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)

Hardware Installation And Maintenance

The Pentium PC to be used for the LDAR Computer Based Training (CBT) arrived in the AMU in late June. Mr. Wheeler installed the sound and interface cards and installed the Microsoft Office software on the hard drive. Since the LDAR CBT task has been postponed until September, the PC will be available for use on other tasks.

2.2 TASK 003 IMPROVEMENT OF 90 MINUTE LANDING FORECAST

Development of Forecaster Applications (Mr. Wheeler)

MIDDS Support

In April 1995, Mr. Wheeler suggested to the 45th Weather Squadron (45WS) that their MIDDS computer CPU's that support launch and ground support operations be upgraded to the faster 486/66 MHz processors that were installed as MIDDS non-operational terminals. In May, the SWO terminal was upgraded with the faster processor. The new terminal has been used to support several launches with noticeable improvements in response time.

Mr. Wheeler installed an F-Key menu shell in support of the Melbourne National Weather Service Office (NWSO) operations in May. The Melbourne NWSO now has the capability to view and analyze a much higher resolution satellite image. The satellite gray scale resolution has gone from 8 gray shades to 256 shades. They now have the capability to request additional weather information via the menu. Added into their menu was the capability to download and view the MASS model images. They will not, however, be able to load and view all the MASS images quickly as one image takes about 3-4 minutes to download from the mainframe.

Mr. Wheeler finished the development and installation of all F-Key menu shells in support of launch operations and in support of the daily operations at Range Weather Operations (RWO). Many of the additional features and utilities designed for the Shuttle Ferry Flight support menu were also migrated over to the other operational support menus. Major improvements include:

- The capability to change satellite projections easily and quickly in support of different operations,
- Utilities that allow quick and easy access to surface observations, terminal forecast, thermodynamic diagrams, mid to high level cloud analyses, and pilot reports,
- Maps that give the SWO quick reference to surface or upper air station ID's along different flight paths, and
- The capability to view MASS model output from the coarse or fine grid model runs.

The AMU will continue to support the F-Key menus designed for the RWO, but no additional features are planned to be developed. The AMU updated McIDAS-X and the graphical user interface (GUI) on the AMU's McIDAS-X terminal with the latest releases of the software.

Finally, Mr. Wheeler and Ms. Schumann began the documentation effort for the MIDDS menu system. The deliverable documentation will include a users' manual and a maintenance manual. The AMU is preparing a detailed outline of the documents as well as example figures and tables for 45WS review and comment.

Microburst Day Potential Index

On 16 August 1994, a severe thunderstorm event at the KSC Shuttle Landing Facility (SLF) produced wind gusts of 65 kts, much greater than what were forecast. Fortunately, there was no operational impact; however, the 45WS suspected that a wet microburst was responsible for the unexpectedly high winds and recognized that their forecast procedures did not adequately address microbursts, especially given the weather sensitivities of space launch operations. Mr. Wheeler analyzed the mesoscale wind tower network, rawinsonde, radar, and other data and confirmed that a microburst had caused the severe winds. Mr. Wheeler based his results on a study by Atkins and Wakimoto (1991) that modeled the thermodynamic structure of wet microbursts and demonstrated the importance of vertical profiles of equivalent potential temperature.

Maj. Bill Roeder of the 45WS proposed implementing a Microburst Day Potential Index (MDPI) based on ThetaE profiles to indicate the likelihood of microbursts on a given day. An MDPI greater than 1 means the difference between ThetaE at the surface and its minimum value aloft is greater than some threshold indicating that the atmosphere is capable of supporting microburst development. Mr. Wheeler developed a McIDAS/McBasi tool on the MIDDS that displays the vertical profiles of ThetaE and computes the MDPI. The MIDDS utility runs automatically updating the ThetaE profile and MDPI each time a new local sounding is received by the MIDDS. Figure 1 is an example of the display generated by the MIDDS utility for a day when a 63 kt (32 m s^{-1}) wind was measured by tower 1007.

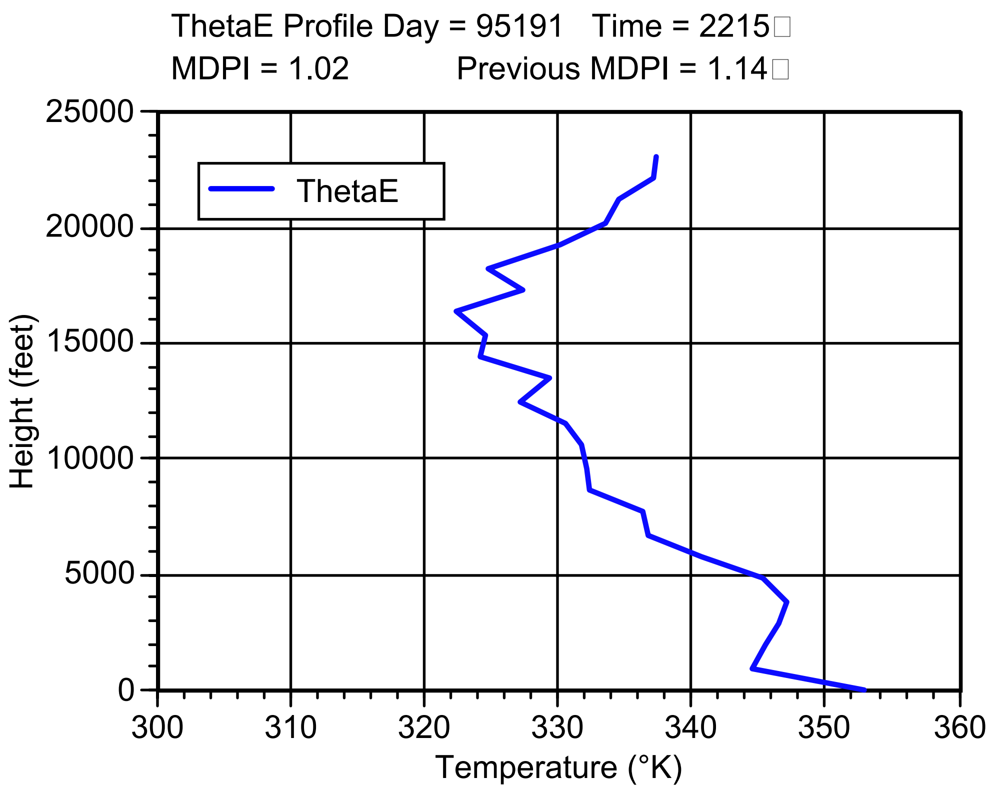

Figure 1. Example of MIDDS Graphic Output of an Afternoon ThetaE Profile

Further research by the AMU and the 45WS indicated that the Wind Index (WINDEX) (McCann 1994) may have utility for forecasting microburst intensity and providing more immediate warnings than provided by the MDPI. WINDEX identifies air masses favorable for producing microbursts and computes a maximum wind associated with the microburst. A separate MIDDS routine calculates and displays the WINDEX gust value. Nowcasting techniques were also jointly developed including using the MDPI as an indicator of microburst potential and the height of the reflectivity of the maximum precipitation core on the WSR-88D as the cell indicator. Mr. Wheeler will continue to collect local data for analysis of the Microburst Day Potential Index (MDPI) and WINDEX through October 1995.

References:

Atkins, N. T. and R. M. Wakimoto, 1991: Wet microburst activity over the Southeastern United States: Implications for forecasting., *Wea. Forecasting*, **6**, 470-482.

McCann, Donald W., 1994: WINDEX––A New Index for Forecasting Microburst Potential. *Wea. Forecasting*, **9**, 532-541.

2.3. TASK 004 INSTRUMENTATION AND MEASUREMENT (DR. TAYLOR)

Subtask 3 50 MHz Doppler Radar Wind Profiler (DRWP) (Ms. Schumann)

During April and May, Ms. Schumann attempted to provide real-time 50 MHz DRWP quality control for a Titan IV simulation and a Titan IV launch. During the simulation on 10 April, the data were exceptionally noisy and the wind profiles were often contaminated with very strong persistent interference signals. Despite Ms. Schumann's quality control efforts, only 1-2 profiles were released per hour.

After the simulation, Ms. Schumann discussed the problem with Ms. Launa Maier and Dr. Merceret. KSC then began troubleshooting the hardware in an attempt to explain and correct the data quality problems. Much of the problem was found to be due to wear on the antenna elements and problems with the receiver.

During the launch countdown on 14 May, the high voltage power supply for the profiler's amplifier failed, and Ms. Schumann was unable to provide quality control during the launch countdown. The purpose of providing quality control during the simulation and the launch countdown was to assist the Titan IV wind community in assessing the potential value of the 50 MHz profiler for operational use.

KSC is working to the profiler, and the AMU has been working closely with them by monitoring the data quality and noting any deficiencies. The Titan IV community is now poised to perform formal evaluation of the profiler's value by comparing the data with at least 10 balloon releases over several months. Prior to Titan's formal evaluation, KSC intends to ensure the profiler is operating in its nominal configuration and that sufficient spares are available to repair the profiler in a reasonable amount of time in case of hardware failure. The AMU will continue to monitor the profiler's data quality and will assist in any necessary data evaluation in preparation for the Titan IV evaluation tests.

Subtask 5 WSR-88D Evaluation (Mr. Wheeler)

In April, Mr. Wheeler discussed WSR-88D level II data archiving and its daily mode of operation with the Melbourne NWSO to determine the availability of the radar's resources for the AMU's evaluation task. Level II WSR-88D data tapes will be kept for about 90 days starting 01 June 1995, and the AMU may request copies at any time. Mr. Dave Sharp also stated that they will try to keep the WSR-88D in clear air mode of operation during the morning hours as long as there are no storms within 20-30 miles of Melbourne. They will switch over to precipitation mode when storms begin to develop. Mr. Wheeler developed internal plans for local data archiving (PUP and MIDDS data) in support of the evaluation.

As a result of the AMU Technical Directive issued 08 June 1995, Ms. Lambert started devoting her efforts towards the WSR-88D evaluation beginning in June.

Mr. Wheeler and Ms. Lambert continued their data collection, review and analysis of WSR-88D data for convection initiation and severe/non-severe storm determination. Though June was not a typical June thunderstorm month, some interesting cases were noted and data were saved for further analysis. There have been some restrictions on operating in clear air mode; thus far, only two short periods have been allocated to clear air mode in the morning hours. Clear air mode of operation for the WSR-88D is needed to analyze the sea breeze boundary prior to convection initiation. A meeting has been scheduled for late July between the Melbourne NWSO, Range Weather Operations (RWO), and the AMU should clarify when it is and is not acceptable to operate in clear-air mode.

The AMU received updated versions of the Motif-IRAS NEXRAD level II data emulator and of the WSR-88D Visualization Software (WVS). A number of tools that allow the user to display and analyze the WSR-88D level II archive data sets have been enhanced.

2.4 TASK 005 MESOSCALE MODELING

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

During the past quarter, Drs. Manobianco, Taylor, and Zack (MESO, Inc.) completed a manuscript entitled "Workstation-based real-time mesoscale modeling designed for weather support to operations at Kennedy Space Center and Cape Canaveral Air Station". This paper describes the capabilities and operational utility of the MASS model as it was designed by MESO, Inc. to support operational weather forecasting at KSC/CCAS. Dr. Manobianco submitted the paper for possible publication in the *Bulletin of the American Meteorological Society*.

In March 1995, Dr. Manobianco delivered a short presentation on the issues relating to mesoscale modeling at the AMU Tasking Meeting. As a result of the consensus reached at the Tasking Meeting, the AMU started sending MASS output in the form of images to MIDDS in real time beginning 24 March 1995. Dr. Manobianco and Ms. Yersavich also implemented real-time Model Output Statistics (MOS) using output from the daily MASS model runs and observations including Lightning Locator and Protection (LLP) data and Neumann-Pfeffer thunderstorm statistics. The MOS is sent hourly to the MIDDS system and is another MASS product available to RWO, SMG, and NWS meteorologists in real time. The following section summarizes MOS and provides an example of the product that is available in real time on MIDDS.

MASS Model Output Statistics

At the time of its design, the computational constraints and the unavailability of high resolution initialization data prohibited the execution of MASS with sufficient resolution and detailed physics to predict precise occurrences of specific weather phenomena such as thunderstorms and lightning at KSC/CCAS. The results presented in the AMU 2nd Quarterly Report from FY-95 showed that 11-km MASS model runs show little objective skill in predicting the exact location and amount of precipitation during May through September 1994. Given this limitation, MESO, Inc. developed a statistical model which was incorporated into the MASS prediction system. The basic concept was to combine model and observational data in a way that would permit the generation of hourly updates of the probability of specific weather phenomena at KSC/CCAS during specified time windows. The expectation was that model-generated variables would have more predictive skill in the longer lead-time forecasts (i.e. early in the day) and that the “latest” values of observation-based variables would provide most of the information for the short lead-time (a few hours before the target time window) forecasts. The system was intended to provide a mechanism to transition smoothly from predictions based more heavily on model-generated variables to those based on observational data as the time of the forecast target window approached. This approach is similar in concept to the Model Output Statistics (MOS) schemes used by NWS to generate forecasts of local variables from regional or global model output.

The statistical model consists of a set of linear discriminant functions (LDFs). In the prototype version of the system, LDFs were developed for four consecutive 2-hour forecast time windows covering the period from 1500 UTC to 2300 UTC and four predictand events: (1) a lightning stroke detected within 10 km of the KSC/CCAS weather observation site (TTS); (2) a report of thunder heard at TTS; (3) a report of rain at the TTS site in either regular or special observations; and (4) a report of a wind gust of 15 m s^{-1} or higher at any of the KSC/CCAS mesonet towers within 10 km of TTS. This statistical model can be used to generate an estimate of the probability of the occurrence of each event within any of the forecast windows.

The statistical model was designed to use both observation-based data and model-generated data simultaneously; generate a new forecast each hour; and generate forecasts beginning at 0000 UTC each day for the afternoon period (1500-2300 UTC) of that day. A separate LDF was constructed for each forecast-generation hour for each of the predictands. All of the selected variables (observation-based or model-generated) that were normally available by the start of a particular hour were used as candidate predictors for that hour. Thus, variables based solely on observational data could be included in the prediction equation for any hour after the time that they were reported. For example, a variable based on the manually digitized radar data reported at 2035 UTC could be used 25 minutes after the reporting time as a predictor in the 2100 UTC forecast equation. In the case of variables computed from model-generated data, the variables were eligible for consideration as a

LDF predictor for any hour after the time that the model simulation normally terminated. Thus, if a scheduled model simulation normally began execution at 0230 UTC and finished at 0630 UTC then any variable computed from the output of that simulation was considered as a candidate only for the LDFs at or after 0700 UTC.

A list of the observation-based and model-generated variables considered as candidate predictors is given in Table 1. The predictors for each hour's LDF were selected from the pool of potential predictors by evaluating the discriminating power of all combinations of three variables and selecting the set of three that yielded that highest ability to discriminate between the occurrence and non-occurrence of each event. The predictor set for each hour was limited to three to avoid overfitting of the data in the limited size developmental sample.

An example of the real-time MOS product sent to MIDDS is shown in Tables 2 and 3. Table 2 displays the probability of occurrence for each event within the four consecutive time windows that is computed at the time shown in the table heading. The asterisks denote missing values which occur if any one of the three predictors for a given hour are missing or the beginning of the time window has passed. The predictors used to compute the probabilities for each event and time window are listed in Table 3 with the letter 'M' denoting missing values. The abbreviations for the predictors follow the convention from Table 1. The information in Table 3 is provided so that users can judge the reliability of MOS for a given hour depending on what predictors are used to compute the probabilities. For example, one of the three predictors for certain events and time windows is the MASS convective precipitation over the four model grid points closest to TTS. As a result, MOS could yield a high probability that rain will be reported at TTS if the model predicts a large amount of precipitation near TTS. However, as pointed out earlier in this section, the 11 km explicit precipitation forecasts from MASS are not very skillful. Therefore, the high probability of rain could be misleading especially if the MASS precipitation forecast is in error.

An example of the potential impact of the dynamical-statistical modeling combination on the objective forecasting of thunderstorm events at KSC/CCAS is illustrated in Figure 2. This chart illustrates the probability of correctly forecasting an event of thunder with rain at 1200 UTC in the 2-hour period from 2100 UTC to 2300 UTC during the warm season with four different methods. The probability estimates are based upon the use of decision rules from the LDFs derived from a sample of 58 warm season cases from 1992. The first method is simply an application of the climatological probability based solely upon the day of the year. The analysis of the 58-case sample indicates that this will yield a correct forecast of the event about 68% of the time. A more sophisticated form of climatological forecast is to combine the climatology with information from the morning KSC sounding. The probability of making a correct forecast with this method is estimated to be 73%. The third method is to use the statistical model with only observational data. This approach would be expected to generate a correct forecast slightly under 80% of the time. The most comprehensive method is to use the statistical model with both observation-based and mesoscale model-generated variables. The data from the limited 58-case sample indicate that this will give the correct forecast slightly over 83% of the time. The same performance relationship among these forecasting techniques was found to exist for the other time periods and events considered in the developmental sample. The AMU is in the process of reconstructing the LDFs using a more extensive data set of cases from the 1994 and 1995 warm seasons.

Table 1. Observed and forecast predictors for MASS Model Output Statistics.

Observed Predictors	
RD500	Dist to closest Manually Digitized Radar (MDR) echo box within 500 km
RD500T	Change in distance to closest MDR echo box
R_500	Number of MDR echo boxes within 500 km
R_500T	Change in number of MDR echo boxes per hour
R_250	Number of MDR echo boxes within 250 km
R_250T	Change in number of MDR echo boxes per hour
VIPDIS	Distance to the nearest level 3 or higher echo
DELVIP	Change in distance to variable VIPDIS per hour
DELDEG	850 mb wind direction minus VIP level 3 cell or higher direction
KSCT	Temperature at TTS or closest available tower
KSCDP	Dew point at TTS or closest available tower
KSCWS	Wind speed at TTS or closest available tower
KSCWD	Wind direction at TTS or closest available tower
KSCU	U wind component at TTS or closest available tower
KSCV	V wind component at TTS or closest available tower
KSCBY	Buoyancy index at TTS or closest available tower
BYTEN	Change in the buoyancy index per hour
RIDGLOC	Location of the ridge axis based on Florida station pressure analysis
ACONV	Convergence x 10^{-5} derived from KSC/CCAS mesonet towers
ACONVT	One hour change in ACONV
NP1	Climatology-based thunderstorm probability (prob) from Neumann-Pfeffer
NP2	850 mb wind-based thunderstorm prob from Neumann-Pfeffer
NP3	500 mb wind-based thunderstorm prob from Neumann-Pfeffer
NP4	Stability index-based thunderstorm prob from Neumann-Pfeffer
NP5	800-600 mb mean RH-based thunderstorm prob from Neumann-Pfeffer
KSCLI	Composite lifted index based on KSC sounding
RH500	Surface to 500 mb mean relative humidity from KSC sounding
RH800	800-600 mb mean relative humidity from KSC sounding
DP800	Layer depth where RH >60% from 800 to 600 mb from KSC sounding
DP500	Layer depth where RH >60% from surface to 500 mb
UAVMOI	Average u-wind component where RH >60% from 50 MHz profiler
VAVMOI	Average v-wind component where RH >60% from 50 MHz profiler
ASHEAR	Average shear in all layers from 50 MHz profiler
DIR850	850 mb wind direction from latest KSC sounding
SPD850	850 mb wind speed from latest KSC sounding
LTGDS	Distance to nearest lightning strike from LLP data in first 30 min.
LTGDST	30 minute change in LTGDS
LTG	Total number of strikes within 60 minutes from LLP data
LTGT	30 minute change in LTG
U850	850 mb u-wind component from latest KSC sounding
V850	850 mb v-wind component from latest KSC sounding
Mesoscale Atmospheric Simulation System (MASS) Model Predictors	
rCAPEn	Convective Available Potential Energy (CAPE) at point nearest TTS
rU850n	850 mb u-wind component at grid point nearest TTS
rV850n	850 mb v-wind component at grid point nearest TTS
rV700n	700 mb vertical velocity (μbars s^{-1}) at grid point nearest TTS
rRELHn	800-600 mb mean relative humidity at grid point nearest TTS
rQCONn	Maximum sigma layer-1 moist convergence index within 100 km of TTS
rPRECn	Convective precipitation over 4 model grid points closest to TTS
rDISTn	Nearest distance from TTS to model grid point with precipitation

r stands for run: C=Coarse grid (45 km) 0000 UTC run (completed by 1000 UTC)
F=Fine grid (11 km) 1200 UTC run (completed by 1500 UTC)

n stands for averaging period: 1=1500-1700 UTC
2=1700-1900 UTC
3=1900-2100 UTC
4=2100-2300 UTC

Example: CCAPE3 = CAPE averaged over hours 1900-2100 from the Coarse grid run

Table 2. MASS Model Output Statistics (MOS) for 1700 UTC 5 Jul 1995. Probability of occurrence for each event within each time window Preliminary Evaluation Data NOT FOR OPS USE				
Event	Nominal Time (UTC)			
	1500-1700	1700-1900	1900-2100	2100-2300
LIGHTNING: Stroke detected within 10 km of TTS	****	****	1.9	****
THUNDER WITH RAIN: Report of thunder and rain at TTS	****	****	50.0	53.7
RAIN: Report of rain in regular or special ob. at TTS	****	****	5.2	50.0
HIGH WIND GUST: Wind gust of 15 m/s within 10 km of TTS	****	****	****	****

Asterisks denote missing values
Note probabilities are not given AFTER start of time windows

Table 3. Predictors for each event within each time window.				
Event	Nominal Time (UTC)			
	1500-1700	1700-1900	1900-2100	2100-2300
LIGHTNING: Stroke detected within 10 km of TTS	Expired Expired Expired	Expired Expired Expired	CBOX3 CU850 VIPDIS	CV7004 CPREC4 BYTEN M
THUNDER WITH RAIN: Report of thunder and rain at TTS	Expired Expired Expired	Expired Expired Expired	LTGDS KSCU R_250T	CBOX4 CRELH4 CBOX4
RAIN: Report of rain in regular or special ob. at TTS	Expired Expired Expired	Expired Expired Expired	CV7003 DELVIP R_250	FCAPE4 CRELH4 LTGDS
HIGH WIND GUST: Wind gust of 15 m/s within 10 km of TTS	Expired Expired Expired	Expired Expired Expired	FQCON3 KSCWS KSCT M	FPREC4 FQCON4 KSCT M

M denotes missing values

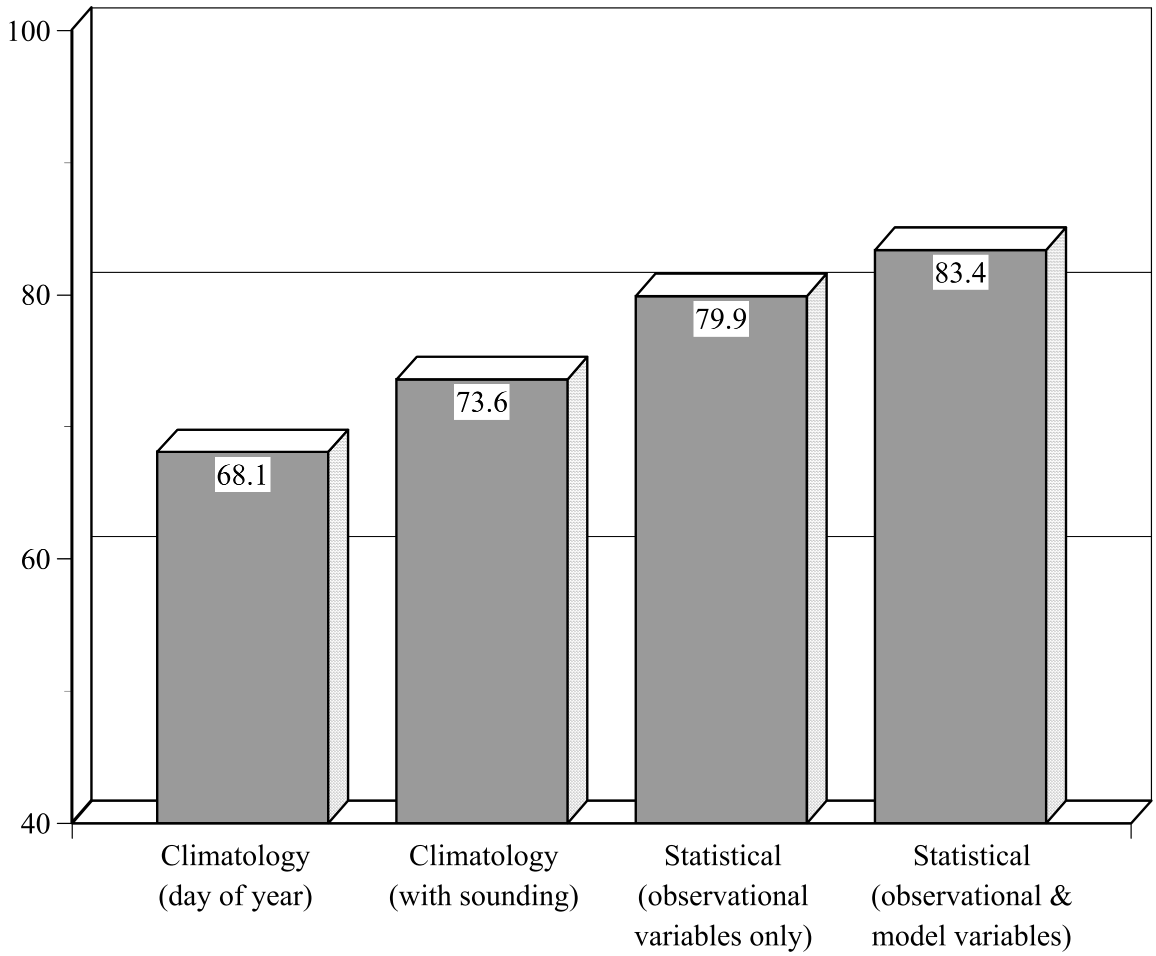

Figure 2. The probability of correctly predicting a thunderstorm with rain event for the 2100 UTC to 2300 UTC at 1200 UTC using four different forecasting techniques. The probabilities are based upon the utilization of linear discriminant functions derived from a 58-case sample for the summer of 1992.

REFERENCES

Zack, J. W., K. T. Waight, S. H. Young, M. Ferguson, M. D. Bousquet, and P. E. Price, 1993: *Development of a mesoscale statistical thunderstorm prediction system*. 203 pp. Final report to NASA under Contract No. NAS10-11670. [Available from MESO, Inc. 185 Jordan Road, Troy, NY 12180].

Subtask 4 Install and Evaluate ERDAS (Mr. Evans)

The Emergency Response Dose Assessment System (ERDAS) was installed in the AMU in March 1994, and has been running automatically twice daily. The AMU's primary tasks on ERDAS have been to make sure ERDAS receives all its required input data, monitor its operation, determine any deficiencies, conduct an evaluation of the RAMS meteorological model, and evaluate the diffusion models HYPACT and REEDM. The evaluation of ERDAS has been ongoing since its installation, and we have documented some of the evaluation results in several interim reports. An extensive description of the meteorological evaluation will be provided in the AMU's ERDAS evaluation final report Mr. Evans will prepare in September.

The primary AMU activity during the past quarter on ERDAS model evaluation was the evaluation of the REEDM and HYPACT diffusion models. The evaluation consisted of comparing model data with launch plume data collected since March 1994 for Space Shuttle and Titan IV launches. The following paragraphs describe the AMU's evaluation of the ERDAS diffusion models for the Titan IV Launch on 03 May 1994.

The Titan IV rocket was launched from Launch Complex 41 (LC-41) at Cape Canaveral Air Station (CCAS) at 1555 UTC on 03 May 1994. Mr. Evans used the ERDAS meteorological model RAMS and diffusion models REEDM and HYPACT to model the transport and diffusion of the exhaust plume and to compare the modeled plume data with observed data collected by Aerospace Corporation's plume imaging cameras. The following is a discussion of the modeling analyses of this launch.

Meteorology

On the morning of 03 May, high pressure was located in the Middle Atlantic States with a weak cold front extending westward from southern Georgia into the northern Gulf of Mexico. Temperatures at the Shuttle Landing Facility (SLF) on 03 May ranged from a low of 66°F to high of 85°F. The winds were from the east and southeast across Florida. Weather observers at the SLF reported scattered clouds during the morning before the launch and thunder and thunderstorms three hours after the launch beginning at 1855 UTC.

RAMS Analyses

ERDAS runs the RAMS model twice daily beginning at 0000 UTC and 1200 UTC. Each simulation runs for 24 hours and produces hourly output of meteorological data. The RAMS simulation starting at 1200 UTC on 03 May was used for this analyses. At 1600 UTC, near the time of the launch, RAMS predicted the surface winds at a height of 10.6 m to be from approximately 110° and the winds aloft at a height of 1212 m to be from approximately 150°. The RAMS wind field for these levels at 1600 UTC are shown in Figures 3 and 4.

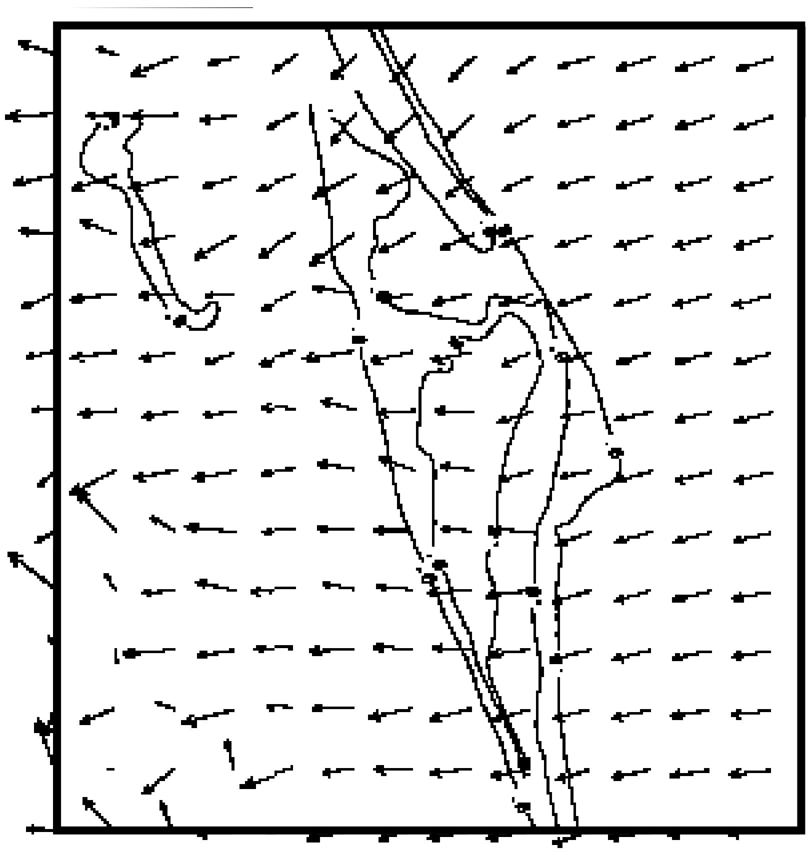

Figure 3. RAMS wind field at the surface (10.6 m)at 1600 UTC on 03 May 1994.

To assess the accuracy of the RAMS wind predictions on the morning of 03 May, RAMS data were compared with data measured at Tower 110, located less than 2 km from LC-41. The winds at the lowest two tower levels (3.6 m and 16.4 m) and the winds in the lowest RAMS layer (10.6 m) for 1500 UTC, 1600 UTC, 1700 UTC are compared in Table 4. For these three times, the data show that the RAMS wind directions at 10.6 m were more easterly than the observed southeasterly winds at 3.6 m and 16.4 m at Tower 110. The RAMS average wind direction was 87° while the average observed wind directions were 122° at 3.6 m and 132° at 16.4 m. The RAMS wind speeds were slightly stronger than the observed wind speeds at both tower levels. RAMS average wind speeds were 5.3 m s^{-1} while the observed wind speeds averaged 3.6 m s^{-1} at 3.6 m and 4.4 m s^{-1} at 16.4 m.

ERDAS Diffusion Analyses

REEDM launch plume source term predictions

ERDAS uses REEDM to predict the initial source term for the Titan IV launch plume. The source term is defined as the release rate (mass per unit time) of emitted material. REEDM generates the source term by taking data stored for each launch vehicle and for each material emitted during a launch and computing the total amount of material released. REEDM then distributes the material into different vertical layers. For the launch analysis presented here, hydrogen chloride (HCl) was selected because it is a chemical routinely modeled by Range Safety during pre-launch operations.

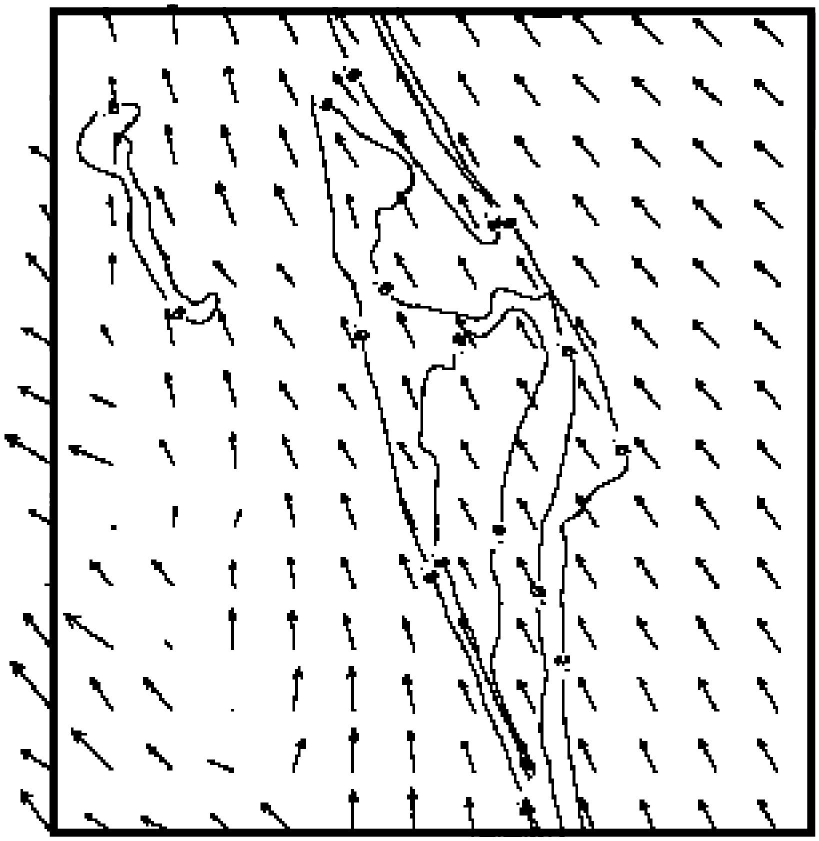

Figure 4. RAMS wind field aloft (1212 m) at 1600 UTC on 03 May 1994.

Table 4. Observed wind data at Tower 110 during the period 1500 UTC to 1700 UTC.

	Observed 3.6 m		Observed 16.4 m		RAMS 10.6 m	
Time	Wind direction	Wind speed	Wind direction	Wind speed	Wind direction	Wind speed
(GMT)	(degrees)	(m s^{-1})	(degrees)	(m s^{-1})	(degrees)	(m s^{-1})
1500	134	3.6	142	4.6	106	4.3
1600	111	3.6	127	4.1	79	5.7
1700	121	3.6	128	4.6	77	5.9

For this case, REEDM generated 29 layers from the surface up to 3000 m and put material in 17 of the highest layers beginning at 400 m (Table 5). The layers with the most material were layers 19 to 22 located at 1000 m to 1400 m. REEDM calculated the cloud stabilization height at 930 meters. The cloud stabilization height is defined as the height of the center of the cloud at the point the cloud temperature approaches the ambient temperature or the cloud buoyancy approaches zero (Bjorklund 1990).

Table 5. REEDM exhaust cloud calculations for Titan IV launch on 03 May 1994. Meteorological data were provided by RAMS predictions from 1200 UTC run.

-----EXHAUST CLOUD-----

MET. LAYER NO.	TOP OF LAYER (m)	LAYER SOURCE STRENGTH (grams)	CLOUD UPDRAFT VELOCITY ($m\ s^{-1}$)	CLOUD RADIUS (m)	STD. DEVIATION MATERIAL DIST. ALONG WIND (m)	CROSSWIND (m)
1	10.1	0.00000E+00	7.6	.0	.0	.0
2	20.1	0.00000E+00	9.3	.0	.0	.0
3	35.1	0.00000E+00	9.9	.0	.0	.0
4	50.0	0.00000E+00	9.7	.0	.0	.0
5	66.6	0.00000E+00	9.3	.0	.0	.0
6	83.3	0.00000E+00	8.7	.0	.0	.0
7	100.0	0.00000E+00	8.1	.0	.0	.0
8	133.3	0.00000E+00	7.2	.0	.0	.0
9	166.6	0.00000E+00	6.4	.0	.0	.0
10	199.9	0.00000E+00	5.7	.0	.0	.0
11	249.9	0.00000E+00	5.0	.0	.0	.0
12	299.9	0.00000E+00	4.5	.0	.0	.0
13	399.9	4.49427E+05	3.8	328.0	152.8	152.8
14	499.9	3.44982E+06	3.3	462.3	215.4	215.4
15	600.2	5.90615E+06	2.8	547.7	255.2	255.2
16	700.1	7.76001E+06	2.3	605.1	282.0	282.0
17	800.1	9.06326E+06	1.7	642.1	299.2	299.2
18	900.1	9.80135E+06	0.8	662.1	308.5	308.5
19	1000.0	1.25856E+07	.0	666.7	310.7	310.7
20	1100.0	1.31756E+07	.0	656.2	305.8	305.8
21	1200.0	1.20427E+07	.0	629.9	293.5	293.5
22	1399.9	1.85109E+07	.0	555.4	258.8	258.8
23	1600.2	7.48185E+06	.0	347.4	161.9	161.9
24	1800.1	5.51435E+06	.0	199.9	93.2	93.2

25	2000.1	5.18670E+06	.0	199.9	93.2	93.2
26	2250.0	6.09702E+06	.0	199.9	93.2	93.2
27	2500.0	5.73472E+06	.0	199.9	93.2	93.2
28	2750.1	5.43047E+06	.0	199.9	93.2	93.2
29	3000.1	5.16506E+06	.0	199.9	93.2	93.2

HYPACT plume predictions

HYPACT is the advanced Lagrangian particle dispersion model in ERDAS. Dispersion in the Lagrangian mode of HYPACT is simulated by tracking a large set of particles. Subsequent positions of each particle are computed from the relation:

$$X[t+\Delta t] = X[t] + [u + u'] \Delta t$$

$$Y[t+\Delta t] = Y[t] + [v + v'] \Delta t$$

$$Z[t+\Delta t] = Z[t] + [w + w' + w_p] \Delta t$$

where u, v and w are the resolvable scale wind components which are derived from RAMS or the hybrid (RAMS/tower observations) wind field, and u′, v′, and w′ are the subgrid turbulent wind components deduced from RAMS. The w_p term is the terminal velocity resulting from external forces such as gravitational settling.

For modeling launch scenarios, the HYPACT model obtains the source term data (release rate) from the REEDM launch plume data. HYPACT then diffuses the plume using the RAMS-predicted wind fields and potential temperature fields to advect and disperse the particles vertically and horizontally downwind from the source.

Comparison with observations

To determine how well ERDAS modeled the launch plume, Mr. Evans compared the REEDM/HYPACT predictions with observations made by Aerospace Corporation's plume imaging cameras (Aerospace 1995). Aerospace Corporation is collecting measurements of Titan IV launch clouds using visible and infrared cameras as part of a project to validate models such as REEDM. A description of the imaging project is provided in Aerospace (1995). Data from the 03 May 1994 Titan IV launch were obtained from Heidner (1994).

Heidner (1994) provided a graph showing a plane view of the horizontal movement of the plume as it moved away from LC-41. Figure 5 shows this plume centerline on a map of CCAS. Heidner (1994) also showed a time-height cross section of the plume from the time of the launch to 45 minutes after launch. This cross section is presented in Figure 6. For the first 5 minutes after launch, the exhaust plume was very buoyant and rose until it stabilized in the layer between 900 m (2950 ft) and 1300 m (4270 ft). The plume was observed to stay close to this level for the remaining 20 minutes of measurements. Data were missing for the period from 5 to 25 minutes after launch. The top of the plume reached a peak of 1500 m (4920 ft) at 33 minutes and the bottom dropped to a minimum height of 700 m (2300 ft) at 25 minutes. The centerline of the plume was also mapped to show the movement of the plume away from the source. Figure 5 shows how the observed plume moved initially to the west with the low-level easterly winds and then moved north as it rose upward reaching the level of the southerly winds at approximately 1200 m.

For this Titan IV launch, HYPACT moved the lowest part of the plume (at a height of approximately 400 m) to the west in response to the low-level easterly flow. HYPACT moved the upper part of the plume (at a height of approximately 1300 m) to the north-northwest with the south-southeasterly flow aloft.

To compare the REEDM/HYPACT modeled plume location to the observed location, HYPACT's plume for the layer 1000 to 1500 meters was used for the comparison since this layer matched the height of the observed plume. Figure 5 shows the paths of the observed and REEDM/HYPACT modeled plumes. The HYPACT-predicted plume followed a very similar trajectory to the observed plume but HYPACT moved it more to the west than observed. HYPACT predicted the northward movement beginning at 15 minutes after launch as it moved the plume in a north-northwesterly direction. The observed plume began moving north after approximately 5 minutes.

3 May 94 Titan IV K7

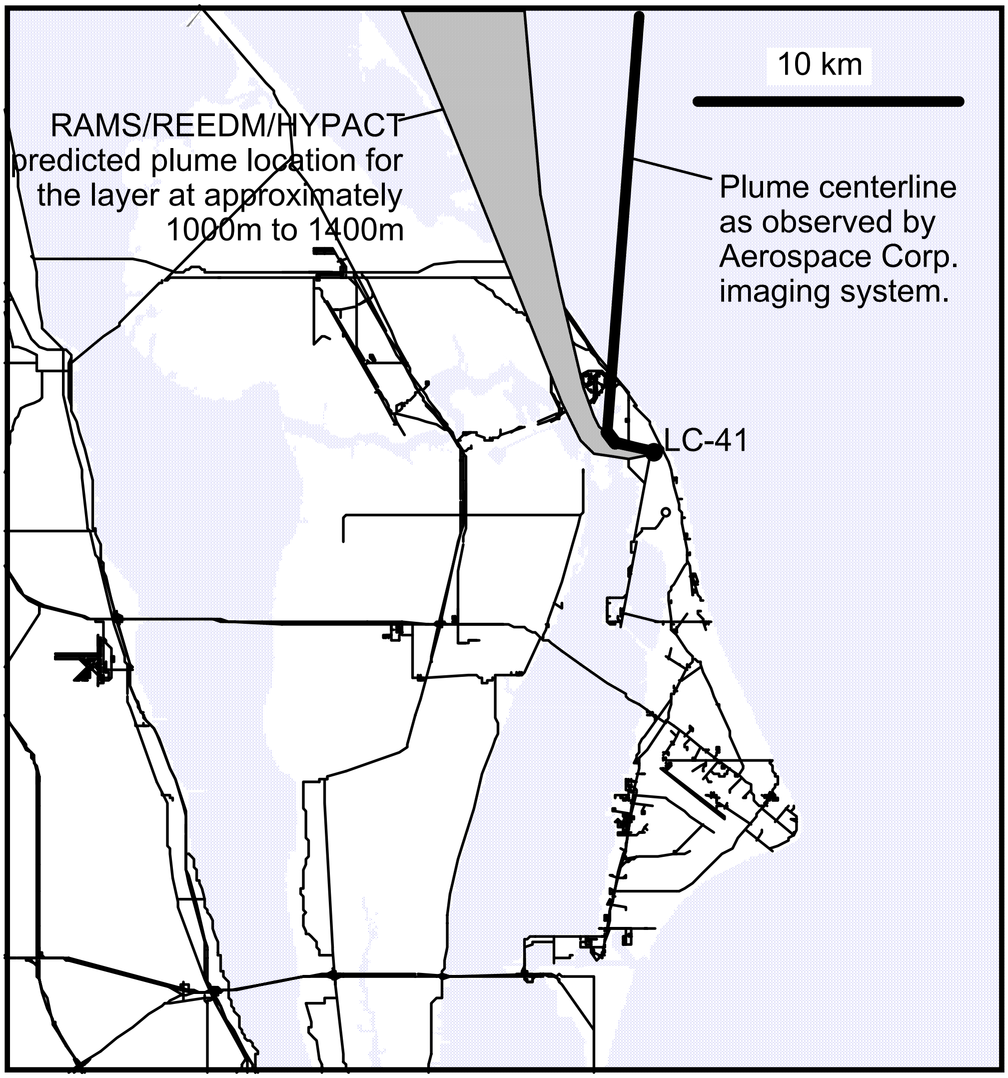

Figure 5. Centerline trajectories of observed plume and REEDM/HYPACT modeled plume for Titan IV K7 launch on 03 May 1994.

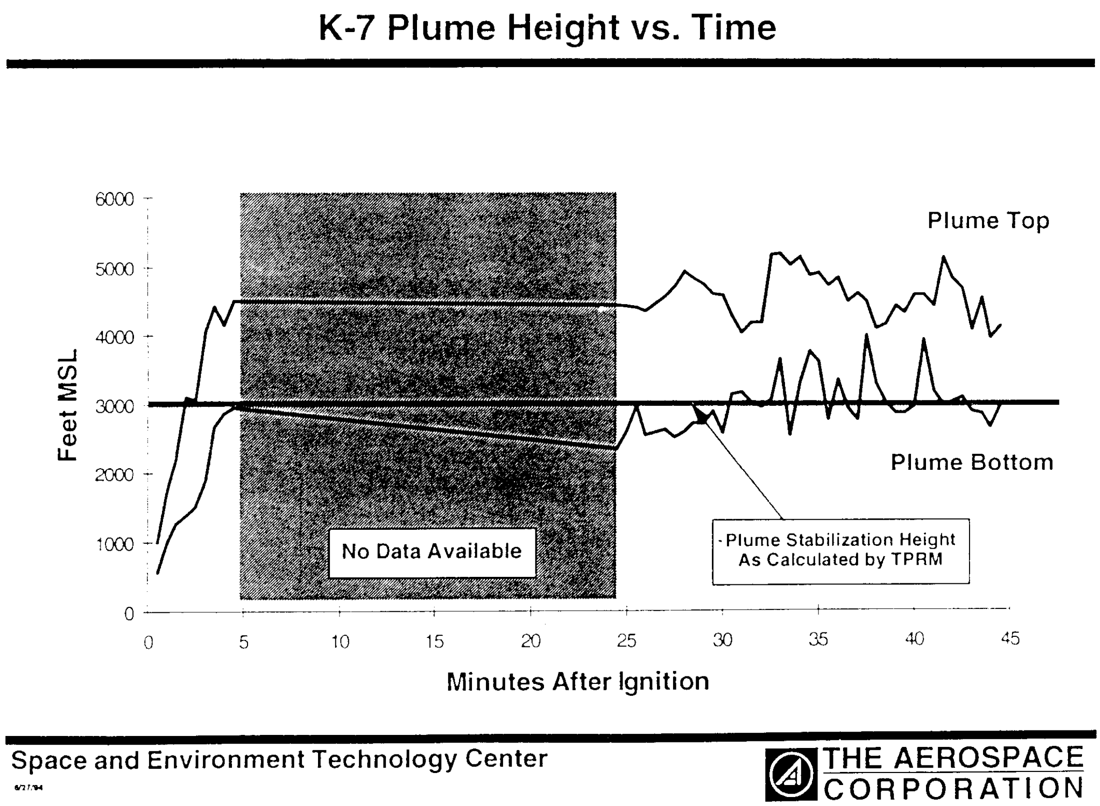

Figure 6. Titan IV plume height versus time for launch on 03 May 1995 as measured by Aerospace Corporation plume imaging cameras (Aerospace 1995).

Results and Conclusions

The analyses of this Titan IV launch case study indicate that the RAMS/REEDM/HYPACT modeling system has promising potential for modeling launch exhaust plumes. However, the case study also showed ERDAS needs improvements in some areas.

The promising results were:

- RAMS predicted the 3-dimensional wind field, but the directions differed by approximately 35° and RAMS slightly overpredicted the wind speeds. The prevailing surface winds on 03 May were southeasterly and the winds at approximately 1200 m were southerly. During the period from the RAMS initialization at 1200 UTC to 1700 UTC, RAMS predictions of the easterly surface winds followed the tower observations but showed a trend of more easterly than southeasterly winds. RAMS overpredicted the wind speeds by 1 to 2 m s^{-1}. RAMS predicted the winds at 1212 m to be from the southeast. However, the plume observations indicated that the winds at the 1000 m to 1500 m level were more southerly than southeasterly.

- HYPACT-predicted plume trajectory closely followed the observed trajectory with some variation over time. Figure 5 shows the comparison of the predicted versus observed plume trajectories. The predicted trajectory followed closely the observed trajectory but went a little further west before rising into the southeasterly flow aloft. The stronger wind speeds predicted by RAMS may account for the initial movement further west than observed. Once reaching the southeasterly flow aloft the RAMS winds moved the plume more to the northwest than north because of the slight difference in the wind direction discussed in the previous paragraph.

The improvements needed are:

- HYPACT should be modified to handle buoyant plumes rather than treating the plumes as passive tracers. The actual Titan IV rocket exhaust plumes are heated and are quite buoyant initially after launch. Although REEDM considers buoyancy effects in computing its source term properties, these are not all taken into consideration by HYPACT. For example, REEDM computes buoyancy-driven updraft velocities ranging from 0.8 to 3.8 m s^{-1} for the layers between 400 and 900 m (Table 5). However, HYPACT does not use these REEDM-predicted vertical velocities to move material vertically out of these layers. HYPACT does not change the plume due to its own buoyant properties but moves and disperses it due to environmental winds and turbulence.

- HYPACT should be modified to handle deposition of solid and liquid plume particulates since deposition from launch plumes is an important factor in the diffusion. Also, because of the solid rocket motor exhaust, there is considerable deposition of HCl particulates and other materials from a Titan IV launch. The version of HYPACT in ERDAS does not model dry deposition effects but only models passive tracer material.

References

Aerospace, Corp., Environmental Systems, Systems Engineering Directorate, Space Launch Operations, “Ground Cloud Dispersion Measurements During the Titan IV Mission #K14 (22 December 1994) at Cape Canaveral Air Station”, Aerospace Report No. TR-95(5448)-2, 15 June 1995.

Bjorklund, J.R.,User’s Manual for the REEDM Version 7 (Rocket Effluent Diffusion Model) Computer Program, TR-90-157-01, April 1990.

Heidner, R.F., B.P. Kaspar, and D.R. Schulthess, “Imagery of the Titan IV Ground Cloud”, Presented at the Toxic Release Assessment Group (TRAG), 28 June, 1994.

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

Wind Sheltering Study

Data collected for this study indicate that cutting the foliage around the SLF to meet the Federal Standards for Siting of Meteorological Equipment at Airports is both necessary and sufficient for to reduce the sheltering effects to 10%. The first draft of the final report for this work has been reviewed, and Dr. Merceret is preparing a revised draft.

Crosswind DTO

Dr. Merceret is consulting with Johnson Space Center (JSC) and Marshall Space Flight Center (MSFC) on the design of appropriate winds for use in the Shuttle simulator in preparation for the crosswind Detailed Test Objective (DTO 805). Wind data obtained from Shuttle Training Aircraft (STA) are being evaluated against tower data to determine their representativeness.

Attachment 1: AMU FY-95 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.