Applied Meteorology Unit (AMU)

Quarterly Update Report

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1. Background

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

2. AMU Accomplishments During the Past Quarter

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

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

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

Mr. Wheeler provided information regarding the hardware and software configuration for the STA downlink to Mr. Al Ordonez, the Eastern Range engineer responsible for specifying requirements for the implementation of the STA downlink in the RWO. Mr. Wheeler directed Mr. Ordonez to Mr. Jim Cecil (DL-ESS-23) as the Kennedy Space Center (KSC) point of contact.

Development of Forecaster Applications (Mr. Wheeler)

Mr. Wheeler developed four new F-key Meteorological Interactive Data Display System (MIDDS) menu shells for the Shuttle Weather Officer terminal during this quarter. F-key menu shells were developed for daily operations and for Titan, Delta and Atlas launch operations. Mr. Wheeler began by first developing prototype menu shells. After the menus were evaluated by the Launch Weather Officers (LWO's), Mr. Wheeler enhanced the menus based upon their requirements and recommendations. Mr. Wheeler is currently designing menu shells for Shuttle launches and Ferry Flights.

The daily operations F-key menu allows the RWO to load and view satellite images easily and direct other products to the screen. The daily operation menu enables the LWO to switch the terminal to a launch operations' configuration by entering a single F-key. When this occurs, the terminal is configured to support a specified vehicle launch operation. New satellite and radar resolutions and center points are automatically entered and required graphics are loaded into the terminal. Also, short cut commands are enabled that allow LWO's to display images or graphics and to setup multiple image and graphic loops quickly. Once the operation is completed, the terminal can be reconfigured to support daily operations.

Mr. Wheeler has made corrections and enhancements to several of the other Range Weather Operations (RWO) MIDDS F-key menu shells that he had developed earlier. Modifications installed in the menu systems include:

- A McBasi utility that allows the RWO to reconfigure their Wide Word Workstation to load and display either Geostationary Operational Environmental Satellite (GOES) 8 or GOES 7 images,

- Enhancements to the Commanders Slide Briefing menu shell that allow the briefer to start or stop the terminal scheduler, start or stop loading images, change graphic colors and/or modify the slide briefing sequence, and

- A McBasi utility that allows the user to remap loaded satellite images.

Mr. Wheeler has begun modifying some of the McBasi utilities that access either local wind tower or field mill data. This is needed to accommodate system upgrades and new data schemes associated with the new wind tower and field mill networks. Final certifications of the new wind tower and field mill systems and their respective MIDDS decoders are expected early in 1995.

Finally, Mr. Wheeler worked several MIDDS issues for the RWO during this quarter. He had two requests to help generate lightning data print outs for Titan operations. While helping retrieve the lightning data, Mr. Wheeler noticed and fixed a problem that caused their lightning printout routines to miss the first data point. Mr. Wheeler also developed a new satellite enhancement that highlights thunderstorm tops for quick visualization.

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)

Subtask 2: Fog and Stratus at KSC (Mr. Wheeler)

Mr. Wheeler developed several MIDDS utilities to assist in data gathering for this year's fog season. The McBasi utilities FSI313 and FSINGM, that were developed and transitioned over to SMG and the RWO as part of the AMU's fog and stratus study, will be evaluated during Florida's fog season, October through May.

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

Subtask 3: Doppler Radar Wind Profiler

Implementation of MSFC DRWP Wind Algorithm (Ms. Schumann)

At the request of the Titan IV community, Ms. Schumann provided operational support for the Titan IV launch attempt on 25 August and the subsequent launch on 27 August. This support was in preparation for the operational quality control training. Ms. Schumann prepared materials for and provided training on the 50 MHz Doppler Radar Wind Profiler (DRWP) quality control methodology to Captain Scott Heckman (45th Weather Squadron) and to NASA/KSC Instrumentation and Measurements Branch and their support contractor NYMA. The AMU is not expecting to provide operational support for future launches, but will be available to assist in any further training or transition as necessary.

KSC has recently undergone considerable re-organization and the personnel responsible for DRWP maintenance have changed since Ms. Schumann provided maintenance training last spring. To reduce the time necessary for the current DRWP maintenance providers to become sufficiently familiar with the system, Ms. Schumann trained KSC and NYMA personnel on the maintenance required to support the MSFC algorithm.

Currently, the Eastern Range contractor, Computer Sciences Raytheon (CSR), is installing a new McIDAS upgrade to the MIDDS. As part of this upgrade, CSR is installing the new decoder for the reformatted DRWP data. This decoder was written and tested by Paramax last spring. Ms. Schumann assisted in the informal testing of this decoder for the Eastern Range on 23 September 1994. NYMA also assisted in this test and will be responsible for assisting the Range for the formal test. Ms. Schumann will be available if needed for technical support.

Also during this quarter, Ms. Schumann and Dr. Taylor along with Dr. Steve Smith of Marshall Space Flight Center (MSFC) and Mr. Tim Wilfong of ITT/FSC prepared a preprint entitled “Application of 50 MHz Doppler Radar Wind Profiler to Launch Operations at Kennedy Space Center and Cape Canaveral Air Station” for poster presentation at the 14th Conference on Weather Analysis and Forecasting to be held in Dallas, TX, from 15-20 January 1995.

Subtask 4 LDAR Evaluation and Transition (Ms. Schumann)

Since its installation in the AMU lab area, Ms. Schumann and Mr. Wheeler have been examining the Lightning Detection And Ranging (LDAR) system output on the real-time display computer and gaining operational experience with the system.

During this initial evaluation of the system, the AMU and NASA/KSC TE-CID personnel noticed an intermittent communications problem where the communications line between the AMU workstation and the workstation in the Central Instrumentation Facility (CIF) would suddenly fail. This often happened in the late afternoon, significantly affecting LDAR’s ability to provide reliable lightning information to the end user. (This communications problem affected the LDAR workstation in the AMU only. It did not affect the display broadcast on the CCTV.) Ms. Launa Maier of NASA/KSC TE-CID and Ms. Schumann worked together to coordinate the troubleshooting efforts of the communications groups from KSC and the Eastern Range. After considerable testing of the line and end equipment, the communications groups found several minor problems contributing to the intermittent failures. All of the problems were corrected by mid October, and the communications scheme has not failed since. This has been the longest continuous operation of the communication line without a failure, indicating the problem has been completely corrected. The AMU and TE-CID will continue to monitor the communication line between the AMU and CIF LDAR workstations to ensure its reliability.

The AMU is currently drafting the evaluation plan for its LDAR tasking. Thus far, the AMU has discussed the priority of the potential subtasks: training, further analysis of

LDAR data in relation to other lightning data and radar, and design and development of new displays with the Range Weather Operations (RWO), Melbourne National Weather Service (NWS) office, and Spaceflight Meteorology Group (SMG). The responses indicated that all of the potential subtasks were important, but there was a significant bias towards the AMU developing training materials. The AMU will develop LDAR training tools that consist of the following:

- A computer based training system for LDAR that explains how the system works, illustrates how to interact with the system's user interface, and identifies and explains known LDAR signatures,
- A VHS video tape that briefly introduces first time users to LDAR, and
- A hard copy users manual that provides basic operating instructions for use of the system.

The computer based training will be developed such that results from future LDAR research and operational observations can easily be incorporated in the system. The final product will enable the RWO, NWS, and SMG to provide consistent training on LDAR to current and new personnel.

Also during the development of the computer based training, the AMU will be investigating new LDAR displays that are less data intensive than the current display. This is necessary to provide the forecasters a longer window in which to view data (The current LDAR window is five minutes.) as well as develop a data reduction scheme for transmitting LDAR data to MIDDS. The current data rates would overwhelm the MIDDS ingestion and storage capabilities.

2.5. Task 005 Mesoscale Modeling (Dr. Manobianco)

Subtask 2 Install and Evaluate MESO, Inc.'s MASS model (Dr. Manobianco)

Primary AMU activities during the past quarter on the Mesoscale Atmospheric Simulation System (MASS) model installation and evaluation include final testing and implementation of software to transfer model initialization and forecast products back to the MIDDS and preparation of a document describing the preliminary evaluation of the MASS model's forecasts of temperature, moisture, and wind at selected rawinsonde locations during February 1994 and July 1994.

The AMU is now running software to reformat MASS model initialization and forecast output on the RISC/6000 Model 560. The reformatted data are read on AMU's IBM PC/Model 80 and written to McIDAS grid files. The grids are then transferred from the Model 80 to designated areas on the IBM test machine every six hours. The automated jobs which control the transfer process are not executed until the MASS forecasts have expired so that the initialization and forecast products can not be used for operational decisions. Mr. Wheeler is in the process of developing F-key inputs so that

RWO forecasters will be able to view MASS output using the same menu system that is currently available to display other data in MIDDS. Both SMG and NWS forecasters will be able to transfer the grids from the IBM test machine to their local host computers to examine MASS output.

The document highlighting MASS model forecasts at selected rawinsonde sites is a pre-print paper co-authored by Drs. Manobianco, Taylor, and Zack (MESO, Inc.) for the Sixth Conference on Aviation Weather Systems that is part of the American Meteorological Society's annual meeting to be held in Dallas, Texas from 15-20 January 1995. The following sections present selected material from this pre-print which is entitled "Forecast Skill of A High Resolution Real-Time Mesoscale Model Designed for Weather Support of Operations at the Kennedy Space Center and Cape Canaveral Air Station".

Preliminary MASS EVALUATION

The results presented in this section focus on the objective evaluation of model forecasts at selected rawinsonde station locations. The skill of coarse and fine grid temperature, moisture, and wind forecasts at rawinsonde stations is assessed by interpolating the model data to the observation locations and then computing the bias and root mean square error (RMSE). Station comparisons provide a stringent test of model capabilities since statistics computed for many grid points do not assess model forecast skill at individual locations. However, station observations sample many scales of atmospheric phenomena some of which can not be resolved by the model. As a result, point verification should benefit higher resolution models which resolve finer scales of motion. It does, however, tend to give a more pessimistic view of model performance than does gridded verification. Nevertheless, model skill scores for stations are of more interest to end users of model guidance since, ultimately, forecasters want to know how accurately the model can predict the weather at specific locations.

Methodology

The analyses and forecast fields from all available 0000 UTC and 1200 UTC coarse grid forecasts during February 1994 and July 1994 have been bilinearly interpolated to the rawinsonde station locations given in Table 1. This list includes all available rawinsonde sites within the fine grid domain and selected sites within the coarse grid domain. The months of February and July have been chosen for the initial comparison of model performance during winter and summer.

Table 1. List of rawinsonde stations

Station number	Location
72407	Atlantic City, NJ
72340	Little Rock, AR
72327	Nashville, TN

72213	Waycross, GA
72235	Jackson, MS
72210	Tampa Bay, FL
72203	West Palm Beach, FL
72201	Key West, FL
74794	Cape Canaveral, FL

The two statistical measures used here to quantify model forecast skill are the bias and RMSE. The bias is computed as:

$$\text{bias}\ (p,t) = \frac{1}{N}\sum_{n=1}^{N}(\Phi_f - \Phi_o) \qquad (1),$$

and the RMSE is computed as:

$$\text{RMSE}\ (p,t) = \left[\frac{1}{N}\sum_{n=1}^{N}(\Phi_f - \Phi_o)^2\right]^{1/2} \qquad (2).$$

In Equations (1) and (2), Φ denotes temperature (˚C), dew point temperature (˚C), wind speed (ms^{-1}) or wind direction (˚) and the subscripts f and o denote forecast and observed quantities, respectively. In cases where the magnitude of the wind direction deviation (i.e. forecast minus observed) exceeds 180˚, the deviation is recomputed by first subtracting 360˚ from the larger of the forecast or observed wind direction.

The subscript n in Equations (1) and (2) refers to an individual model run and N is the total number of coarse grid runs initialized at 0000 UTC (C00) and 1200 UTC (C12). The bias and RMSE for each variable are a function of pressure and time. These quantities are computed at 50 mb intervals from 1000 mb to 150 mb for the analysis times (0 h), and the forecasts times (12 h, 24 h) at 12-h intervals corresponding to the standard rawinsonde observation times. Errors which are greater than two standard deviations from the mean forecast minus observed differences are removed. This objective procedure is very useful in flagging bad data points.

Temperature Bias and RMSE

The temperature (T) bias (˚C) for February and July are shown in Figures 1a and

1b, respectively. The statistics have been averaged for all stations in Table 1 and include both 0000 UTC and 1200 UTC forecasts for each month. The number of deviations (N in Equations (1) and (2)) used to compute the bias and RMSE at any given level depends on the availability of both observations and model runs and is usually greater than 350 with a maximum 504 in February and 558 in July (i.e. number of days in the month ∞ two coarse grid cycles per day ∞ 9 stations).

The initial analyses show a negative (cool) bias for T in February less than -0.25˚ C between 950 mb and 300 mb (Fig. 1a). In July, the 0-h T bias at these same levels is very close to 0˚C. The 0 -h negative T bias increases to more than -1.0˚C at 1000 mb in February, whereas in July, it remains close to 0.0˚C (Fig. 1b). Above 300 mb, the model shows a maximum positive (warm) bias for T of almost 1.0˚C in February and 1.5˚C in July. DiMego et al. (1992) also report a warm bias for T of 0.9˚C at 250 mb for the 0 -h forecasts from the Regional Analysis and Forecast System (RAFS) which is used to initialize the NGM. (Note that the RAFS was verified against 66 eastern North American rawinsonde observations for the period 24 March to 20 April 1991.) The bias in the MASS upper tropospheric T analyses for February and July is probably related to having insufficient vertical model resolution to resolve the temperature minima that are observed at the tropopause.

The 12-h coarse grid forecasts exhibit negative T biases except above 300 mb in both February and July and below 800 mb in July. The negative T bias does not become substantially more negative by 24-h, although it does reverse sign becoming positive in the lower levels below 850 mb in February. Above 300 mb, the 0-h warm bias for T actually increases slightly in the 12-h forecasts with very small changes thereafter in the 24-h forecasts during February and July (Figs. 1a and 1b).

The RMSE (˚C) for T at 0, 12, and 24 h during February and July are shown in Figures. 2a and 2b. The RMSE for T at 0 h for both months are less than 1.0˚C between 950 mb and 300 mb and are on the order of the rawinsonde measurement errors for temperature. The MASS preprocessor uses a Barnes objective analysis procedure to blend first guess fields and observations into a consistent three-dimensional initialization data set. In general, the objective analysis scheme does not provide an exact fit to the data.

In February and July, the RMSE for T increased by a factor of 2 to 3 between the 0-h analyses and 12-h forecasts (Figs. 2a and 2b). There is a slight increase in RMSE for T at most pressure levels between the 12-h and 24-h forecasts in February, whereas in July, the most notable increase occurs below 800 mb and between 500 and 300 mb.

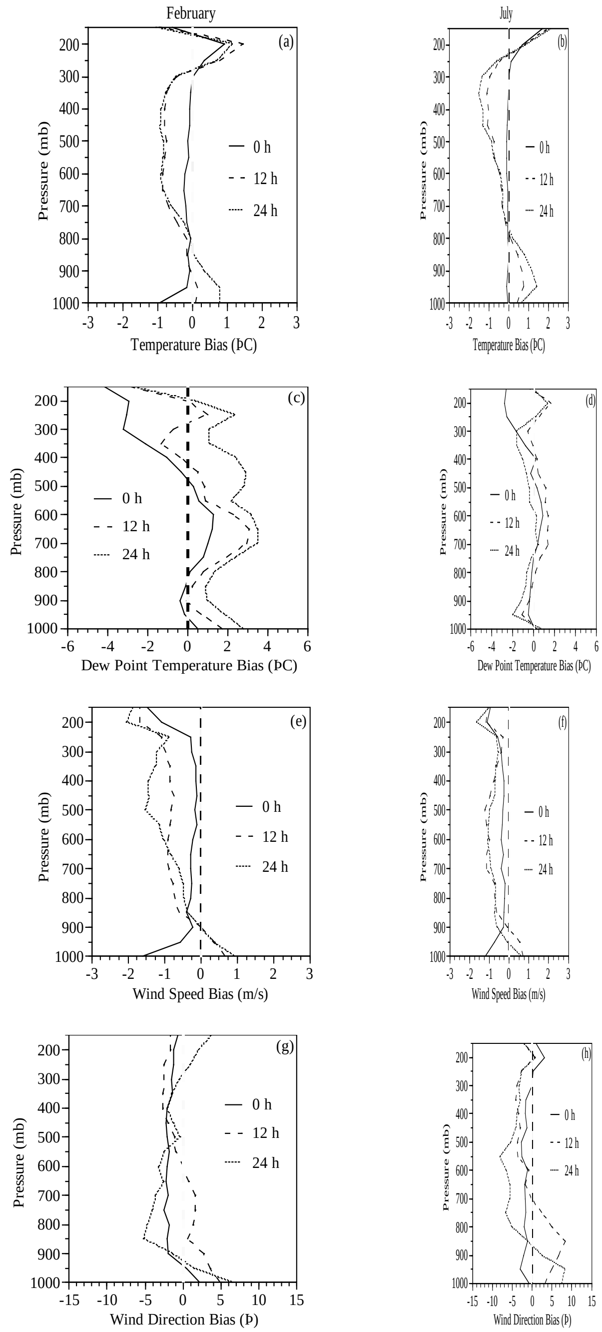

Figure 1. Average bias for temperature (˚C), dew point temperature (˚C), wind speed (ms^{-1}), and wind direction (˚) plotted as a function of pressure for February 1994 in panels (a), (c), (e), and (g), respectively, and for July 1994 in panels (b), (d), (f), and (h), respectively.

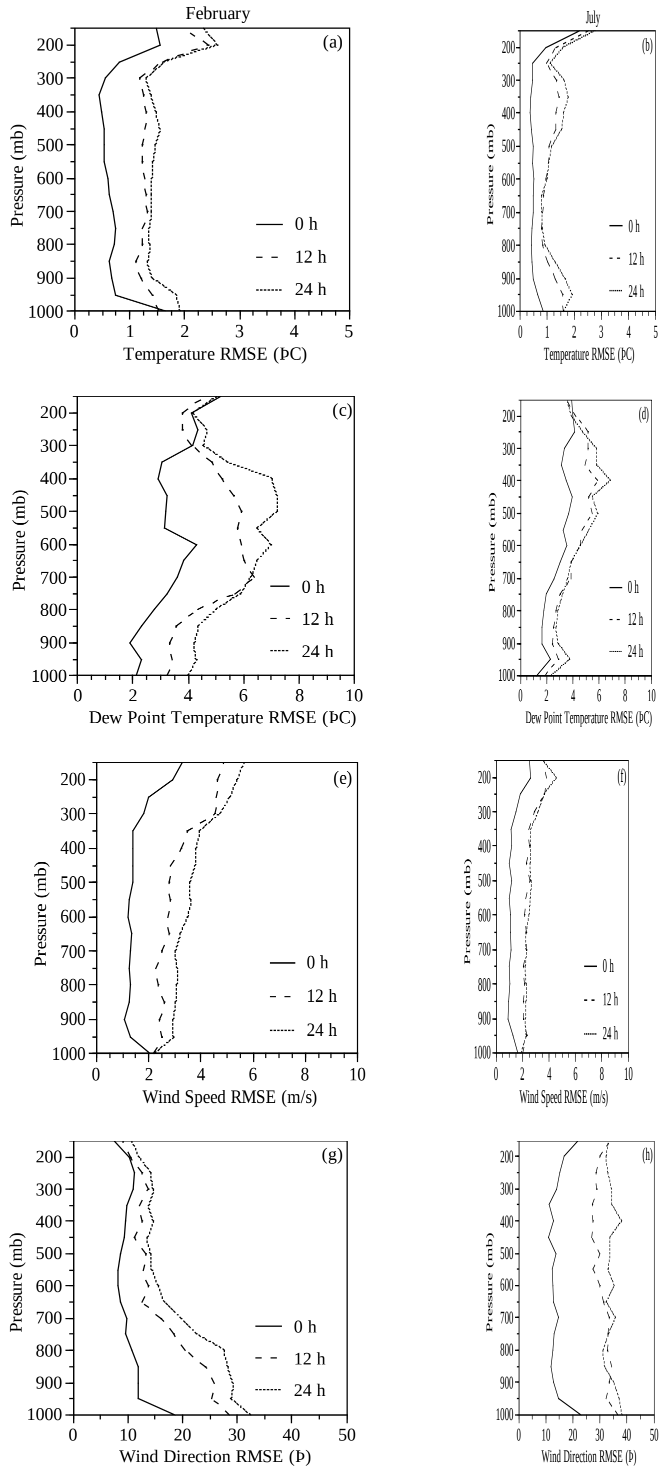

Figure 2. Average root mean square error for temperature (°C), dew point temperature (°C), wind speed (ms $^{-1}$), and wind direction (°) plotted as a function of pressure for February 1994 in panels (a), (c), (e), and (g), respectively, and for July 1994 in panels (b), (d), (f), and (h), respectively.

Dew Point Temperature Bias and RMSE

The dew point temperature (T_d) bias (˚C) for February and July are shown in Figures 1c and 1d, respectively. The analyses show a T_d bias of not more than 1˚C below 400 mb during either month. The most notable feature in the analyses appears above 400 mb where the T_d bias is negative (i.e. too dry) in both February and July (Figs. 1c and 1d). The model develops a moist bias on the order of 3˚C by 12 h in the February forecasts below 500 mb . By 24 h, a moist bias in these same runs exists at all levels below 200 mb and is as large as 3˚C near 1000 mb and from 600 mb to 750 mb.

During July, the magnitude of the moist bias is smaller than during February especially in the middle troposphere between 800 mb and 300 mb in either the 12-h or 24-h forecasts. Note that the model also tends to moisten the upper troposphere during the July forecasts producing the largest positive bias of nearly 2˚C at 12 h. Assuming no error in T, a 2˚C T_d error at 300 mb yields a relative humidity error of ~15%. Wilson (1993) also found a moist bias of nearly 10% in 300 mb RH averaged over seven 12-h forecasts during February 1989 using the Pennsylvania State University (PSU) / National Center for Atmospheric Research (NCAR) mesoscale model, version 4 (i.e. MM4).

The RMSE (˚C) for T_d during February and July from the analyses and forecasts are shown in Figures 2c and 2d, respectively. The 0-h RMSE for T_d increase with height (i.e. decreasing pressure) during both months. Except in the upper troposphere above 300 mb, the RMSE for T_d are larger in the 12-h forecasts than in the 0-h analyses for both months. However, the 24-h RMSE for T_d in July are very similar to those at 12 h, whereas in February, they continue to increase reaching a maximum of 7˚C at 500 mb (Figs. 2c and 2d). In July, the maximum RMSE for T_d of greater than 6.5˚C are found at 400 mb in the 24-h forecasts. The fact that the RMSE for T_d increases more rapidly in February than in July from 12-24 h is likely a result of the more dynamically active weather regimes which prevail during winter.

At present, there are no first guess NGM moisture fields provided above 300 mb. Therefore, the MASS pre-processor uses the last level of moisture information (in this case 300 mb) to derive first guess fields above that level by extrapolating relative humidity. Additionally, rawinsonde relative humidity measurements are considered unreliable at temperatures below -40˚C. Furthermore, rawinsondes sample the atmosphere at specific points and are highly sensitive to whether the balloon passes through cloudy or clear areas. For these reasons, care must be exercised in interpreting the results that focus on the accuracy of the moisture analyses and forecasts especially in the upper troposphere above 400 mb.

Wind Speed Bias and RMSE

The wind speed bias (ms^{-1}) for February and July are plotted as a function of pressure in Figures 1e and 1f, respectively. In general the analyses and forecasts exhibit a negative (slow) bias except below 900 mb in both months for the 12-h and 24-h forecasts. The slow bias in the analyses is less than 1.0 ms^{-1} between 950 mb and 200 mb. At 1000 mb, the negative bias present in the 0-h February and July analyses changes sign in the 12-h forecasts and remains positive in the 24-h forecasts indicating that the low-level model wind speeds are too strong (Figs. 1e and 1f). During February, the slow bias increases most rapidly between the 12-h and 24-h forecasts reaching 1.5 ms^{-1} at 500 mb. In comparison, DiMego et al. (1992) found that the 12-h NGM forecasts exhibit a 4.3 ms^{-1} vector wind bias at 500 mb when verified against eastern North American rawinsondes during March and April 1991.

The RMSE (ms^{-1}) for wind speed in the February and July analyses is less than 2 ms^{-1} below 250 mb (Figs. 2e and 2f). During both months, the error growth is largest during the first 12 h of the forecasts. The RMSE for wind speed continue to increase from the 12-h to 24-h forecasts in February but not in July. The maximum RMSE for wind speeds occurs at the level where wind speeds are the largest in the upper troposphere.

Wind Direction Bias and RMSE

The wind direction bias (°) is plotted in Figures 1g and 1h. The analyses show a small but consistent negative bias of not more than -2° to -3° during both months except below 950 mb in February and above 250 mb in July. The 12-h forecasts from February exhibit a positive bias below 600 mb indicating a clockwise shift of forecast wind direction relative to the observed wind direction. The same statement applies to the 12-h July forecasts below 700 mb although the positive bias in the lower troposphere is somewhat larger than in February reaching a maximum of 8° at 850 mb.

The model develops the largest positive bias in the 24-h forecasts from February and July at the lowest levels below 950 mb. The model develops a pronounced negative (counter-clockwise) bias on the order of -5° in the lower troposphere between 900 and 700 mb during the 24-h forecasts from February (Fig. 1g). A similar negative wind direction bias appears in the 24-h July forecasts between 850 and 500 mb.

A positive (clockwise) bias in the low-level wind direction during both months may be caused by underestimating the frictional forces in the planetary boundary layer. As a result, the forecast winds would tend to be more geostrophic since friction tends to rotate the winds counterclockwise relative to the isobars. If the low-level frictional stress is too weak, the winds would be too strong. This argument is consistent with a positive speed bias which does exist although only below 900 mb in the 12-h and 24-h forecasts (Figs. 1e and 1f).

The RMSE (°) for wind direction during February and July are shown in Figures 2g and 2h, respectively. The RMSE for wind direction are largest at 1000 mb on the order of 20° in the analyses and decrease with height up to 300 mb. The same trend appears in the 12-h and 24-h forecasts during February with the maximum RMSE for wind direction of greater than 30° at 1000 mb for the 24 -h forecasts. The amplitude of RMSE above 950 mb is slightly larger in the July rather than February analyses. Compared with the 12-h February forecasts, the RMSE for wind direction increase more dramatically during the 12-h July forecasts. This result may be related to the fact that the winds are generally weaker and more variable during the summer.

Summary

The results presented in previous sections highlight the preliminary evaluation of MASS model forecasts at selected rawinsonde sites for February 1994 and July 1994. The complete evaluation will consider error statistics for all model runs from January 1994 through October 1994. The assessment of model forecast skill will use an objective and subjective evaluation strategy.

The goal of the evaluation is to determine how accurately MASS can predict the weather that impacts ground and aerospace operations at KSC/CCAS. At this point, it would be premature to assess the forecast skill of MASS based only upon the error statistics presented here. The possible explanations offered to account for the bias and RMSE shown in Figures 1 and 2 are very speculative. Additional diagnostics and more careful analyses of the results (such as stratification based upon initialization times, weather regimes, etc.) are needed to fully understand and explain these errors.

References

DiMego, G.J, K.E. Mitchell, R.A. Petersen, J.E. Hoke, J.P. Gerrity, J.J. Tuccillo, R.L. Wobus, and H-M. H. Juang, 1992: Changes to NMC's Regional Analysis and Forecast System. *Wea. Forecasting*, 7, 185-198.

Wilson, K.B, 1993: Verification of cloud prediction from the PSU/NCAR mesoscale model. M.S. Thesis, The Pennsylvania State University, 116 pp.

Subtask 4 Install and Evaluate ERDAS (Mr. Evans)

The primary AMU activities during the past quarter on the Emergency Response Dose Assessment System (ERDAS) model evaluation include the preparation of a memorandum describing the AMU's plan for evaluating the ERDAS system performance and the accuracy of the Regional Atmospheric Modeling System (RAMS) predictions. Excerpts of the model evaluation plan are presented here.

The primary AMU ERDAS evaluation tasks listed in AMU Technical Directive 5-006 are to evaluate:

- The ERDAS system performance,
- The accuracy of the ERDAS meteorological predictions using available statistical methods, and
- The accuracy of the ERDAS diffusion models.

ERDAS contains two major models: the meteorological model, RAMS (Regional Atmospheric Modeling System), and the diffusion model, HYPACT (HYbrid Particle And Concentration Transport). ERDAS also contains these other diffusion models: Rapid Exhaust Effluent Dispersion Model (REEDM), Air Force Toxic Chemical Dispersion Model (AFTOX), and Ocean Breeze Dry Gulch (OBDG).

The AMU is scheduled to complete the meteorological model and system performance evaluation in February 1995. The plan for evaluating the diffusion models will be presented at the beginning of the six-month task designated specifically for ERDAS diffusion models evaluation. The diffusion model evaluation task, scheduled to start in February 1995, is contingent upon follow-on funding to the AMU from the Air Force Space and Missile Systems Center.

The RAMS model configuration for ERDAS has been documented in several reports and papers written by Drs. Lyons and Tremback. The ERDAS Final Report (Lyons and Tremback, 1994) presents details of the configuration. Important features of the model configuration are:

- The horizontal grid spacing of the three nested grids are 60 km (38 x 36 points), 15 km (34 x 38 points), and 3 km (37 x 37 points).
- The vertical grid of 22 points extends to approximately 13.5 km for the 60-km and 15-km grids. The 3-km vertical grid of 21 points extends to approximately 3 km.
- The model runs twice daily producing hourly forecasts for a total of 24 hours beginning at 0000 UTC and 1200 UTC.
- The model physics selected for ERDAS do not include clouds, condensation, or precipitation.

All of the runs since 01 April 1994 should be available for the model evaluation except for those runs that failed due to various problems. The problems have been documented in the AMU Monthly Activity Reports and include missing NGM grids, erroneous input data, missing MIDDS input data, and other miscellaneous system problems. Data and system problems have affected approximately 30% of the runs since 01 April.

We have designed the ERDAS evaluation to be consistent with the MASS model evaluation described in Dr. John Manobianco's memorandum titled: *Proposed evaluation plan for the MASS model*. Many of the statistical tests and procedures planned for MASS will be used for the evaluation of ERDAS.

ERDAS System Performance Evaluation

The AMU Technical Directive 5-006 listed five criteria for evaluating the system performance of the ERDAS. In this section, we list each of the criteria and discuss our plans for evaluating each of them. The performance evaluation criteria are:

- <u>Evaluate ERDAS graphics in terms of how well they facilitate user input and user understanding of the output.</u> To complete this task the AMU will:

- Compile a list of new and remaining deficiencies discovered since the initial check-out reports,

- Compile and prioritize a list of recommended graphic improvements determined after 9 to 12 months of operating the system on a daily basis, running the RAMS model, and running and displaying meteorological and diffusion model output, and

- Include comments and suggestions by Range Weather Operations and Range Safety personnel into the lists of graphic deficiencies and recommended improvements.

• <u>Determine the requirements that operation of ERDAS places upon the user.</u> After operating ERDAS on a daily basis and during launch operations for 9 to 12 months, we will compile a list of operator requirements. These requirements will focus on operator interaction required to run the system and to display the various ERDAS products. We will also address training requirements.

• <u>Document system response times based on actual operation.</u> We will document model runtimes and display response times.

• <u>Evaluate (in conjunction with range safety personnel) the ability of ERDAS to meet range requirements for the display of toxic hazard corridor information.</u> We will compile a list of the general strengths and weaknesses observed during the operation of the diffusion models. We will query Range Safety personnel to determine if the ERDAS outputs meet their requirements for diffusion data products. Range Safety requirements will be based upon their use of toxic hazard prediction models and displays to predict the launch exhaust plume and accidental releases.

• <u>Evaluate how successfully ERDAS can be integrated in an operational environment at CCAS.</u> We will compile a list of items which must be completed to make ERDAS operational. This list will be based on system deficiencies as well as requirements imposed by:

- 45th Space Wing,

- Eastern Range Program Office (SMC/CW-OLAK),

- Range Weather Operations, and

- Range Safety.

Meteorological Model Evaluation

Model performance evaluation is the process of testing a meteorological model's ability to predict accurately the observed state variables over a range of physical conditions. Model evaluation should identify the problems, limitations, and strengths of a model and/or its input data base.

Our primary approach for the ERDAS evaluation is to evaluate:

- Large-scale features. Determine how well the model predicts the large-scale features on the 60-km and 15-km grid. Is the model at these scales negatively impacting the finer grid? Is it allowing the local small-scale forcing mechanism (e.g. sea breeze) to be modeled correctly?

- Small-scale features. Determine how well the model predicts the variables used by the diffusion models (e.g. winds and temperature). Also, determine if the model accurately predicts the parameters such as dew point and pressure which give insight into the model's strengths and weaknesses.

- Hybrid wind field. Determine how well the observed winds compare with the hybrid wind field derived from an objective analysis of the 5-minute observed wind data blended with the RAMS model fields.

Some of the questions posed by Lyons and Tremback in the ERDAS Final Report which we plan to address during the model evaluation are:

- To what input parameters are the forecast results most sensitive?

- How well can RAMS routinely reproduce the various mesoscale flow features found to occur at Cape Canaveral Air Station/Kennedy Space Center (CCAS/KSC)?

- Can an ERDAS be demonstrated to be equal or superior to current techniques for dispersion forecasting during the upcoming 12 hour period at CCAS/KSC?

- How well can "sensible weather" (wind speed, temperature, humidity, etc.) be deduced from the RAMS model?

- What are the strengths and limitations of the ERDAS concept?

One of the most important mesoscale circulations in the KSC/CCAS area which will be addressed during our model evaluation is the sea breeze. We will compare the following observed versus predicted phenomena:

- Inland penetration of the sea breeze,

- Inflow depth of the sea breeze,

- Time of onset and breakdown of the sea breeze, and

- Conditions under which the model does the best/worst at predicting the sea breeze.

In general, we will determine under what meteorological conditions the model does and does not work well. We will quantify and document the meteorological conditions associated with accurate and inaccurate sea breeze forecasts.

We will evaluate the model's predictions against the collected observations using a combination of statistical and graphical techniques. The observed data which are available for comparison with model predictions are presented in Table 2. We will pair, with respect to time and space, the observed and predicted data.

The RAMS model produces hourly predictions of numerous meteorological variables at all of the three-dimensional grid points in each of the three grids. We will perform analysis on the wind speed, wind direction, temperature, dew point, and pressure/height at various levels.

For the model evaluation of ERDAS we will compare predicted and observed variables at station points (towers, surface stations, rawinsondes, etc.) and at grid points (60 km, 15 km, 3 km grids). The statistical comparisons planned for the large and small-scale features are discussed below.

- <u>Large-scale model features.</u> Our objective for this test is to determine how well RAMS predicts features on the large scale grids of 60-km and 15-km. We will compare observed versus predicted variables from grid points, soundings, and selected surface stations. The variables to be compared will be temperature, dew point, wind speed, wind direction, and pressure (height). For the upper air analyses, the comparisons will be made at the model forecast times of 12 and 24 hours. For the surface comparisons, we will interpolate the model-predicted hourly data to surface stations and compare them to observed data. The statistical analysis of the model predictions at 15 and 60 km grids will tell us if there are any systematic problems on the coarser grids which may be causing problems with predictions on the finer 3-km grid.

- <u>Small-scale features.</u> Our objective for this test is to determine the accuracy of the principal variables (e.g. winds and temperature) used by the diffusion models . We will compare wind speed, wind direction, temperature, dew point, and pressure at the towers and surface stations at hourly intervals. We will conduct the statistical analysis by comparing model predictions within the 3-km grid to observations from towers at KSC/CCAS, surface stations, soundings, and the 50 MHz wind profiler

- <u>Hybrid wind field.</u>Our objective for this test is to determine the accuracy of the wind field produced by the blending function in ERDAS. The blending function combines the observed winds with the model-predicted winds to produce a hybrid wind field. We will statistically compare the hybrid wind field with the observed wind to determine if the hybrid wind field provides the diffusion models with better wind data. We will assess the effect of the different wind fields on the OBDG and the HYPACT models.

Table 2. Observed Data Available for Model Evaluation.

Data Source	Variables	Frequency of Measurement	Vertical levels	Locations
Towers	temperature, dew point ,wind speed/wind direction (u, v), pressure	every 5 minutes	Various heights depending on tower (6, 12, 30, 54, 60, 162, 204, 295, 394, & 492 ft)	approximately 51 towers at KSC/CCAS (Grid 1)
Surface Stations & Buoys	temperature, dew point ,wind speed/wind direction (u, v), pressure	hourly	surface (10 m)	Approximately 220 surface stations on Grid 1, 32 on Grid 2, 5 on Grid 3
Rawinsondes	temperature, dew point ,wind speed/wind direction (u, v), pressure	twice daily (0000 UTC, 1200 UTC) except for TTS at KSC/CCAS (900 and 2100 UTC, 1500 UTC [summer only])	1000, 925, 850, 700, 500 mb	Approximately 20 rawinsonde stations on Grid 1, 3 on Grid 2, 1 on Grid 3
50 MHz Profiler	wind speed/wind direction (u, v),	every 30 minutes	125 levels at 150 m interval with 8 levels between 2011 m to 3061m	One profiler at KSC/CCAS (Grid 1)
*915 MHz Boundary Layer Profiler	wind speed/ wind direction, vertical velocity (u, v, w), virtual temperature	3 to 60 minute averaging time	40 levels ranging from 120 m to 2-4 kilometers with 60 to 400 m spacing	One profiler to be installed at CCAS/KSC during the fall of 1994.

* The 915 MHz Boundary Layer Profiler is scheduled for installation in October 94. Limited data may be available for part of the ERDAS evaluation period.

The statistical comparisons will provide information on how well the model is performing with respect to time of day, season, location, and meteorological condition.

Lyons and Tremback (1994) have listed and defined several statistical measurements which they have found useful for evaluating the RAMS model. We will compute several of these standard statistics such as mean and standard deviation of predictions and observations, mean absolute difference between predictions and observations, and the root mean square error. We will also compute the index of agreement which is a statistical quantity defined by Willmott (1981) as a measurement which condenses all the differences between model estimates and observations into one statistical quantity.

For the statistical analysis, the data will be grouped for the different model runs by time, space, and meteorological regime. For example, statistics will be computed for observations at one surface point for one time of day. These statistics can then be compared with other locations, times, or regimes to see if the model shows better forecast skill for these times, locations, or regimes. Grouping by meteorological regime is very important because it will help determine the meteorological conditions associated with accurate and inaccurate model runs.

We will perform a subjective, phenomenological verification of RAMS using case studies to determine the model's accuracy during specific meteorological regimes. We will compare the accuracy of model forecasts during one meteorological regime to model forecasts during a different regime. For example, we will compare sea breeze predictions during cloud-free days to sea breeze predictions during partly cloudy days.

To support the subjective evaluation, we will also conduct a categorical analysis which involves determining the occurrence of some event such as the sea breeze. For example, the occurrence of a sea breeze at observing sites can be compared to model estimates and a simple yes/no scoring system can then be quantified (Mason, 1982). Statistics may then be computed from this analysis.

Conclusions

We have developed a plan for evaluating the RAMS meteorological model within the ERDAS which is currently running twice daily in the AMU. We will perform a number of statistical tests to compare modeled predictions to observations. The evaluation should provide us with a good understanding of RAMS' strengths, weaknesses and capabilities as a forecast tool for CCAS/KSC. The evaluation should also give us a confidence (or lack thereof) in RAMS' ability to accurately predict the timing, location, and intensity of the sea breeze. RAMS output for use by diffusion models will be assessed.

We will evaluate the ERDAS system performance by evaluating the graphics, the displays, and the system operation. We will determine the requirements of ERDAS with respect to the operational users.

References

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Tesche, T.W., 1991: Evaluating Procedures for Using Numerical Meteorological Models as Input to Photochemical Models, *Preprints, 7th Joint Conf. on Appl. of Air Pollution Meteor.*, AMS/AWMA, New Orleans, 256-259.

Willmott, C.J., 1981: On the Validation of Models, *Phys.Geogr.*, **2**, 161-180.

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

SLF Wind Study

During this quarter, Dr. Merceret prepared the first draft of a NASA Technical Memorandum on the wind spacing results and a paper on the spatial separation work for the 6th Conference on Aviation Weather Systems. The Technical Memorandum draft is in review, and the spatial separation paper has been submitted to the American Meteorological Society.

The JSC Navigation, Control and Aeronautics Division requested support from Dr. Merceret regarding characteristics of Shuttle Landing Facility (SLF) winds. Dr. Merceret supplied statistical information, a synthetic wind algorithm, and several diskettes of real wind data. By telecon, he also discussed their use and the results obtained by JSC.

Lightning Launch Commit Criteria

Dr. Merceret developed an electric field analysis to assist evaluation of proposed revisions to rule B.1(b) of the Lightning Launch Commit Criteria (LCC). He provided matrices of surface electric field as a function of charge height and distance to KSC Weather Projects and the Lightning Peer Review Committee. Point and dipole charge models were used.

3. Project Summary

The AMU continued development of the F-key menu systems for the RWO MIDDS terminals. Mr. Wheeler has developed and installed four new menu systems on the Launch Weather Office (LWO) terminal. The menus customize the terminal's graphics, model products, and satellite and radar loops for daily operations or expendable launch vehicle (ELV) launches. Mr. Wheeler has begun the design of the Shuttle and Ferry Flight F-key menu systems which will also be installed on the LWO terminal.

Mr. Wheeler has also enhanced several of the MIDDS F-key menu systems he had installed on other RWO terminals previously. These enhancements include a McBasi utility that allows the RWO to configure their Wide Word Workstation to load and display either GOES 8 or GOES 7 images, more control of the Commanders Slide Briefing menu, and a McBasi utility that allows users to remap loaded satellite images.

Mr. Wheeler has addressed several MIDDS issues this quarter. He began modifying the McBasi utilities that access either local wind tower or field mill data in preparation for the final certification of the new wind tower and field mill systems and their respective MIDDS decoders. He also fielded requests to assist in generating lightning data print outs for Titan operations and developed a new satellite enhancement scheme that highlights thunderstorm tops.

This winter, the AMU will be evaluating the McBasi utilities FSI313 and FSINGM that Mr. Wheeler developed during the fog and stratus study. In preparation for that evaluation, Mr. Wheeler developed several McBasi utilities to assist in data compilation.

At the request of the Titan IV community, Ms. Schumann provided operational support for the Titan IV launch attempt and subsequent launch on 25 and 27 August, respectively. In preparation for transitioning the operational quality control of the MSFC wind algorithm data, Ms. Schumann trained Captain Scott Heckman of the 45th Weather Squadron on the 50 MHz DRWP quality control methodology.

KSC has recently undergone considerable re-organization and the personnel responsible for DRWP maintenance have changed since Ms. Schumann provided maintenance training last spring. To reduce the time necessary for the current DRWP maintenance providers to become sufficiently familiar with the system, Ms. Schumann trained KSC and NYMA personnel on the maintenance required to support the MSFC wind algorithm as well as the quality control methodology associated with it.

The Eastern Range contractor, CSR, is installing the new MIDDS decoder for the MSFC wind algorithm data as part of the regular McIDAS upgrade . The decoder was written and tested by Paramax last spring. Ms. Schumann assisted in the informal testing for the Eastern Range. NYMA also assisted in the test and will be responsible for supporting the Eastern Range in the formal test.

Ms. Schumann and Dr. Taylor along with Dr. Steve Smith of MSFC and Mr. Tim Wilfong of ITT/FSC prepared a preprint entitled "Application of 50 MHz Doppler Radar Wind Profiler to Launch Operations at Kennedy Space Center and Cape Canaveral Air Station" for poster presentation at the 14th Conference on Weather Analysis and Forecasting to be held in Dallas, TX, from 15-20 January 1995.

Ms. Schumann and Mr. Wheeler have been examining the Lightning Detection And Ranging (LDAR) system output on the real-time display computer and gaining operational experience with the system since its installation last June. The AMU is currently drafting the evaluation plan for its LDAR tasking. After polling the user community, the AMU will concentrate its initial efforts on building training tools that describe how to interact with the LDAR system as well as how to interpret its results.

Primary AMU activities during the past quarter on the MASS model installation and evaluation include final testing and implementation of software to transfer model initialization and forecast products back to the MIDDS and preparation of a document describing the preliminary evaluation of the MASS model's forecasts of temperature, moisture, and wind at selected rawinsonde locations during February 1994 and July 1994.

The automated jobs which control the transfer of model initializations and forecast products back to the MIDDS are not executed until the MASS forecasts have expired so that the initialization and forecast products can not be used for operational decisions. Mr. Wheeler is in the process of developing F-key inputs so that RWO forecasters will be able to view MASS output using the same menu system that is currently available to display other data in MIDDS. Both SMG and NWS forecasters will be able to transfer the grids from the IBM test machine to their local host computers to examine MASS output.

The skill of coarse and fine grid temperature, moisture, and wind forecasts at rawinsonde stations was assessed by interpolating the model data to the observation locations and then computing the bias and root mean square error (RMSE). Station comparisons provide a stringent test of model capabilities since statistics computed for many grid points do not assess model forecast skill at individual locations. However, station observations sample many scales of atmospheric phenomena some of which can not be resolved by the model. As a result, point verification should benefit higher resolution models which resolve finer scales of motion. It does, however, tend to give a more pessimistic view of model performance than gridded verification. The analyses and forecast fields from all available 0000 UTC and 1200 UTC coarse grid forecasts during February 1994 and July 1994 were bilinearly interpolated to rawinsonde station locations within the fine grid domain. The bias and RMSE were then computed and analyzed for temperature, dew point temperature, wind speed and wind direction.

Preparation of the ERDAS model evaluation plan comprised the primary AMU activity during the past quarter on the ERDAS model evaluation task. Key points in the evaluation plan are presented within the main body of this report. The evaluation plan includes the methodology to be used in the evaluation of the meteorological model’s and system performance only. The AMU will address the diffusion models’ evaluation in February 1995 pending follow-on funding to the AMU from the Air Force Space and Missile Systems Center.

The AMU Chief prepared the first draft of a NASA Technical Memorandum on the wind spacing results and a paper on the spatial separation work for the 6th Aviation Weather Systems. The JSC Navigation, Control and Aeronautics Division requested support from Dr. Merceret regarding characteristics of SLF winds. Dr. Merceret supplied statistical information, a synthetic wind algorithm, and several diskettes of real wind data. By telecon, he also discussed their use and the results obtained by JSC. Finally, Dr. Merceret developed an electric field analysis to assist evaluation of proposed revisions to ruleB.1(b) of the Lightning LCC. He provided matrices of surface electric field as a function of charge height and distance to KSC Weather Projects and the Lightning Peer Review Committee.

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/CCAS 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/CCAS (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/CCAS 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/CCAS 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 CCAS.