required at Weather Station B. Weather observations are currently being taken by the Range Center Technical Services Contractor personnel at Weather Station B. These weather observers maintain a continuous weather watch 24 hours a day, 365 days a year.

- The LACB provides a better view of the SLF runway than Weather Station B. The LACB is located next to the SLF runway and an observer at the LACB can see a portion of the runway. Weather Station B is located approximately 3000 feet east of the SLF runway and low bushes and trees prevent an observer at Weather Station B from seeing the SLF runway.

- The proposed concept of operations provides supplemental data 15.5 hours/day, 7 days a week. A certified weather observer will be at the LACB for 15.5 hours a day, 7 days a week and during shuttle launch and landing operations to input human observation of:
  - Cloud tenths, type and height
  - Prevailing visibility
  - Present weather
  - Additive remarks.

- The proposed concept of operations provides a consolidated text file of local weather observations (Weather Station A, VAB, and ROCC) on MIDDS during shuttle launch and landing operations.

- The use of multiple sensors will provide a more complete depiction of the meteorological conditions at the SLF.

- The use of the recommended ASOS units provides:
  - Consistent observations.
  - Sky conditions up to 25000 feet.
  - Tenths of cloud cover.

Deficiencies/Disadvantages of Concept of Operations #1

- There would be an additional cost associated with training LACB personnel to become certified weather observers.

- The accuracy of ASOS tenths of cloud cover is unknown when used as a stand-alone unit (from 2230 to 0600 local time).

- The accuracy of ASOS tenths of cloud cover depends upon cloud movement and adequate spacing of the ceilometers.

- ASOS observations would not include information about prevailing visibility, hail, thunderstorms and additive remarks from 2230 to 0600 local time. However, point visibility would be available 24 hours a day from the three ASOS sensor groups at the SLF. If desired, thunderstorm reports could be included in ASOS observations by ingesting the National Lightning Detection Network, Lightning Location and Protection system, or possibly Lightning Detection and Ranging system data into the SLF ASOS unit.

Suggested Concept of Operations #2

The second proposed concept of operations is based on having an ASOS system at the SLF and using a Weather Station B observer with limited duty hours to augment ASOS observations. In the case of a partial or complete failure of ASOS, the instrumentation currently at Weather Station B will be used as backup for observations until the ASOS equipment is returned to operational status.

Key components of this concept of operations include:

- Installing the recommended ASOS sensor group at the SLF.
- Installing the ASOS input and display terminals at the recommended locations.
- Installing one ASOS input terminal at Weather Station B.
- Monitoring the data from three SLF wind towers on MIDDS or dedicated equipment. In the current procedure, the data from three SLF wind towers are manually added to the remarks section of the observation during shuttle launch and landing operations.
- Having an observer at Weather Station B with limited duty hours to augment/modify ASOS observations to include cloud tenths, type and height, prevailing visibility, present weather, and additive remarks. Observers would be used at the SLF for five 8-hour days Monday-Friday and during shuttle launch and landing operations. During non-operation times, the 8-hour shifts could be mission variable work hours depending on the next shuttle launch and landing times or have set times such as:

    - October through April: 0400 to 1300 local time (fog season)
    - May through September: 1000 to 1900 local time (thunderstorm season).

    During shuttle launch operations, the proposed weather observer hours would be from launch minus 6 hours to launch plus 2 hours from two days prior to launch through launch day. During shuttle landing operations, the proposed weather observer hours would be from landing minus 6 hours to landing plus 2 hours from one day prior to landing through landing day.

- Having personnel at the LACB and the Control Tower augment the ASOS observation only when a weather observer was not on duty at Weather Station B. The augmentation by LACB and Control Tower personnel would be limited to current observation duties and no additional training would be necessary.

- Having the RWO observer gather weather observations from the ROCC, Weather Station A, and Vehicle Assembly Building (VAB) during shuttle launch and landing operations (from the VAB only during launch operations). The observer would then enter the observations into a text file on MIDDS for distribution to SMG and MSFC. An example of the type of data contained in the text file follows:

  - ROCC: cloud tenths, type and height, present weather and additive remarks.
  - VAB: cloud tenths, type and height, present weather and additive remarks.
  - Weather Station A: complete observation including additive remarks.

  A reduction in Air Force weather observers is scheduled and may impact the RWO's ability to perform this procedure.

Advantages of Concept of Operations #2

- The proposed concept of operations provides a potential reduction in cost since there would be a reduced number of hours of manual weather observations from Weather Station B. Currently, manual weather observations are taken at Weather Station B 24 hours a day, 365 days a year. In the proposed concept of operations, manual weather observations would only be taken 40 hours per week.

- The proposed concept of operations would not require additional weather observer training for LACB personnel. Proposed concept of operations #1 would require additional weather observer training for LACB personnel.

- The proposed concept of operations provides a consolidated text file of local weather observations (Weather Station A, VAB, and ROCC) on MIDDS during shuttle launch and landing operations.

- The use of multiple sensors will provide a more complete depiction of the meteorological conditions at the SLF.

- The use of the recommended ASOS units provides:
  - Consistent observations.
  - Sky conditions up to 25000 feet.
  - Tenths of cloud cover.

Deficiencies/Disadvantages of Concept of Operations #2

- The cost of manual weather observations at Weather Station B would be greater for proposed concept of operations #2 as compared to proposed concept of operations #1.

- The number of hours per week of manual weather observations would be less for proposed concept of operations #2 (i.e., 40 hours a week at Weather Station B) as compared to proposed concept of operations #1 (108.5 hours per week at the LACB).

- The accuracy of ASOS tenths of cloud cover is unknown when used as a stand-alone unit (from 2230 to 0600 local time).

- The accuracy of ASOS tenths of cloud cover depends upon cloud movement and adequate spacing of the ceilometers.

- ASOS observations would not include information about prevailing visibility, hail, thunderstorms and additive remarks from 2230 to 0600 local time. However, point visibility would be available 24 hours a day from the three ASOS sensor groups at the SLF. If desired, thunderstorm reports could be included in ASOS observations by ingesting the National Lightning Detection Network, Lightning Location and Protection system, or possibly Lightning Detection and Ranging system data into the SLF ASOS unit.

Options for the Concept of Operations

Either or both of the following two options may be added to enhance concept of operations #1 or #2. Option A involves a transition period between the time an ASOS system is installed at the SLF and the time the ASOS provides the official weather observations for the SLF. Option B is based on installing an ASOS unit at the Cape Canveral Air Force Station (CCAFS) Skid Strip to replace existing meteorological instrumentation and enhance the credibility of the SLF ASOS observation.

Option A: Transition Period After Installing ASOS at the SLF

After the ASOS unit is installed and operating at the SLF, manual and ASOS observations would be taken concurrently at the SLF for a period of at least six months. This would provide data for comparison tests between human and ASOS observations and allow the weather support community to develop confidence in the quality and accuracy of the ASOS observations. In addition, it gives the weather support community time to evaluate the multiple sensors,/multiple sensor algorithms of the ASOS at the SLF and, depending upon the transition time period, time to incorporate for improvements in ASOS sensors and algorithms. The only disadvantage of this option is the increased cost associated with taking both manual and ASOS observations concurrently at the SLF.

Option B: Install an ASOS at the CCAFS Skid Strip

This option is based on installing an ASOS at the CCAFS Skid Strip. The ASOS unit would consist of one production-line Combined Sensor Group with no modifications to the hardware or software. The primary input terminal would be located at Weather Station A and the Skid Strip would be added to the list of official observing sites for data distribution. Advantages to this option include:

- Increasing confidence in observations from the SLF ASOS.
- Facilitating the detection of problems with the SLF ASOS.
- Providing continuous, consistent observations 24 hours a day, 365 days a year from the Skid Strip. Since the Skid Strip is the primary landing field for carriers of major sensitive components (e.g., satellites, shuttle equipment, etc.), the ASOS observations will supply important flight information.
- Replacing the old and hard-to-maintain meteorological instrumentation at Weather Station A.

The draft report of this evaluation is currently undergoing internal review and should be ready for external review in November. The AMU report will contain the SLF observation requirements, a comparison of the capabilities of a standard ASOS configuration to SLF observation requirements, and the above options for satisfying the SLF observations requirements which are not satisfied by the standard ASOS configuration.

2.5. Task 005 Mesoscale Modeling (Dr. Manobianco)

Sub task 2 Install and Evaluate MESO, Inc.'s MASS model

This section describes the AMU's efforts in getting the MASS pre-processor and model running on a real-time basis using data transferred from MIDDS. Primary AMU activities during the past quarter include:

- Completing the development and testing of all software needed to reformat MIDDS data for the MASS pre-processor and model,
- Installation of a 5.8 GB external hard disk and two additional processors for the Stardent 3000, and
- Preliminary testing of the MASS pre-processor and model.

Data Extraction and Reformatting

The AMU has developed a routine to extract specified grids from MIDDS data files. It is now possible for the higher resolution NGM analyses (rather than MRF analyses) to be transferred to the Stardent 3000 for use in the MASS pre-processor. This method of gridded data extraction is extremely reliable and can be completed about ten times faster than saving gridded values to a graphics window. Currently, the gridded data extraction process is set-up to run twice-daily on the IBM PC (Model 80).

The same routine is also being used to extract manually digitized radar (MDR) data that has been saved to a MIDDS grid file using the MIDDS 'mdr' command. The MDR grids provide precipitation intensity information which is used for data assimilation and mesoscale re-analysis of the moisture fields. MESO, Inc. has E-mailed two files containing the statistics which relate surface cloud observations to vertical profiles of relative humidity. These files could not be recovered from the Stardent backup tape that MESO, Inc. delivered to the AMU along with the hardware in March 1993. This is the last data set which is required to run the mesoscale re-analysis of the moisture fields in MASS.

The one remaining data set that is not yet available for use in the MASS pre-processor is the National Meteorological Center (NMC) global sea-surface temperature (SST) analyses. The NMC $2^{\circ} \times 2^{\circ}$ global SST grids are being received on the Numerical Products Service in GRIB format. However, they are no longer correctly decoded and stored by MIDDS because the GRIB file format has been changed. Programmers at the University of Wisconsin (SSEC) are aware of this problem and are working on a solution. Until the NMC SST data can be extracted from MIDDS grid files, the MASS model pre-processor will use the coarser monthly climatological gridded data along with SST observations from buoys, ships, and coastal stations for the objective analysis of SST.

The testing and implementation of all software needed to reformat MIDDS data for the MASS pre-processor and model has now been completed. An automatic procedure that uses UNIX scripts has been set-up to run twice-daily at 0000 UTC and 1200 UTC on the Stardent 3000. This procedure reformats data and executes the MASS pre-processor routines. The AMU will be examining the output of the pre-processor to be sure that each component program is handling data I/O correctly and producing output data files suitable for the mesoscale model initialization.

The evaluation of the pre-processor is expected to be completed by the end of November, at which time the MASS model can then be run on a regular basis. The AMU is in the process of specifying a run-time configuration for the model which includes the physical parameterization options and the daily forecast and data assimilation schedules. Once the initialization and forecast products are produced on a regular basis, the products will be provided to the SMG and RWO for their review and analysis. The feedback from their examination will be key in deciding which model products will be transferred to MIDDS for display in the SMG and RWO.

Hardware Acquisitions

Two major hardware components, a 5.8 GB external hard disk and two additional central processing units (CPU) for the Stardent 3000, have been delivered to the AMU. Brief descriptions of how this hardware facilitates the mesoscale modeling task are presented in the following subsections.

5.8 GB External Hard Disk

The hard disk was delivered to the AMU in late September. The disk has been formatted specifically for use on IBM computers and is connected to the IBM RISC 6000 in the AMU laboratory. After initial configuration of the disk on the RISC 6000 model 560 workstation, it has been cross-mounted with the two IBM model 320H workstations and the Stardent 3000 so that any of one of these machines on the ethernet can read or write to the disk. Based upon present data storage estimates, it is anticipated that approximately 40 days of twice-daily MASS model analyses and forecasts (including observed data) can be stored on-line for the purpose of model evaluation and case studies.

Two Additional Processors for the Stardent 3000

MESO, Inc. was able to reduce the amount of time required to execute the MASS model on the Stardent 3000 by restructuring the code and using the vectorizing and parallelizing compiler options. MESO, Inc. also found that not all subroutines perform better when compiled using the parallelizing option. In fact, certain subroutines, (e.g. those that comprise the Kuo-Anthes convective parameterization) execute more rapidly when compiled without the parallelizing option. The degradation in performance of selected subroutines is because the time spent setting up the parallel computations exceeds the time saved by doing the calculations in parallel. As a result, MESO, Inc. set-up the compilation of the MASS model code so that only the subroutines that performed well in the parallel processing mode were compiled using the parallelizing option. In fact, less than 15% of the MASS model subroutines are compiled in parallel mode.

MESO, Inc. performed a series of benchmark tests to measure the computational performance of the MASS code and to document the improvement in execution speed that could be obtained by effective use of compiler options (see Chapter 6 of MESO, Inc.'s SBIR Phase II Final Report delivered to NASA KSC in June 1993). The results of the benchmark simulations show that the use of two processors rather than one processor in selected parallelization mode reduces the execution time by 11% for a 24-hour coarse grid simulation and 17% for a 12-hour fine grid simulation. Based upon these benchmark tests, the AMU decided to purchase two additional processors for the Stardent 3000 computer in order to achieve further reductions in time required to run the model and produce real-time forecast products.

The processors were delivered to the AMU laboratory and installed in the Stardent 3000 during the last week of September. System diagnostics tests revealed that the two new processors are functioning properly. The latest benchmark tests have been performed using 0000 UTC 15 September 1993 data (which is different from the data used by MESO, Inc. for their benchmark runs). A 24-hour coarse grid and 12-hour fine grid simulation were run using one, two, and four processors. The execution times and percent improvements of the benchmark runs from the 0000 UTC 15 September 1993 case are summarized in Table 2. [Note the MASS pre-processor requires approximately 1 h to run on the coarse or fine grid. Therefore, the total execution time for the MASS pre-processor and model using four processors in this case is 1 h (pre-processor) + 2.74 h (coarse grid run) + 4.40 h (fine grid run) = 8.14 h.] The results indicate that:

- The execution time is reduced by 10.1% for the coarse grid and 13.2% for the fine grid by parallel processing (i.e. using two rather than one processors). These values are smaller than the 11% and 17% improvements for the coarse and fine grid simulations, respectively, reported by MESO, Inc. for their benchmark runs. This result is primarily due to the fact that the execution times (and speed-up due to parallelization) depend heavily on the amount of convective activity since the Kuo-Anthes cumulus parameterization scheme in the MASS model is one of the subroutines that is not compiled using the parallelizing option.

- The execution time is reduced an additional 9.3% for the coarse grid and 11.6% for the fine grid by running the software on four rather than two processors. These improvements are slightly less than those achieved in the one- versus two-processor configuration. Parallel processing on the Stardent 3000 generates threads or sub-processes for each available processor that require about 0.14 seconds to create. As a result, there is potentially more overhead or time required for processing with four rather than two processors. For example, the percent improvements in using a two- versus four-processor configuration depends on how much time can be saved by the 15% of the subroutines that are performing parallel computations compared with the cost in using additional processors.

- The percent improvements are larger for the fine grid than for the coarse grid simulations that have been run on one versus two or two versus four processors (see Table 2). The larger reductions in execution time for the fine grid relative to the coarse grid runs are due to the fact that a greater fraction of the calculations are performed by the parallelized subroutines in the fine grid runs. These results are also consistent with MESO, Inc.'s benchmark statistics cited above.

The performance of the MASS model on the Stardent 3000 can be improved further by modifying the time step ratio. Since the fastest gravity waves have phase speeds that are much higher than the advective velocity, the time step used for advective terms can be much larger than that used for the gravity wave terms. The gravity wave (advective) time step is referred to as the short (long) time step. At present, the ratio of the long to short time step is 2:1. MESO, Inc. has been experimenting with a time step ratio of 3:1 which would reduce the number of advective term calculations on the coarse or fine grid by more than 30% thereby decreasing the overall execution time. As soon as time step ratio experiments have been completed, MESO, Inc. will send the AMU the necessary software modifications needed to increase the time step ratio in the MASS model.

Table 2. Execution Times for MASS Benchmark Simulations on the Stardent 3000

Coarse Grid (45 km) 24-hour simulation			
Number of Processors	Execution Time seconds	hours	Percent Improvement by Doubling Number of Processors
1	12080	3.36	-
2	10875	3.02	10.1
4	9872	2.74	9.3
Fine Grid (11 km) 12-hour simulation			
Number of processors	Execution Time seconds	hours	Percent Improvement by Doubling Number of Processors
1	20646	5.74	-
2	17920	4.98	13.2
4	15829	4.40	11.6

Preliminary MASS Pre-Processor and Model Testing

In addition to the benchmark case discussed in the previous section, several other cases have been arbitrarily selected for the preliminary testing of the MASS pre-processor and model. The MASS pre-processor was set-up for a 1200 UTC 6 October 1993 initialization using NGM gridded, rawinsonde, surface, KSC tower, buoy, ship, and sea-surface temperature data. The mesoscale moisture re-analysis of the relative humidity field was not used because the programs that read and process the surface cloud observations, infrared satellite data, and manually digitized radar (MDR) data have not been tested completely. In addition, the software which prepares data sets for four-dimensional data assimilation has not been tested, therefore no data assimilation was performed.

The 45 km coarse grid simulation was run for 24 hours from 1200 UTC 6 October through 1200 UTC 7 October 1993. The 11 km fine grid simulation was initialized at 0000 UTC 7 October 1993 using output from the coarse grid and then integrated 12 hours to 1200 UTC 7 October 1993. The boundary conditions for the coarse grid simulation were derived from the 6-hourly NGM data sets, whereas those for the fine grid were derived from the 1-hourly coarse grid run. Two examples of the fine grid output at 3-hour intervals from 0300 UTC 7 October through 1200 UTC 7 October 1993 are shown in Figures 1 and 2. Figure 1 displays a modified Fog Susceptibility Index (FSI) computed from the model predicted data at the surface and 500 foot levels The formula for the original FSI and a more detailed discussion of how the FSI can be used in forecasting fog development at KSC is given in Section 2.3 under Task 003 (Improvement of 90 Minute Landing Forecast), Sub Task 2 (Fog and Stratus at KSC).

The shading in Figure 1 depicts the following:

Amount of Shading	FSI	Risk of Fog Formation
dark	> 26	low
medium	15-26	moderate
light	< 15	high

Figure 1. Predicted Fog Susceptibility Index (FSI) and precipitation exceeding 0.01 in hr^{-1} from the MASS model 11 km fine grid simulation at 3-h intervals from (a) 0300 UTC 7 October, (b) 0600 UTC 7 October, (c) 0900 UTC 7 October, and (d) 1200 UTC 7 October. The standard surface weather observations are plotted in each panel. The calculation of the FSI and the levels of shading are described in the text. The dashed lines in panels (a)-(d) enclose regions where the model precipitation > 0.01 in hr^{-1}.

Figure 2. Predicted surface wind speed and direction (half barb = 5 kt; full barb = 10 kt) from the MASS model 11 km fine grid simulation at 3-h intervals from (a) 0300 UTC 7 October, (b) 0600 UTC 7 October, (c) 0900 UTC 7 October, and (d) 1200 UTC 7 October. The fine grid run was initialized at 0000 UTC 7 October from the 12-h coarse grid output. The isopleth interval for isotachs is 2 kt.

Also shown in Figure 1 are the standard surface weather observations (e.g., F = Fog) plotted at their time of observation and regions where the model precipitation exceeds 0.01 inches h^{-1}. Figure 2 displays the predicted surface wind speed and direction at the same synoptic times as the FSI and weather observations shown in Figure 1. The time evolution of the simulated FSI and surface winds, and surface weather observations depicted in Figures 1 and 2 indicates:

- The model precipitation exceeding 0.01 inches h^{-1} at 0600 UTC 7 October and 0900 UTC 7 October (Figs. 1b, 1c) occurs in the northeast corner of Florida where light rain showers (R-) were reported throughout the 12-h forecast period (Figs. 1a-d).

- The predicted area of high risk for fog formation (light shading) expands northward after 0600 UTC 7 October (Figs. 1c, 1d) and correlates reasonably well with observations of fog (F) along the east and west coasts of Florida (Figs 1a-d).

- According to the AMU's report on the analysis of rapidly developing fog at KSC, the occurrence of fog along Florida's east coast is typically associated with weak westerly flow. However, the predicted surface winds maintain an easterly component from 0300 UTC 7 October through 1200 UTC 7 October (Figs. 2a-d) as the area of weak winds (< 4 kt) expands north covering more than two-thirds of the peninsula and adjacent coasts by 1200 UTC 7 October (Fig. 2d). In this case, the FSI computed from the MASS model's predictions of surface and 500 ft temperature and moisture could have provided useful guidance on the potential for fog formation.

2.6. AMU Chief's Technical Activities (Dr. Merceret)

This is a new section which will be included in our Quarterly Update Reports. Previous AMU Quarterly Update Reports presented only the work performed by the ENSCO employees, and not AMU products generated by the NASA AMU Chief. As a result, important AMU technical work such as our efforts to help resolve the issue of chaff interference with weather radar during launch operations went unreported. Addition of this section to our reports will provide readers with a more complete picture of AMU activities.

In the fourth quarter of FY 1993, the AMU Chief worked on three major technical projects; two derived from the Shuttle Program's revision of the Minimum Temperature Launch Commit Criteria (LCC) and one dealing with program concerns about siting of the SLF wind sensors.

A field experiment to evaluate the SLF wind sensor siting is planned for the first half of FY 1994. This quarter's work included site surveys, aerial photographs, and instrumentation of the portable wind towers to be used in the experiment.

The Minimum Temperature LCC has been revised to include effects of latent heat of condensation on vehicle heat transfer and provide for a recovery algorithm in case of a violation. The AMU Chief was asked to review the critical temperature table (T_{crit} as a function of relative humidity and wind speed). As a result, it was discovered that the existing relative humidity sensors at the launch pads had a response time of nearly two hours whereas five minutes or faster was required. The AMU Chief's recommended changes in the type and placement of the relative humidity sensors were adopted. The AMU Chief provided oversight to the qualification testing of the new sensors.

The recovery algorithm, developed by MSFC's Thermal Analysis Branch, will eventually be programmed into MIDDS. Since the MIDDS version will not be ready until April 1994 at the earliest, the AMU Chief was tasked to implement it on a DOS PC for use this winter. The software, called LOWTEMP, is being written, tested, and validated as launch critical software. Work began in September and was completed in October. Formal validation is required by November 15, 1993, for use on STS-61 (Hubble repairs).

3. Project Summary

Based on an AMU Tasking and Priorities Meeting held on 8-9 October 1992 and subsequent teleconferences and memorandums, the AMU tasks and priorities for FY 1993 were established in late December 1992. The FY 1993 tasking includes the completion of tasks started in FY 1992 and a number of new tasks which have already been or will be started in FY 1993. A brief description of the current tasks is contained in Attachment 1.

The FY 1994 AMU Tasking and Priorities Meeting was held on 1-2 July 1993 and new and revised tasking was issued to the AMU during the fourth quarter of FY 93. An updated task description will be included with the FY 94 first quarter report.

Part of the AMU efforts this past quarter focused on ongoing FY 1992 tasks. This includes the KSC fog and stratus study, the implementation and evaluation of the MSFC wind algorithm in NASA's 50 MHz DRWP, and the development of McBasi routines to enhance the usability of the MIDDS for forecasters at the RWO and SMG. The implementation and evaluation of the MSFC wind algorithm in NASA's 50 MHz DRWP is nearly complete. The remaining tasks, wrap-up of documentation and testing, should be completed in the first part of this next quarter. The KSC fog and stratus study is also near completion. The final report is in internal review and should be ready for external review in November. The MIDDS enhancement task is an ongoing effort with product deliverables as required.

Fiscal year 1993 tasks which have received attention this past quarter include the evaluation of the MASS mesoscale model, the ASOS evaluation, the development of forecaster guidance tools using ANN, and the acquisition of the RAMS model. This past quarter, AMU efforts associated with the MASS mesoscale model included

- Completing the development and testing of all software needed to reformat MIDDS data for the MASS pre-processor and model,
- Installing a 5.8 GB external hard disk and two additional processors for the Stardent 3000, and
- Preliminary testing of the MASS pre-processor and model.

Testing of the MASS pre-processor and model fourth will be completed in the first quarter of FY 93. At that time evaluation of the MASS mesoscale model will begin.

The AMU also made significant progress on the ASOS evaluation task this past quarter. A draft of the ASOS evaluation report has been written and the task should be completed in the first quarter of FY 94. Progress has also been made on the task to acquire and tailor the RAMS model for use at KSC. Preliminary efforts have focused on

- Selecting the computer hardware for the model,
- Outlining the System Design Document,

- Outlining the Model Evaluation Protocol, and
- Selecting the initial case study days.

This next quarter the AMU will start work on two of the FY 1993-94 tasks:

- LDAR evaluation, and
- Melbourne NEXRAD evaluation.

Attachment 1: AMU FY-93 Tasks

Task 1 AMU Operations

- Operate the AMU. Coordinate operations with NASA/KSC and its other contractors, 45th Space Wing and their support contractors, the NWS and their support contractors, other NASA centers, and visiting scientists.

- Establish and maintain a resource and financial reporting system for total contract work activity. The system shall have the capability to identify near-term and long-term requirements including manpower, material, and equipment, as well as cost projections necessary to prioritize work assignments and provide support requested by the government.

- Monitor all Government furnished AMU equipment, facilities, and vehicles regarding proper care and maintenance by the appropriate Government entity or contractor. Ensure proper care and operation by AMU personnel.

- Identify and recommend hardware and software additions, upgrades, or replacements for the AMU beyond those identified by NASA.

- Prepare and submit in timely fashion all plans and reports required by the Data Requirements List/Data Requirements Description.

- Prepare or support preparation of analysis reports, operations plans, presentations and other related activities as defined by the COTR.

- Participate in technical meetings at various Government and contractor locations, and provide or support presentations and related graphics as required by the COTR.

- Design McBasi routines to enhance the usability of the MIDDS for forecaster applications at the RWO and SMG. Consult frequently with the forecasters at both installations to determine specific requirements. Upon completion of testing and installation of each routine, obtain feedback from the forecasters and incorporate appropriate changes.

Task 2 Training

- Provide initial 40 hours of AMU familiarization training to Senior Scientist, Scientist, Senior Meteorologist, Meteorologist, and Technical Support Specialist in accordance with the AMU Training Plan. Additional familiarization as required.

- Provide KSC/CCAFS access/facilities training to contractor personnel as required.

- Provide NEXRAD training for contractor personnel.

- Provide additional training as required. Such training may be related to the acquisition of new or upgraded equipment, software, or analytical techniques, or new or modified facilities or mission requirements.

Task 3 Improvement of 90 Minute Landing Forecast

- Develop databases, analyses, and techniques leading to improvement of the 90 minute forecasts for STS landing facilities in the continental United States and elsewhere as directed by the COTR. Specific efforts will be designated as numbered subtasks. The two initial subtasks are specified below. Additional sub tasks will be of similar scope and duration, and will be assigned by technical directives issued by the COTR.

- Subtask 1 - Two Tenths Cloud Cover

•• Develop a database for study of weather situations relating to marginal violations of this landing constraint. Develop forecast techniques or rules of thumb to determine when the situation is or is not likely to result in unacceptable conditions at verification time. Validate the techniques and transition to operations.

- Subtask 2 - Fog and Stratus At KSC

•• Develop a database for study of weather situations relating to marginal violations of this landing constraint. Develop forecast techniques or rules of thumb to determine when the situation is or is not likely to result in unacceptable conditions at verification time. Validate the techniques and transition to operations.

Subtask 3 - Two Tenths Cloud Cover Data Base

•• The 0.2 cloud cover sub task is extended to include maintenance of its associated data base indefinitely. This shall include keeping the data base current and accessible.

Subtask 4 - Forecaster Guidance Tools

•• The 0.2 cloud cover sub task is extended to include development of forecaster guidance tools including those based on artificial neural net (ANN) technology.

Subtask 5 - PBL Post-Sunrise Winds

•• Commence a study of the PBL post-sunrise wind field at KSC by compiling the requisite data base.

Task 4 Instrumentation and Measurement Systems Evaluation

- Evaluate instrumentation and measurement systems to determine their utility for operational weather support to space flight operations. Recommend or develop modifications if required, and transition suitable systems to operational use.

- Subtask 3 - Doppler Radar Wind Profiler (DRWP)

•• Evaluate the current status of the DRWP and implement the new wind algorithm developed by MSFC. Operationally test the new algorithm and software. If appropriate, make recommendations for transition to operational use. Provide training to both operations and maintenance personnel. Prepare a final meteorological validation report quantitatively describing overall system meteorological performance.

• Subtask 4 - Lightning Detection and Ranging (LDAR) System

•• Evaluate the NASA/KSC Lightning Detection and Ranging (LDAR) system data relative to other relevant data systems at KSC/CCAFS (e.g., LLP, LPLWS, and NEXRAD). Determine how the LDAR information can be most effectively used in support of NASA/USAF operations. If appropriate, transition to operational use.

• Subtask 5 - Melbourne NEXRAD

•• Evaluate the effectiveness and utility of the Melbourne NEXRAD (WSR-88D) operational products in support of spaceflight operations. This work will be coordinated with appropriate NWS/FAA/USAF personnel.

• Subtask 6 - SLF Wind Sensor Siting

•• Commence a study of the siting of the wind sensors at the shuttle Landing Facility (SLF) by assembling the appropriate data base.

• Subtask 7 - ASOS Evaluation

•• Evaluate the effectiveness and utility of the ASOS data in terms of spaceflight operations mission and user requirements.

Task 5 Mesoscale Modeling

• Evaluate Numerical Mesoscale Modeling systems to determine their utility for operational weather support to space flight operations. Recommend or develop modifications if required, and transition suitable systems to operational use.

• Subtask 1 - Evaluate the NOAA/ERL Local Analysis and Prediction System (LAPS)

•• Evaluate LAPS for use in the KSC/CCAFS area. If the evaluation indicates LAPS can be useful for weather support to space flight operations, then transition it to operational use.

• Subtask 2 - Install and Evaluate the MESO, Inc. Mesoscale Forecast Model

•• Install and evaluate the MESO, Inc. mesoscale forecast model for KSC being delivered pursuant to a NASA Phase II SBIR. If appropriate, transition to operations.

• Subtask 3 - Acquire the Colorado State University RAMS Model

•• Acquire the Colorado State University RAMS model or its equivalent tailored to the KSC environment. Develop and test the following model capabilities listed in priority order:

1) Provide a real-time functional forecasting product relevant to Space shuttle weather support operations with grid spacing of 3 km or smaller within the KSC/CCAFS environment.

2) Incorporate three dimensional explicit cloud physics to handle local convective events.

3) Provide improved treatment of radiation processes.

4) Provide improved treatment of soil property effects.

5) Demonstrate the ability to use networked multiple processors.

Evaluate the resulting model in terms of a pre-agreed standard statistical measure of success. Present results to the user forecaster community, obtain feedback, and incorporate into the model as appropriate. Prepare implementation plans for proposed transition to operational use if appropriate.