Applied Meteorology Unit (AMU)

Quarterly Update Report

First Quarter FY-94

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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 during the launch of STS-58. The downlink system displays the aircraft track and aircraft wind estimates on a PC and the aircraft track overlaid on McGill radar products. During this demonstration hard copy printouts of the aircraft track and McGill radar products were provided to Spaceflight Meteorology Group (SMG) and Range Weather Operations (RWO) forecasters and a video tape of the displays was produced and delivered to NASA/ME for their review.

The AMU also reviewed and provided comments on a proposed Program Requirements Document (PRD) for the STA downlink system. Two primary areas of concern are

- Determining how to incorporate the STA information into the McGill radar data ingested by the MIDDS so SMG has access to STA downlink data and
- Ensuring that equipment and software configuration control requirements are satisfied since the new hardware and software will interface with Range equipment.

Development of Forecaster Applications (Mr. Wheeler)

During this quarter the AMU designed, developed, and implemented four F-key menu systems on the MIDDS in the Range Weather Operations (RWO). The menus were designed for the duty forecaster terminal, the Department of Defense Manager for Space Shuttle Support (DDMS) terminal, the WideWord Workstation terminal, and the weather aircraft support terminal. RWO personnel provided the requirements for menu system functionality and user interaction.

After the menu systems were completed and installed in the RWO MIDDS, RWO forecasters provided several suggestions to further enhance the menu systems' capability and utility. Based on these suggestions, the AMU revised and installed new versions of the menu systems.

The AMU is also designing and developing a user friendly F-key menu system for the Launch Weather Officers (LWO) terminal in the RWO. Currently, the AMU is soliciting the requirements for the menu system from RWO personnel.

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)

This section will first provide an overview of the work performed on the development of the artificial neural network to forecast cloud cover and then present an evaluation of the network developed thus far. The AMU began development of a prototype artificial neural network to provide short-term cloud cover forecasts in late September. Before performing extensive work on this task, the AMU provided the Weather Support Office, RWO, and SMG a work plan describing artificial neural networks and their uses and the approach the AMU would take during the task. Subsequent discussions were then held with the Weather Support Office, RWO, and SMG during development of the neural network.

The first neural network developed used daytime hourly surface observations from the SLF to predict the amount of cloud cover out two hours. The hourly surface observations and hourly tenths cloud cover below 10 000 feet for years 1986 through 1992 were taken from the data set compiled during the AMU's cloud cover study: *Shuttle Landing Facility Cloud Cover Study: Climatological Analysis and Two-Tenths Cloud Cover Rule Evaluation.*

The AMU separated the data into one training and two independent test data sets. The training set data consisted of approximately 1000 records uniformly representing cloud cover changes of 0, 1 2, 3, 4, 5, and 6 or more tenths over a two hour period. Unlike the training set, both test data sets accurately represented the true distribution of cloud cover changes over the seven year period.

During training of the neural network, both the training data set and the first test data set were used. The test data were used to assist in developing the model (e.g.. determining which inputs to use, the number of hidden units, and when to stop training). Since the first test data set influenced the model itself, the second test data set was used to evaluate the network's performance (presented below).

The artificial neural network was generally able to learn whether the amount of cloud cover increased or decreased over the two hour time period. It did not, however, perform well predicting the magnitude of this change. In an attempt to improve the network's ability to discriminate between large and small changes in cloud cover, the AMU incorporated the upper air data from the same time period into the training and test data sets. This did not have the desired effect. The temporal resolution of the upper air data was much less than that of the actual observed tenths of cloud cover. The amount of cloud cover would change dramatically in both directions while the upper air data did not change at all. The overall effect of including the upper air data was the neural network tended to output a zero change in cloud cover all the time.

The AMU then decided to evaluate the performance of the neural network prior to the addition of the upper air data. From the standpoint of operational meteorology, the artificial neural network did not meet the requirements of an operational forecast aid. The following paragraphs describe the evaluation performed on the artificial neural network developed using only the surface observations for input and training.

The following items were used as inputs to the artificial neural network:

- Dew point depression,
- Wind direction,
- Change in dew point depression over last three hours,
- Change in temperature over last three hours,
- Time of day,
- Season,
- Change in cloud cover over last hour, and
- Change in cloud cover over last two hours.

Each of the above variables was scaled to the interval [-1,1]. The artificial neural network output was the change in cloud cover occurring over the next two hours. Two different artificial networks were generated, one trained and tested with data spanning the entire year and another trained and tested with summer time (May - September) data only.

As mentioned above, the artificial neural networks had trouble predicting the exact change in cloud cover. Tables 1 and 2 show the actual number of correct responses generated by the neural networks compared to persistence. For evaluation purposes, any response output by the neural network within one tenth of the desired response was considered correct and any change less than or equal to one tenth in the actual observed data was considered to be characterized by persistence.

Table 1. Prediction of Cloud Cover Change Over Two Hours ANN Output VS Persistence (Entire Year)			
Initial Cloud Cover	# of Samples	% Correct by Persistence	% Correct Output by ANN
0	4701	87	78
1	3869	84	67
2	3110	74	55
3	2244	66	46
4	1288	51	45
5	631	32	44
6+	3719	70	60
Total	19362	75	62

Table 2. Prediction of Cloud Cover Change Over Two Hours ANN Output VS Persistence (Summer Only)			
Initial Cloud Cover	# of Samples	% Correct by Persistence	% Correct Output by ANN
0	1826	86	80
1	1414	85	71
2	1586	80	59
3	1176	72	49
4	587	57	55
5	217	37	49
6+	647	54	49
Total	7953	75	62

Although the data in Tables 1 and 2 indicate the artificial neural networks did not perform as well as persistence, the artificial neural networks were more successful than persistence in correctly identifying whether the cloud cover would increase or decrease over the next two hours. They did not, however, handle situations where the change in cloud cover was one tenth or less in either direction. In those cases, the neural networks' responses centered about 0, but were not reliable in direction and often indicated large increases or decreases in cloud cover when none were reported.

Tables 3 and 4 below provide the probabilities the neural networks would detect an increase or decrease in the amount of cloud cover. The percentages provided in Tables 3 and 4 are defined as follows:

POD^P: The probability the neural network would detect an increase in cloud cover greater than or equal to delta. (If delta equals 0, then assume delta = 1/10.)

FAR^P: The probability the neural network would predict an increase in cloud cover when the actual change in cloud cover was a decrease of delta or more.

POD^M: The probability the neural network would detect a decrease in cloud cover greater than or equal to delta. (If delta equals 0, then assume delta = 1/10.)

FAR^M: The probability the neural network would predict a decrease in cloud cover when the actual change in cloud cover was an increase of delta or more.

The artificial neural network results presented here are not as promising as it was hoped they would be, and they certainly do not meet the criteria for useful forecasting tools. They do, however, indicate the network is able to learn. Given that the only data input to the ANN during training and testing were the surface observations, the results are encouraging. The effort exerted on this task by the AMU was very small (approximately three months) and revealed that though artificial neural network technology may eventually assist in short term forecasting, the research community will have to pursue its application further before it is ready for transition to operational forecasting. The following paragraphs suggest some directions for this research.

Table 3. Ability of ANN to Distinguish Between Increases and Decreases in Cloud Cover (Entire Year)

Delta	POD^P (%)	FAR^P (%)	POD^M (%)	FAR^M (%)
0	62	78	32	65
1/10	62	34	32	23
2/10	63	22	44	23

Table 4. Ability of ANN to Distinguish Between Increases and Decreases in Cloud Cover (Summer Only)

Delta	POD^P (%)	FAR^P (%)	POD^M (%)	FAR^M (%)
0	62	62	40	42
1/10	62	32	40	18

2/10	63	19	56	16

Several options are available for improving the performance of the network. First, the network should be trained and tested with the one hour forecast rather than the two hour forecast to see if the surface observations are more indicative of immediate cloud cover changes rather than those spread over the next two hours.

Secondly, data more indicative of cloud cover changes should be incorporated into the neural network. The upper air data could be incorporated into the network during training. However, instead of using the same upper air data throughout the entire day (i.e. when there is only one sounding per day), forecast values from mesoscale models could be used when the latest sounding is no longer representative of the atmosphere. Also, more spatial data could be incorporated into the network. The neural network was not provided any information regarding cloud cover which may be advecting towards the SLF.

Finally, developing different neural networks for the different times of the year should improve performance. (The summer only neural network performed slightly better than the neural network trained with data from the entire year.) Forecasters use entirely different sets of rules based on the time of year. In their tendency to generalize, neural networks average the seasonal effects over the entire year. Developing different neural networks for the different seasons would allow the networks to develop their own sets of rules for the different seasons.

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

During this quarter the AMU completed the draft of the final report for the AMU's evaluation of fog development at the Shuttle Landing Facility (SLF). The draft is currently undergoing external review and should be revised and distributed by the end of March.

The final report includes an analysis of all fog events at TTS (the observation site at the SLF) during the 5 year period (1986-1990). Figures 1 and 2 present fog onset times at TTS during the 5 year period based on 7 and 5 miles visibility criteria. Throughout this section the following symbols will represent the defined data sets:

- 5-mile - Visibility less than 5 miles.
- 7-mile - Visibility less than 7 miles.

The 7-mile data indicate the highest frequency of occurrence of fog onset between 0900 to 0959 UTC. The time period with the highest frequency of occurrence of fog onset for the 5-mile fog cases is one hour later (e.g., 1000 to 1059 UTC) than the corresponding time periods for the 7-mile fog cases. In addition, the frequency of fog onset times for the 5-mile fog cases is more uniformly distributed among a number of time periods (e.g., 0900 to 1259) whereas the frequency of fog onset times to the 7-mile fog cases events peaks at 0900 to 0959 UTC.

The explanation for the differences in the fog onset time distributions is based on the differences between the composition of the data sets. The all fog events samples contain fog events which are characterized by rapid deterioration of visibility due to fog as well as fog events characterized by *gradual* deterioration in visibility. The fog onset times for the 5-mile fog cases will be later than the fog onset times to the 7-mile fog cases for the events characterized by *gradual* deterioration in visibility. Consequently, the distribution of the fog onset times for the 5-mile fog cases will be different from the distribution of the fog onset times of the 7-mile fog cases.

Another factor which may account for some component of the differences in the fog onset time distributions is not all of the fog events included in the distribution of onset times for the 7-mile fog cases are included in the distribution of onset times to the 5-mile. This is because the visibility did not drop below 5 miles in some of the fog events included within the visibility less than 7 mile sample.

Figures 3 and 4 present the times when the visibility at TTS improved to at least 7 or 5 miles, respectively, for all fog cases between 1986 and 1990. The time of fog dissipation at TTS for the complete 5 year data base is typically between 1200 and 1600 UTC. In particular, the fog dissipated for most of the fog events (i.e. 96%) by 1600 UTC. The general tendency for the fog to dissipate at TTS by no later than 1600 UTC can be very useful in forecasting and planning of shuttle de-orbit operations. Most of the fog events characterized by dissipation after 1600 UTC are associated with frontal boundaries.

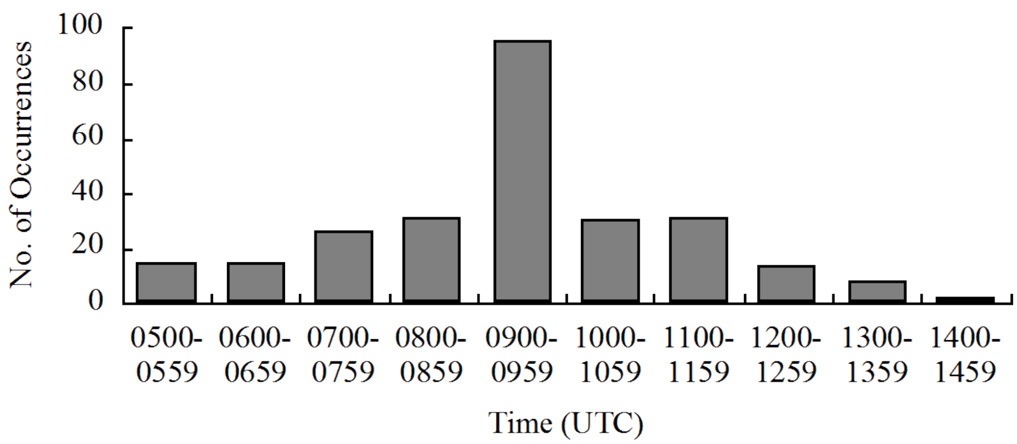

Figure 1. Fog Onset for the period 1986 - 1990 (Visibility less than 7 miles, 335 events).

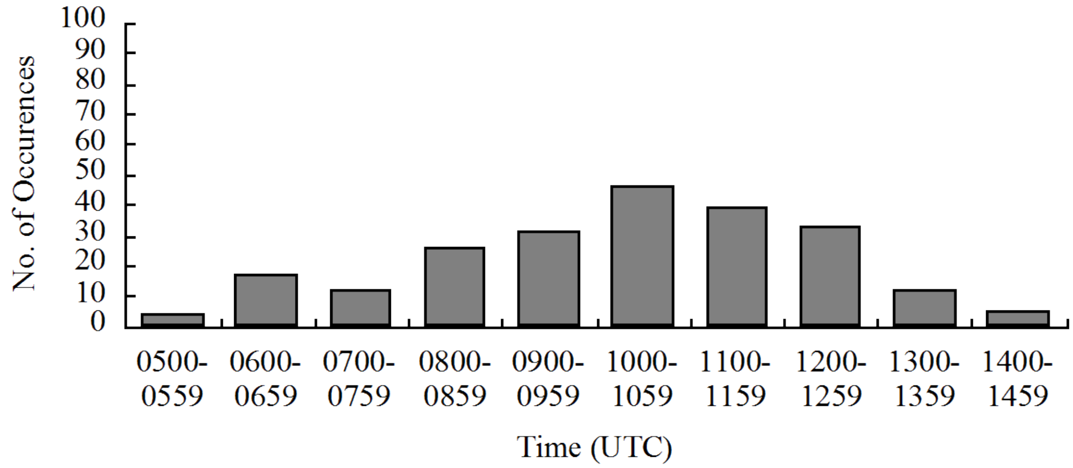

Figure 2. Fog Onset at TTS for the period 1986 - 1990 (Visibility less than 5 miles, 267 events).

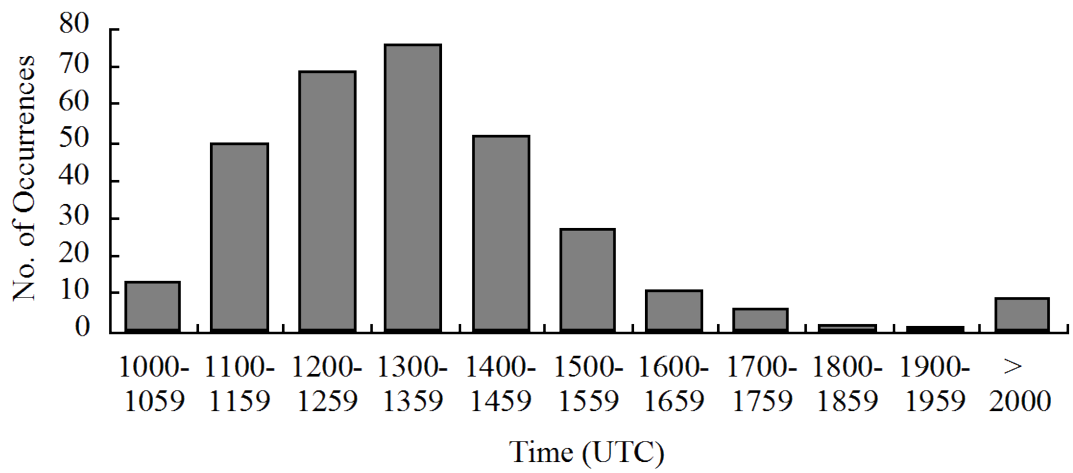

Figure 3. Time of Fog Dissipation at TTS for the period, 1986 - 1990, (Visibility less than 7 miles), 335 Fog Events.

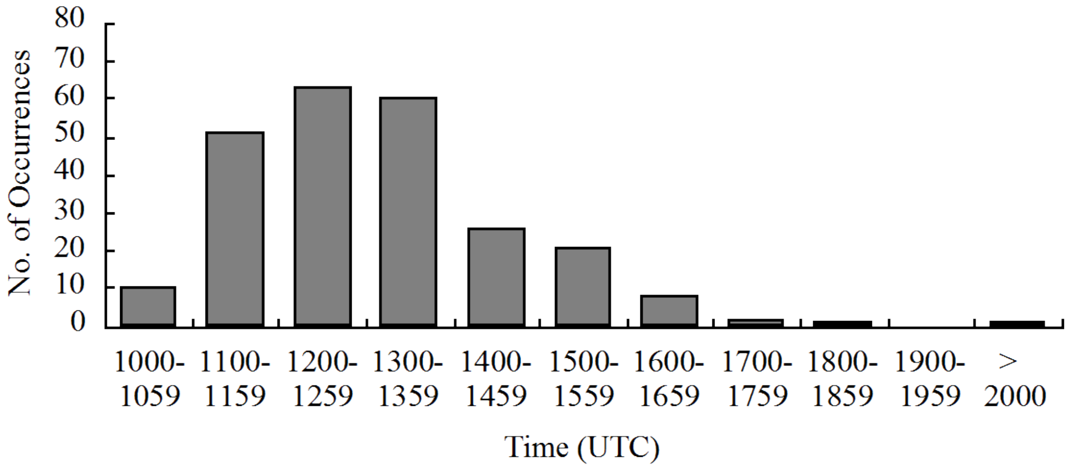

Figure 4. Time of Fog Dissipation at TTS for the period, 1986 - 1990, (Visibility less than 5 miles) 267 Fog Events.

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 has nearly completed all development work associated with the implementation of the new MSFC wind algorithm in the NASA 50 MHz Doppler Radar Wind Profiler. The MSFC wind algorithm has been running continuously since August. Two minor software changes have been requested and implemented since that time.

The first modification involved working around the DEC VMS directory allocation scheme which makes poor use of available disk space. The new wind algorithm generates a new file as often as every three minutes. The directory's file allocation table, which stores information about the files within the directory, would fill up with the large number of filenames and associated information long before the disk would become full (e.g., the file allocation table would fill in approximately two days of operation whereas the disk would fill in approximately three days of operation). When the file allocation table for the directory fills, the VMS operating system must find additional free contiguous space of at least one and one half times the current size of the entire directory. Since the hard disk on the MicroVAX is small and already fragmented, a contiguous block of disk space at least one and one half times the size of the data directory generally does not exist. Consequently, when the file allocation table would fill, VMS would not be able to find the required contiguous disk space and the program would halt execution because it could not open an output file.

As a solution, the AMU modified the filenames of the program's output files reducing the amount of space used per file in the file allocation table. The original filenames were 19 characters and the new filenames are 8 characters. The filenames contain the same amount of information (i.e. date and time); however, the new filenames are considerable more cryptic. Preliminary testing indicates that this extends the amount of time before the program fails by one day. Prior to the filename change, the KSC Instrumentation and Measurement Branch would have to archive and delete all data every two days in order to keep the MSFC wind algorithm program from stopping. This should now be extended to at least three days.

The other software change is based on a request from MSFC to make the processing software more flexible in its support of six mode operation. When the radar is configured for six mode operation, the DRWP produces two different wind profiles with potentially different first gate heights and different gate spacings during each radar cycle. Formerly, the processing software distinguished between high and low modes (i.e., the two different profiles) based upon which first gate heights were below ten kilometers; and consequently, would not support a configuration where all six modes had first gate heights below ten kilometers. In response to MSFC's request, the AMU modified the processing software to make it more flexible in its support of six mode operation and, in particular, to support a configuration where all six modes had first gate heights below ten kilometers.

Testing of the software changes was performed in conjunction with the final interface test of the MicroVAX-MIDDS interface.

The first DRWP-MIDDS interface test failed in September because the DRWP MicroVAX to modem connection was improperly configured. The flow control between the modem and the MicroVAX had never been enabled. Flow control is unnecessary for the jimsphere data format currently used because the entire transmission is less than the modem's buffer size. The new format specified by MSFC is several times larger than the old format and requires reliable flow control.

The AMU, in conjunction with the KSC Instrumentation and Measurements Branch, configured the MicroVAX-modem connection to include flow control. The AMU then performed two separate informal tests of the MicroVAX-MIDDS interface with the cooperation of Mr. Bryan Batson of Paramax. Both tests involved sending data in the new format for 24 hours. No data were lost during either informal test of the interface.

On 18 and 19 January, the AMU in conjunction with Mr. Bryan Batson of Paramax performed the final interface test of the MicroVAX-MIDDS interface. The test consisted of first sending test data over the interface to ensure the integrity of the data after they were ingested and decoded at the MIDDS. Then the MicroVAX was allowed to transmit real-time data for another 20 hours during which no data were lost during transmission.

The results of the MicroVAX-MIDDS interface test will be documented in the final test report which should be completed by the end of January. At that time the user community's suggested revisions for the final maintenance manual and users guide should also be complete.

DRWP Meteorological Evaluation (Dr. Taylor)

The final report on the AMU's implementation and meteorological evaluation of the MSFC wind algorithm has been revised based on reviewers comments and submitted to the KSC Public Affairs for permission to distribute the document as a NASA contractor report.

Sub task 5: Melbourne NEXRAD Evaluation (Dr. Taylor)

During this past quarter, the AMU began working on the NEXRAD Exploitation task. This effort focuses on evaluating the effectiveness and utility of the WSR-88D and its products in support of spaceflight operations.

In December, meetings were held with the Melbourne office of the National Weather Service, the RWO, and the SMG concerning specific tasking for AMU's NEXRAD exploitation effort. The primary focus of each meeting was to discuss the concerns and issues each group has with the WSR-88D related to its use in support of operations and the possible tasks the AMU could perform to help improve the use of the WSR-88D. A list of issues and possible AMU NEXRAD tasks was created from the discussions with the three groups. The Operations Support Facility (OSF) was subsequently contacted to discuss the list of issues and possible AMU tasks in order to

- Identify and remove from the list any tasks the OSF or other organizations are currently addressing,
- Identify high-risk tasks, and
- Determine which tasks have near-term results.

Based on the discussion with the OSF, the potential task list is being revised. After the revisions are completed, the potential task list will be distributed to the three groups for review and prioritization.

WSR-88D Visualization System software (Ms. Yersavich)

During November, the AMU received the WSR-88D Visualization System software and user's guide from Lt. Col. Tim Crum, Chief of the Applications Branch of the OSF. This software, produced by the National Severe Storms Laboratory and the Cooperative Institute for Mesoscale Meteorological Studies, was developed to use and visualize WSR-88D level II archive data sets. The AMU expects this visualization software to be an important tool in the AMU's NEXRAD Exploitation task.

The Visualization System software can read WSR-88D level II data and then display images of reflectivity, velocity, spectrum width, and composite reflectivity. It is also capable of displaying overlays of county lines, city locations, and range rings. Other system features include zoom capability, automatic data update, animation, and display of radar parameters such as azimuth, range, and height. The system is also capable of displaying point values of reflectivity, velocity, or spectrum width.

The software has been installed on one of the AMU's IBM RISC/6000 Model 320H computers and is ready to read and display data. Lt. Col. Tim Crum provided the AMU with a sample of WSR-88D level II data from the Oklahoma City area to test the software. This data set has been read from tape by the WSR-88D Visualization System data ingester and placed on disk in the appropriate format to be read by the display software.

During December, the AMU performed a brief evaluation of the WSR-88D Visualization System software. The evaluation, performed at the request of Lt. Col. Crum, included testing of the software's capabilities, user friendliness, and usability. Comments, questions, and suggestions regarding the software were then sent to the National Severe Storms Laboratory (NSSL) personnel for review.

Sub Task 7: ASOS Evaluation (Ms. Yersavich)

This quarter, the AMU completed their evaluation of ASOS capabilities in relation to SLF observation requirements. The evaluation focused on how ASOS, in conjunction with other systems and procedures, could be used at the SLF to satisfy SLF observations requirements. The AMU report contains the SLF observation requirements, a comparison of the capabilities of a standard ASOS configuration to SLF observation requirements, and options for satisfying SLF observations requirements which are not fulfilled by the standard ASOS configuration.

A draft copy of the ASOS evaluation report was distributed for external review in December with a request that comments be sent to the AMU no later than 14 January 1994. The AMU will make any necessary revisions after reviewers’ comments are received prior to the completion of the final report.

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 testing of MASS pre-processor and model,
- Initiation of twice daily pre-processor and model runs, and
- Preliminary development of routines to post-process and display MASS model output.

MASS Pre-Processor and Model Testing

The AMU has examined the output from the MASS pre-processor to be sure the component programs are handling data I/O correctly and producing output data files suitable for MASS model initialization. The testing and evaluation of the following pre-processor routines have been performed:

- PREPGRD (determines the model horizontal grid structure from user inputs and reads surface data bases including land use, land/water, terrain, and vegetation data),

- PREPDAT (reads raw gridded and observational data including rawinsonde, wind profiler, surface, KSC tower, buoy, ship, and sea-surface temperature data),

- PREPRO (reads intermediate data files produced by PREPDAT, objectively analyzes the observed data onto the model grid, and vertically interpolates the analyses from pressure to sigma coordinates),

- PREPBOG (uses surface cloud observations, infrared satellite data, and manually digitized radar data to adjust the relative humidity in the model initialization file),

- PREPBC, BCPROC (prepares the boundary conditions for the MASS model runs), and

- PREPNUDG, PREPRAD (prepares data sets for four-dimensional data assimilation using Newtonian relaxation or nudging).

The AMU has run the pre-processor and model for several arbitrarily selected cases to complete the testing of the MASS software. The AMU has also incorporated a new subroutine in the MASS model to compute the magnitude of the domain-averaged first (NP1) and second (NP2) derivative of surface pressure with respect to time. These parameters are typically used to measure the amount of gravity wave activity or noise in numerical models. The temporal evolution of NP1 and NP2 can be used to identify errors or deficiencies in the pre-processor routines that perform the initial data quality control and analysis and the model routines that handle physical parameterizations, temporal and spatial finite differencing, data assimilation, and boundary conditions.

The time series plots of NP1 and NP2 from the test cases show that the level of noise in the coarse grid and fine grid model runs decreases rapidly during the first 3-h of the integration and then remains relatively constant for the duration of the run. The NP1 and NP2 noise statistics from these selected cases do not reveal any problems with the MASS software.

Initiation of Real-Time MASS Pre-Processor and Model Runs

The AMU has developed and tested two UNIX shell scripts that initiate jobs to run the MASS pre-processor and model on the Stardent 3000. A separate script is used for coarse grid (45 km) and fine grid (11 km) model runs. These automated procedures also (1) move and reformat data for present model runs that have been transferred from

MIDDS on the IBM PC (Model 80) to the Stardent, (2) remove old files from previous model runs, and (3) copy output and diagnostic files from the Stardent's disk to the 5.8 GB external disk on the IBM RISC 6000 after model runs have completed. The MASS pre-processor and model have been running twice daily in real-time since 1 December 1993 to facilitate the development of model post-processing capabilities and archiving capabilities of model output (and observations) that will be required for model evaluation.

Preliminary MASS Pre-Processor and Model Configuration

The AMU has specified a preliminary run-time configuration for the MASS pre-processor and model which includes the initialization data sources and the daily forecast and data assimilation schedules for coarse and fine grid model runs. The pre-processor currently uses NGM grid point, rawinsonde, surface, KSC tower, buoy, ship, infrared (IR) satellite, and manually digitized radar (MDR) data to initialize coarse grid (45 km) simulations. A 24-h coarse grid run, that is initialized with 0000 UTC data (designated A0), begins at 0815 UTC and assimilates hourly surface and MDR data from 0000-0400 UTC. The A0 run cycle, which includes the execution of the pre-processor, data preparation for assimilation, and model integration, is completed by 1245 UTC.

Next, a 12-h fine grid (11 km) run (designated B0) is initialized with 1200 UTC rawinsonde, surface, KSC tower, buoy, ship, IR satellite, and MDR data. The 12-h forecast from the 0000 UTC coarse grid run (i.e. valid at 1200 UTC) provides the first guess fields for the B0 run. The B0 simulation starts at 1405 UTC, assimilates the 1300 UTC surface and MDR data, and finishes by 1930 UTC.

The cycle is then repeated using 1200 UTC data to initialize the 1200 UTC coarse grid run (designated A1) at 2015 UTC. The A1 run cycle assimilates hourly surface and MDR data from 1200-1600 UTC and is completed by 0045 UTC. Finally, the 0000 UTC data and 12-h forecast fields from A1 (valid at 0000 UTC) are used to initialize the 0000 UTC fine grid run (designated B1). The B1 simulation starts at 0205 UTC, assimilates the 0100 UTC surface and MDR data, and finishes by 0730 UTC.

While this is a preliminary configuration for running the pre-processor and model, it does have the following advantages:

- The 1200 UTC or B0 and 0000 UTC or B1 fine grid simulations utilize all available 1200 UTC or 0000 UTC data and begin at the earliest time that these data are available on the Stardent 3000.

- The first guess fields used to initialize 24-h coarse grid runs (A0 or A1) are obtained from the current NGM analyses (e.g. 1200 UTC coarse grid runs are initialized using 1200 UTC NGM analyses). MESO, Inc. had set up a MASS model configuration such that 24-h coarse grid runs were initialized with 12-h forecast fields from the previous NGM run cycles.

- A majority of MASS model output from the 1200 UTC or B0 fine grid run will be available by 1600 UTC for use in evaluating the potential for convective activity during the active thunderstorm season (June-August).

- The A0-B0 and A1-B1 coarse-fine grid simulation cycles are identical so that the most current MASS model run will be available to provide year-round guidance for weather forecasting during any ground or spaceflight operations at KSC.

Preliminary MASS Post-Processing and Display Capabilities

Now that the MASS pre-processor and model are running twice daily, the AMU has set-up automated procedures to post-process and display MASS model output. These post-processing and display capabilities are required to provide the AMU qualitative and quantitative information concerning the performance of MASS model coarse and fine grid forecasts. The next step will be to transfer MASS output into MIDDS so that RWO and SMG forecasters can begin to examine model initialization and forecast products.

At the present time, the Stardent 3000 is used primarily to run the MASS pre-processor and model while the IBM RISC 6000 is used to perform all post-processing and display functions. (Note that the GEneral Meteorological PAcKage or GEMPAK, developed by GSFC, is used for all MASS post-processing and display.) A sequence of jobs initiated on the RISC 6000 performs the following functions:

- Converts model output from ASCII data files on the Stardent 3000 to GEMPAK data files on the RISC 6000,

- Interpolates model data from the model's vertical sigma coordinate to standard pressure levels,

- Generates hourly nine-panel color displays of A0 and A1 coarse grid output (e.g. winds, temperatures, and relative humidity at the surface, 850 mb, 700 mb, and 500 mb) that can be animated using xloop image display software on the RISC 6000,

- Generates hourly four-panel color displays of thermodynamic soundings from coarse grid model output that can also be animated using xloop, and

- Generates hard copy plots of temperature, dew point, wind, and precipitation time series, and time-pressure cross sections of wind, relative humidity, and vertical motion from coarse or fine grid model output.

An example of time series plots of temperature, dew point, wind speed, wind direction, and precipitation are shown in Figure 5. Additionally, time-pressure cross sections of wind, relative humidity, and vertical motion appear in Figure 6. These plots are generated using hourly output from a 24-h coarse grid (45 km) model forecast initialized at 0000 UTC 18 January 1994. The model data displayed in Figures 5 and 6 are taken from a grid point over land with coordinates closest to the latitude and longitude of station TTS (the Shuttle Landing Facility). The same format is used to plot time series and time-pressure cross sections from the fine-grid (11 km) model forecasts except that hourly output can be displayed only for the 12 hours corresponding to the length of fine grid run. Time series plots of forecast variables, such as those shown in Figures 5 and 6, are easy to read and provide a convenient summary of specific MASS model coarse (or fine) grid forecasts at a given location. Furthermore, these types of displays substantially reduce the amount of model output a forecaster has to examine in order to get the same quantitative information from a model run.

Figure 7 illustrates a black and white version of predicted thermodynamic soundings at 0800 UTC 18 January (8-hr forecast) which are also generated from the coarse grid model run initialized at 0000 UTC 18 January 1994. The four soundings are shown using standard skew-T plots of the model forecast data at grid points whose coordinates are closest to the latitude and longitude of stations TTS, AYS (Waycross, GA), TPA (Tampa, FL), and PBI (West Palm Beach, FL). The next step will be to compute stability indices such as the K or Lifted Index from the forecast soundings and display the values on each panel. Time animation of hourly thermodynamic soundings on the RISC 6000 provides a quick and efficient means to monitor changes in the model's prediction of atmospheric stability at station TTS and at surrounding locations to the north (AYS), south (PBI), and west (TPA).

A subset of the nine-panel color display of model output is shown in Figure 8. The color shading depicts relative humidity (%) at 700 mb and 850 mb (Fig. 8a, 8d) and wind speeds (kt) at 10 m and 200 mb (Figs. 8b, 8c). The isopleths of 700 mb and 850 mb geopotential height and vertical velocity overlay the color-coded relative humidity (Figs. 8a, 8d). Similarly, isopleths of 10 m and 200 mb temperature overlay the color-code wind speeds (Figs. 8b, 8c). The use of color combined with time animation of the full nine-panel displays make it easy to identify trends in the model predicted temperature, wind, and moisture fields while still providing specific quantitative information (such as the forecast 10 m temperatures over a given location). Note that the geographic area displayed in Figure 8 corresponds to the entire horizontal extent of the 45 km coarse grid which covers the southeastern United States.

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

Low Temperature LCC Recovery Algorithm

Working with Brian Goode of MSFC's Thermal Analysis Branch, the AMU Chief wrote PC software to compute the recovery algorithm for the Low Temperature Launch Commit Criterion. The software underwent independent verification and validation by ENSCO, Inc. through the AMU as well as a NASA conducted test program. The AMU Chief provided test documentation and a detailed User's Manual. The software, called LOWTEMP, was certified for operational use by the Shuttle Program.

Shuttle Landing Facility Wind Measurements Evaluation

Working with TE-CID-3 and DL-ESS-23, with funding from JSC/GF, the AMU Chief is principal investigator on a program to determine the validity and limitations of the current SLF wind tower sites for forecasting and nowcasting SLF centerline winds. Two effects are of concern: the separation between the towers and the runway, and the presence of foliage close to two of the three sites.

Twelve trailer-mounted 30 ft. towers instrumented with wind speed and direction and temperature sensors were constructed. Seven have been tested, intercompared, and deployed. The remaining five will be tested next quarter. Upon acceptance of all twelve, six will remain at KSC and six will be shipped to Edwards AFB for use in a crosswind landing Detailed Test Objective (DTO). The DTO will also be conducted at KSC using the remaining towers.

An array of seven towers was deployed in mid-December. Correlation coefficients and structure functions as well as coherence spectra were produced for spacings from 200 feet to 1400 feet. Wind environments from 4 to 14 knots were sampled. Longitudinal, lateral, and skewed orientations were analyzed. Preliminary results suggest structure functions remain within a factor of 2 of the variance over the range sampled. Correlations and spectra suggest that coherent fluctuations are dominated by large scale motions only and not by advected “frozen” turbulence.

Next quarter should include completion of the work on the separation problem and much of the work on the foliage problem. The DTO may also begin operation.

Figure 5. Time series plot of (a) total precipitation (mm hr^{-1}), (b) wind speed (kt) and wind direction (deg), and (c) temperature (˚F) and dew poin t (˚F) generated using hourly output from a 24-h coarse grid (45 km) model run initialized at 0000 UTC 18 January 1994. The model data are taken from grid point 28,23 whose latitude and longitude coordinates are closest to those of station TTS (the Shuttle Landing Facility). The wind speed (solid lines) and wind direction (dashed lines) in panel (b) are shown for the 10 m (thin line) and 150 m (thick line) levels. The right hand ordinate in panel (b) is labeled for wind directions from 0-360 deg. The temperature (solid line) and dew point (dashed line) plotted in panel (c) are for the 10 m level.

Figure 6. Time-pressure cross sections of (a) wind speed (kt) and direction, (b) vertical velocity (μbar s^{-1}), and (c) relative humidity (%) generated using hourly output from a 24-h coarse grid (45 km) model run initialized at 0000 UTC 18 January 1994. The model data are taken from grid point 28,23 whose latitude and longitude coordinates are closest to those of station TTS (the Shuttle Landing Facility). The isopleth interval is 5 kt for wind speed, 2 μbar s^{-1} for vertical velocity with negative values (upward motion) given by dashed lines, and 10% for relative humidity with values ≥ 80% given by thick lines.

Figure 7. Skew-T plots of temperature (thick solid lines) and dew point (thick dashed lines) at 0800 UTC 18 January (8-hr forecast) from a 24-h coarse grid (45 km) model run initialized at 0000 UTC 18 January 1994. The model data are taken from grid points whose latitude and longitude coordinates are closest to those of station (a) TTS (Shuttle Landing Facility), (b) AYS (Waycross, GA), (c) TPA (Tampa, FL), and (d) PBI (West Palm Beach, FL). The wind speeds (kt) and direction at 50 mb intervals from the surface to 200 mb are given by the wind barbs to the right of the sounding plots in each panel.

Figure 8. Model output from 0800 UTC 18 January (8-hr forecast) from a 24-h coarse grid (45 km) model run initialized at 0000 UTC 18 January 1994. Relative humidity (color shading), geopotential height (pink lines), and vertical velocity (white lines) are shown at 700 mb in panel (a) and at 850 mb in panel (d). Wind speed (color shading), wind direction (black barbs), and temperature (white lines) are shown at 200 mb in panel (b) and at 10 m in panel (c). The color shaded intervals for relative humidity (%) and wind speeds (kt) are indicated by the color bars at the top of each panel. The isopleth interval is 30 m for geopotential height, 4 μbar s^{-1} for vertical velocity with negative values (upward motion) given by dashed lines, and 2°C (4 °F) for temperatures in panel (b) [(c)] with negative isotherms given by dashed lines.

3. Project Summary

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. The AMU FY 1994 tasks were subsequently revised in January 1994. The current FY 1994 tasking includes the completion of tasks started in FY 1992 and FY 1993 and a number of new tasks which have already been or will be started in FY 1994. A brief description of the current tasks is contained in Attachment 1.

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 evaluation report has been completed and will be distributed after permission to release the document is received from the KSC Public Affairs Office. 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 has been reviewed and final revisions to the report are being made. The MIDDS enhancement task is an ongoing effort with product deliverables as required.

Fiscal year 1993 and 1994 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 NEXRAD exploitation task. This past quarter, AMU efforts associated with the MASS mesoscale model included

- Completing the testing of MASS pre-processor and model,
- Initiation of twice daily pre-processor and model runs, and

- Preliminary development of routines to post-process and display MASS model output.

Evaluation of the MASS mesoscale model will begin in the second quarter of FY 1994.

The AMU also completed an evaluation of ASOS and a draft of the ASOS evaluation report was subsequently completed and distributed for external review. After reviewer comments are received, the report will be revised and distributed.

Progress has also been made on the task to develop forecaster guidance tools using ANN. The AMU has developed prototype neural networks which predict the two-hour change in cloud cover at the SLF. Although not sufficiently accurate for forecaster guidance tools, they do demonstrate the ability of the technique to learn relationships.

The AMU also started the NEXRAD Exploitation task during this past quarter. Initial efforts focused on defining the specific NEXRAD tasks and installing and testing WSR-88D visualization software on the AMU's UNIX workstations.

This next quarter the AMU will start work on three new tasks: the Emergency Response Dose Assessment System (ERDAS) Evaluation, the LDAR Evaluation, and the Boundary Layer Profiler Network Support.

Attachment 1: AMU FY-94 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.

• 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 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.

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 7 - ASOS Evaluation

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

• Subtask 9 - Boundary Layer Profilers

•• Evaluate the meteorological validity of current site selection for initial 5 DRWPs and recommend sites for any additional DRWPs (up to 10 more sites). Determine, in a quantitative sense, advantages of additional DRWPs. The analysis should determine improvements to boundary layer resolution and any impacts to mesoscale modeling efforts given additional DRWPs. Develop and/or recommend DRWP displays for operational use.

• Subtask 10 - NEXRAD/McGill Inter-evaluation

•• Determine whether the current standard WSR-88D scan strategies permit the use of the WSR-88D to perform the essential functions now performed by the PAFB WSR-74C/McGill radar for evaluating Flight Rules and Launch Commit Criteria (including the proposed VSROC LCC).

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.

- Subtask 4 - Evaluate the Emergency Response Dose Assessment System (ERDAS)

•• Perform a meteorological and performance evaluation of the ERDAS. Meteorological factors which will be included are wind speed, wind direction, wind turbulence, and the movement of sea-breeze fronts. The performance evaluation will include:

1) Evaluation of ERDAS graphics in terms of how well they facilitate user input and user understanding of the output.

2) Determination of the requirements that operation of ERDAS places upon the user.

3) Documentation of system response times based on actual system operation.

4) Evaluation (in conjunction with range safety personnel) of the ability of ERDAS to meet range requirements for the display of toxic hazard corridor information.

5) Evaluation of how successfully ERDAS can be integrated in an operational environment at CCAFS.