Applied Meteorology Unit (AMU) Quarterly Report

31 October 2010   Fourth Quarter FY-10   Contract NNK06MA70C

In this issue:

Launch Support

Dr. Merceret and Ms. Crawford supported the Atlas V launch on 14 August.

This Quarter's Highlights

Three AMU tasks were completed in this Quarter, each resulting in a forecast tool now being used in operations and a final report documenting how the work was done:

- Mr. Barrett completed Phase II of the Peak Wind Tool for General Forecasting task by delivering an improved wind forecasting tool to operations and providing training on its use;
- Dr. Watson completed a graphical user interface (GUI) she updated with new scripts to complete the ADAS Update and Maintainability task, and delivered the scripts to the Spaceflight Meteorology Group on Johnson Space Center, Texas and National Weather Service in Melbourne, Fla.; and
- Dr. Bauman completed the Verify MesoNAM Performance task after he created and delivered a GUI that forecasters will use to determine the performance of the operational MesoNAM weather model forecast.

ENSCO

1980 N. Atlantic Ave., Suite 830
Cocoa Beach, FL 32931
(321) 783-9735, (321) 853-8203

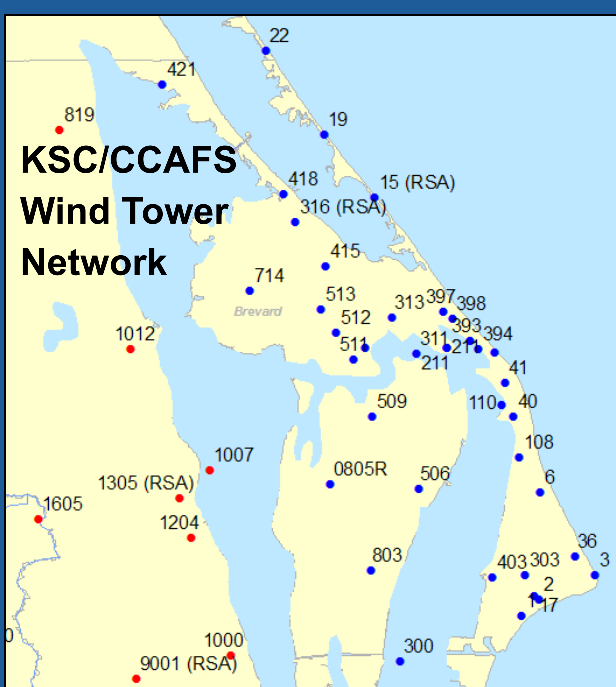
Quarterly Task Summaries

This section contains summarizes of the AMU activities for the fourth quarter of Fiscal Year 2010 (July - September 2010). The accomplishments on each task are described in more detail in the body of the report starting on the page number next to the task name.

Objective Lightning Probability Tool, Phase III (Page 4)

Purpose: Re-create the lightning probability forecast equations used in 45th Weather Squadron (45 WS)operations with new data and stratifications based on the progression of the lightning season. These modifications were anticipated to improve the performance of the equations used to make the daily lightning probability forecasts for operations on Kennedy Space Center (KSC) and Cape Canaveral Air Force Station (CCAFS).

Accomplished: New equations were created for each sub-season and their performance was tested against the Phase II equations in current operational use. The new equations outperformed several forecast methods, but caused a degradation in the forecast by as much as 12% compared to the Phase II equations. Therefore, the Phase III equations will not be transitioned to operations. The superior Phase II equations will remain in the operational objective lightning probability tool.

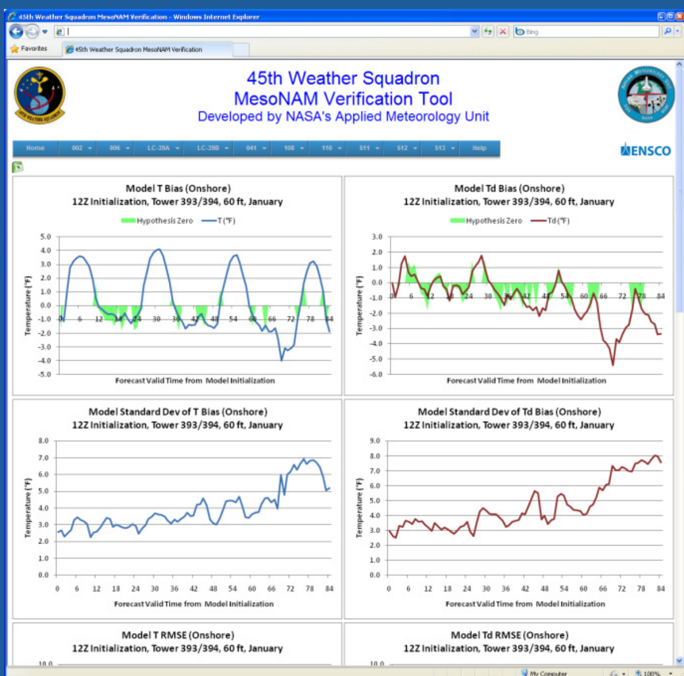


Peak Wind Tool for General Forecasting, Phase II (Page 6)

Purpose: Update the 45 WS tool, developed by the AMU in Phase I, that forecasts the peak wind speed during the cool season (October-April). This tool forecasts the peak wind speed for the day from any of the towers on KSC/CCAFS and its associated mean speed, and provides the probability of issuing wind warnings in the KSC/CCAFS area. The period of record was expanded to increase the size of the data set used to create the forecast equations and new predictors were evaluated.

Accomplished: The Phase I and Phase II tools were compared, and the Phase II tool had superior performance. This tool was delivered and a training session on its use was conducted for the 45 WS. The final report was completed after making modifications suggested in the internal AMU and external customer reviews. It is now available on the AMU website: http://science.ksc.nasa.gov/amu.

Quarterly Task Summaries
(continued)



Verify MesoNAM Performance (Page 6)

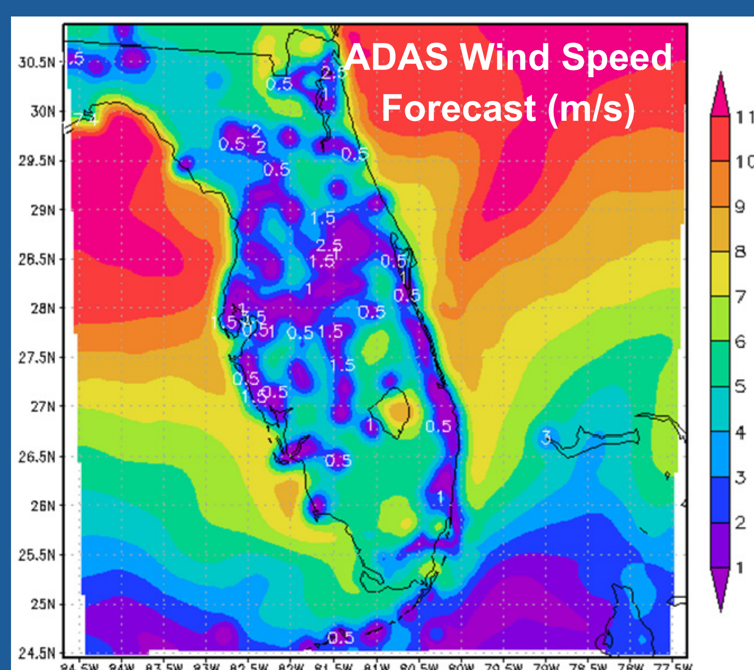
Purpose: Verify the performance of the 12-km North American Mesoscale model (MesoNAM) forecasts for CCAFS and KSC. The verification consisted of an objective statistical analysis comparing the MesoNAM forecast winds, temperature and moisture, and their changes over time, to the observed values at customer-specified KSC/CCAFS wind towers. This objective analysis and the resulting GUI helps forecasters understand the model's strengths and weaknesses, resulting in improved forecasts for operations.

Accomplished: The charts in the GUI were updated with data from additional sensor heights and delivered to the 45 WS in July. The final report was completed after internal AMU and customer reviews and was delivered in September. It is available on the AMU website: http://science.ksc.nasa.gov/amu.

ADAS Update and Maintainability (Page 7)

Purpose: Acquire the latest version of the Advanced Regional Prediction System (ARPS) Data Analysis System (ADAS) for the local data integration system (LDIS) at the National Weather Service in Melbourne, Fla. (NWS MLB) and the Spaceflight Meteorology Group (SMG) at Johnson Space Center, Texas. Update the AMU-developed shell scripts to govern the LDIS so it can be easily maintained, and update the ADAS GUI.

Accomplished: The analysis of the error statistics for the MADIS data showed that altering the error statistics for each data source had little impact on the ADAS analyses. Therefore, the error values used in the previous version of the LDIS scripts were not changed. The updated scripts were installed at NWS MLB and SMG. Installation instructions and a user's guide are included in the final report.



AMU ACCOMPLISHMENTS DURING THE PAST QUARTER

The progress being made in each task is provided in this section, organized by topic, with the primary AMU point of contact given at the end of the task discussion.

SHORT-TERM FORECAST IMPROVMENT

Objective Lightning Probability Tool, Phase III (Ms. Crawford)

The 45th Weather Squadron (45 WS) includes the probability of lightning occurrence in their daily morning briefings. This information is used by forecasters when determining the likelihood of violating launch commit criteria and weather flight rules, and planning for daily ground operations on Kennedy Space Center (KSC) and Cape Canaveral Air Force Station (CCAFS). In Phase I, the AMU developed a set of equations that calculate the probability of lightning occurrence for the day (Lambert and Wheeler 2005) and a graphical user interface (GUI) to display the output. These equations outperformed several forecast methods used in operations. The GUI allowed forecasters to interface with the equations by entering predictor values to output a probability of lightning occurrence. In Phase II (Lambert 2007), two warm seasons were added to the period of record (POR), the equations redeveloped with the new data, and the GUI transitioned to the Meteorological Interactive Data Display System (MIDDS). The MIDDS GUI retrieves the required predictor values automatically, reducing the possibility of human error. In this phase, three warm seasons (May–September) will be added to the POR, increasing it to 20 years (1989–2008), and data for October will be included. The goal of this phase is to create equations based on the progression of the lightning season instead of creating an equation for each month. These equations will capture the physical attributes that contribute to thunderstorm formation more so than a date on a calendar.

Sub-Season Start Dates

None of the three methods developed and tested by Ms. Crawford, described in the previous AMU Quarterly Report (Q3 FY10), were able to discern the sub-season start dates in each year. Ms. Crawford and Mr. Roeder agreed to end testing and, instead, define the dates using the daily lightning climatology. The black Xs in **Figure 1** show the beginning of each sub-season:

- Ramp-up begins 18 May when the lightning frequency begins to increase;
- Lightning begins 6 June when the rate of increase in the frequencies starts to decrease;
- Ramp-down begins 17 August when the large decrease in lightning frequency begins; and
- Post begins 12 October when the rate of decrease lessens and the value reaches 0.13, the same as in the pre-lightning sub-season.

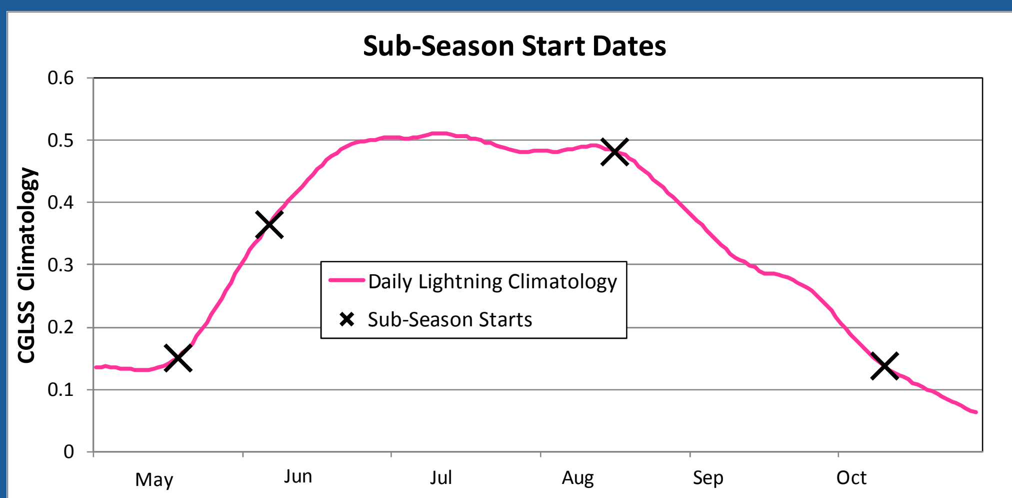


Figure 1. The 1989–2008 daily lightning climatology with the sub-season start dates indicated by black Xs.

Equation Development

Ms. Crawford stratified the data by sub-season first, then into development and verification datasets. The amount of data available for equation development was critical to the reliability of the new equations. Ms. Crawford determined the number of records in the development datasets for each sub-season stratification, and found they met and exceeded the threshold of the 250 events deemed necessary by the World Meteorological Organization (1992) in order to derive stable statistical relationships. Once satisfied that there were sufficient data, Ms. Crawford developed a set of five equations, one for each sub-season.

As in Phases I and II, Ms. Crawford used the logistic regression method to create the five equations. She conducted predictor selection for each individual sub-season to account for the possibility that different variables may be more critical to convection formation as the lightning season progresses. Detailed descriptions of logistic regression and the predictor selection procedure are found in the Phase II final report (Lambert 2007).

Ms. Crawford developed and tested several versions of each equation, each with varying numbers of predictors. The version that performed best on the verification data set was chosen as the final equation. **Table 1** shows the predictors for each of the sub-season equations in rank order of their importance in predicting lightning. The predictor names are color-coded to highlight their occurrence in each equation. The first predictor in the first four equations, Thompson Index, accounts for instability and moisture in the profile, which are both necessary ingredients for thunderstorm formation. The flow regime probability accounts for the lifting mechanism, or lack thereof, from the low-level flow interacting with the sea breeze, which occurs almost daily in the warm season.

Table 1. The predictors for each sub-season equation, in order of their importance in predicting lightning occurrence and colorized to highlight their occurrence in each equation.

Pre-Lightning	***Ramp-Up***	***Lightning***	***Ramp-Down***	***Post-Lightning***
Thompson Index	Thompson Index Flow Regime Persistence	Thompson Index Flow Regime Persistence	Thompson Index Flow Regime Vertical Totals	Flow Regime Lifted Index

Equation Testing

Ms. Crawford used the predictors from the verification dataset in the Phase II and III equations to produce 'forecast' probabilities for the tests. Using the verification dataset provided an assessment of equation performance that could be used to conclude how the equations will perform in future operations. She compared the forecast methods using the Brier Skill Score (Wilks 2006), which is a measure of equation performance versus other forecast methods. In this case, it would be Phase III performance versus 1-day persistence and the daily climatological, flow regime, sub-seasonal, and Phase II probabilities.

In Phase II, an equation was developed for each month, May–September. In order to conduct a fair comparison, Ms. Crawford stratified the verification data by month for the calculations, and used the Phase II flow regime values. After she calculated the probabilities for each month, she re-stratified the data into sub-seasons for comparison with the Phase III probabilities.

The Phase III probabilities were calculated for all sub-seasons, May–October. Ms. Crawford could not compare the performance of the post-lightning sub-season equation to the Phase II equations since there was not an October equation from that work. The ramp-down season was compared, but only using data through the end of September. This caused 39 days out of 197 (~20%) in the ramp-up verification dataset to be excluded from the comparison.

The Brier Skill Scores for each of the Phase III equations and a composite result for the entire warm season are shown in **Table 2**. The Phase III equations show 7–57% improvement in skill over the first four methods in the table. However, their performance against the Phase II equations was poor. In no sub-season did the Phase III equations outperform the Phase II equations.

The degradation in skill of the Phase III equations could have several causes. The development datasets for the pre-lightning and ramp-up seasons had fewer samples than the monthly datasets in Phase II. More cases may result in better predictor selection. However, the lightning and ramp-down sub-seasons had more samples in their development datasets and the equations were still under-performers. The data were not stratified by sub-season in each individual year, but the same start dates were used in every year. It is likely there was overlap of sub-season days at the beginning and end of each sub-season in each individual year, which could affect equation performance. Regardless of the cause, the Phase III equations produced a degradation in skill and will not be transitioned to operations.

Final Report

Ms Crawford wrote an initial draft of the final report and submitted it for internal AMU review. Once an external customer review is completed and Ms. Crawford makes the appropriate modifications to the report, it will be distributed to the customers. She will post it on the AMU website when she receives NASA approval.

Contact Ms Crawford at 321-853-8130 or crawford.winnie@ensco.com for more information.

Table 2. Percent (%) improvement or degradation (red) in skill of Phase III over Phase II and other standard forecast methods.

Forecast Method	***Pre-Ltg***	***Ramp-Up***	***Ltg***	***Ramp-Dn***	***Post-Ltg***	***Season***
Persistence	52	48	51	47	57	50
Daily Climatology	17	18	25	23	23	23
Sub-Season Climatology	18	22	25	27	21	31
Flow Regime	7	13	7	15	18	11
Phase II Equations	-12	-12	-0.6	-4.1	__	-3.6

Peak Wind Tool for General Forecasting, Phase II (Mr. Barrett)

The expected peak wind speed for the day is an important element in the daily morning forecast for ground and space launch operations at KSC and CCAFS. The 45 WS must issue forecast advisories for KSC/CCAFS when they expect peak gusts to exceed 25, 35, and 50 kt thresholds at any level from the surface to 300 ft. In Phase I of this task (Barrett and Short 2008), the AMU developed a tool to help forecast the highest peak non-convective wind speed, the timing of the peak speed, and the average wind speed at the time of the peak wind from the surface to 300 ft on KSC/CCAFS for the cool season (October – April). For Phase II, the 45 WS requested that additional observations be used in the creation of the forecast equations by expanding the POR. In Phase I, the data set included observations from October 2002 to February 2007. In Phase II, observations from March and April 2007 and October 2007 to April 2008 were added. To increase the size of the data set even further, the AMU added data prior to October 2002. Additional predictors were evaluated, including wind speeds between 500 ft and 3000 ft, static stability classification, Bulk Richardson Number, mixing depth, vertical wind shear, inversion strength and depth, wind direction, synoptic weather pattern and precipitation. Using an independent data set, the AMU compared the performance of the Phase I and II tools for peak wind speed forecasts. The Phase II equations had better performance and were transitioned to operations.

As in Phase I, the tool was delivered as a Microsoft Excel GUI. In addition, at the request of the 45 WS, the AMU made the tool available in MIDDS, their main weather display system. This allows the tool to ingest observational and model data automatically and produce 5-day forecasts quickly.

Final Report and Training

Mr. Barrett provided training on the Peak Wind Tool to the 45 WS. covering how to use the Excel and MIDDS versions of the tool. He also completed the first draft of the final report and modified it based on recommendations received from internal AMU and external customer reviews. He then distributed the report to the customers and submitted a request to NASA for public release of the report.

Contact Mr. Barrett at barrett.joe@ensco.com for

MESOSCALE MODELING

Verify MesoNAM Performance (Dr. Bauman)

The 45 WS launch weather officers use the 12-km NAM (MesoNAM) text and graphical product forecasts extensively to support launch weather operations. However, the actual performance of the model has not been measured objectively. In order to have tangible evidence of model performance, the 45 WS tasked the AMU to conduct a detailed statistical analysis of model output compared to observed values. The model products are provided to the 45 WS by ACTA, Inc. and include hourly forecasts from 0 to 84 hours based on model initialization times of 00, 06, 12 and 18 UTC. The objective analysis will compare the MesoNAM forecast winds, temperature and dew point, as well as the changes in these parameters over time, to the observed values from the sensors in the KSC/CCAFS wind tower network shown in **Table 3**. Objective statistics will give the forecasters knowledge of the model's strength and weaknesses, which will result in improved forecasts for operations.

GUI Update and Final Report

Dr. Bauman updated the GUI to include data from the additional sensor heights shown in the far right column of Table 3. He delivered the updated GUI to the 45 WS in July. The final report was completed in September and uploaded to the AMU web site.

For more information contact Dr. Bauman at 321-853-8202 or bauman.bill@ensco.com

Table 3. Towers, launch activities and sensor heights at KSC and CCAFS used in the objective analysis to verify the MesoNAM forecasts. Additional sensor heights were added last quarter as shown in the right hand column.

Tower Number	*Supported Activity and Facility*	*Original Sensor Heights (ft)*	*Additional Sensor Heights (ft)*
002	Delta II (LC-17)	6, 54, 90	145, 204
006	Delta IV (LC-37) / Falcon 9 (LC-40)	54	6, 12, 162, 204
0108	Delta IV (LC-40) / Falcon 9 (LC-40)	54	6, 12
0110	Atlas V (LC-41) / Falcon 9 (LC-40)	54, 162, 204	6, 12
0041	Atlas V (LC-41)	230	—
393 / 394	Shuttle / Constellation (LC-39A)	60	—
397 / 398	Shuttle / Constellation (LC-39B)	60	—
511 / 512 / 513	Shuttle Landing Facility	6, 30	—

ADAS Update and Maintainability (Dr. Watson)

Both the National Weather Service in Melbourne, Fla. (NWS MLB) and the Spaceflight Meteorology Group (SMG) have used a local data integration system (LDIS) since 2000 and routinely benefit from the frequent analyses. The LDIS uses the Advanced Regional Prediction System (ARPS) Data Analysis System (ADAS) package as its core, which integrates a wide variety of national and local-scale observational data. The LDIS provides accurate depictions of the current local environment that help with short-term hazardous weather applications and aid in initializing the local Weather Research and Forecasting (WRF) model. However, over the years the LDIS has become problematic to maintain since it depends on AMU-developed shell scripts that were written for an earlier version of the ADAS software. The goal of this task is to update the NWS MLB/SMG LDIS with the latest version of ADAS and upgrade and modify the AMU-developed shell scripts written to govern the system. In addition, the previously developed ADAS GUI will be updated.

Optimize Error Statistics

The quality of the ADAS analyses is affected by user-configurable error parameters. Large (small) errors assigned to a data source result in a smaller (larger) influence of that data on the nearby grid points. Dr. Watson examined a set of control error parameters assigned to the observations, and then varied them to determine how much the background field was modified by the observations with a different set of error parameters. She did this to find out if the ADAS analyses could be improved by optimizing the error parameters for the Meteorological Assimilation Data Ingest System (MADIS) mesonet data.

The first test involved reducing the observational error variances to half of their control values while the second doubled the error variances. The results from both tests revealed that varying the error parameters for each data source had little impact on the ADAS analyses. The primary change that took place was an increase (decrease) in magnitude of some of the observational "bull's eyes" due to the greater (lesser) weight assigned to the observations. In addition, multiple data sets available from MADIS did not have enough hourly observations available to fully optimize the error parameters. Therefore, Dr. Watson left the values of error used in the previous version of the LDIS scripts unaltered, and she created new error parameter files for the MADIS data will use the same error statistics.

Site Visits

Dr. Watson visited both NWS MLB and SMG to install and configure the LDIS scripts on their local Linux systems. She included installation instructions and a user's guide in the final report.

Final Report

Dr. Watson completed the final report after making modifications from internal AMU and external customer reviews. It will be distributed and posted on the AMU website when she receives NASA approval.

For more information contact Dr. Watson at watson.leela@ensco.com or 321-853-8264.

References

Barrett, J. H. and D. A. Short, 2008: Peak Wind Tool for General Forecasting Final Report. NASA Contractor Report CR-2008-214743, Kennedy Space Center, FL, 59 pp. [Available from ENSCO, Inc., 1980 N. Atlantic Ave., Suite 830, Cocoa Beach, FL, 32931 and http://science.ksc.nasa.gov/amu/final-stfi.html]

Lambert, W. and M. Wheeler, 2005: Objective lightning probability forecasting for Kennedy Space Center and Cape Canaveral Air Force Station. NASA Contractor Report CR-2005-212564, Kennedy Space Center, FL, 54 pp. [Available from ENSCO, Inc., 1980 N. Atlantic Ave., Suite 830, Cocoa Beach, FL, 32931, and http://science.ksc.nasa.gov/amu/final-stfi.html]

Lambert, W., 2007: Objective lightning probability forecasting for Kennedy Space Center and Cape Canaveral Air Force Station, Phase II. NASA Contractor Report CR-2007-214732, Kennedy Space Center, FL, 59 pp. [Available from ENSCO, Inc., 1980 N. Atlantic Ave., Suite 830, Cocoa Beach, FL, 32931, and http://science.ksc.nasa.gov/amu/final-stfi.html]

Merceret, F.J. and J.C. Willett, 2010: *A History of the Lightning Launch Commit Criteria and the Lightning Advisory Panel for America's Space Program*, NASA/SP-2010-216283, August, 2010, 234 pp.

Wilks, D. S., 2006: *Statistical Methods in the Atmospheric Sciences*. 2d ed. Academic Press, Inc., San Diego, CA, 467 pp.

World Meteorological Association (WMO), 1992: *Methods of Interpreting Numerical Weather Prediction Output for Aeronautical Meteorology*. Technical Note No. 195, ISBN 92-63-10770-X, 89 pp

AMU ACTIVITIES

AMU Chief's Technical Activities (Dr. Merceret)

Dr. Merceret and Dr. Willett completed editing the history of the Lightning Advisory Panel and the Lightning Launch Commit Criteria. It is now available to the public (Merceret and Willett, 2010). Dr. Merceret continued contributing as an author to the companion Rationale document and was also appointed as a co-editor of that document. The internal, Government-only version of the Rationale was completed except for final editing.

AMU OPERATIONS (AMU Team)

IT

Dr. Bauman and Mr. Barrett completed the annual testing of the Contingency and System Security Plans.

Conferences, Meetings, and Training:

The following posters and presentation were completed for the for the 35th National Weather Association Annual Meeting in Tucson, Ariz., 2-7 Oct 2010:

- Mr. Barrett prepared a poster titled "Tool For Forecasting Cool-Season Peak Winds Across Kennedy Space Center and Cape Canaveral Air Force Station, Phase II".
- Ms. Crawford prepared a poster titled "Modifications to the Objective Lightning Probability Forecast Tool at Kennedy Space Center / Cape Canaveral Air Force Station, Florida".
- Dr. Bauman prepared a presentation titled "Statistical Analysis of Model Data for Operational Space Launch Weather Support at Kennedy Space Center and Cape Canaveral Air Force Station".

Mr. Roeder of the 45 WS will present both posters and the oral presentation on behalf of the AMU.

Launch Support

Ms. Crawford and Dr. Merceret supported the Atlas V launch on 14 August.

Personnel Changes

Due to a reduction in AMU funding in FY11, the AMU staff was reduced from 5 full time equivalents (FTE) to 4 FTE. Mr. Barrett was reassigned to a new position at ENSCO and his last work day in the AMU was 1 October 2010.

LIST OF ACRONYMS

14 WS	14th Weather Squadron
30 SW	30th Space Wing
30 WS	30th Weather Squadron
45 RMS	45th Range Management Squadron
45 OG	45th Operations Group
45 SW	45th Space Wing
45 SW/SE	45th Space Wing/Range Safety
45 WS	45th Weather Squadron
ADAS	ARPS Data Analysis System
AFSPC	Air Force Space Command
AFWA	Air Force Weather Agency
AMU	Applied Meteorology Unit
ARPS	Advanced Regional Prediction System
CCAFS	Cape Canaveral Air Force Station
CSR	Computer Sciences Raytheon
FSU	Florida State University
FY	Fiscal Year
GSD	Global Systems Division
GUI	Graphical User Interface
JSC	Johnson Space Center
KSC	Kennedy Space Center
LAP	Lightning Advisory Panel
LDIS	Local Data Integration System
LWO	Launch Weather Officer
MADIS	Meteorological Assimilation Data Ingest System
MesoNAM	12-km resolution NAM
MIDDS	Meteorological Interactive Data Display System
MSFC	Marshall Space Flight Center
NAM	North American Mesoscale Model
NOAA	National Oceanic and Atmospheric Administration
NWS MLB	National Weather Service in Melbourne, FL
POR	Period of Record
SMC	Space and Missile Center
SMG	Spaceflight Meteorology Group
USAF	United States Air Force
UTC	Universal Coordinated Time
WMO	World Meteorological Organization
WRF	Weather Research and Forecasting Model

The AMU has been in operation since September 1991. Tasking is determined annually with reviews at least semi-annually.

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They are also available in electronic format via email. If you would like to be added to the email distribution list, please contact Ms. Winifred Crawford (321-853-8130, crawford.winnie@ensco.com).

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NASA DFRC/RA/E. Teets
NASA LaRC/M. Kavaya
45 WS/CC/E. Borelli
45 WS/DO/L. Shoemaker
45 WS ADO/W. Whisel
45 WS/DOR/M. McAleenan
45 WS/DOR/M. Buchanan
45 WS/DOR/K. Josephson
45 WS/DOR/R. Parker
45 WS/DOR/F. Flinn
45 WS/DOR/ T. McNamara
45 WS/DOR/J. Tumbiolo
45 WS/DOR/K. Winters
45 WS/SYA/B. Boyd
45 WS/SYR/W. Roeder
45 RMS/CC/W. Rittershaus
45 SW/CD/G. Kraver
45 SW/SESL/K. Womble
45 SW/XPR/R. Hillyer
45 OG/CC/J. Ross
45 OG/TD/C. Olive
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CSR 7000/M. Maier
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SMC/RNP/T. Nguyen
SMC/RNP/R. Bailey
SMC/RNP(PRC)/K. Spencer
HQ AFSPC/A3FW/J. Carson
HQ AFWA/A3/5/M. Surmeier
HQ AFWA/A8TP/G. Brooks
HQ AFWA/A5R/M. Gremillion
HQ USAF/A30-W/R. Stoffler
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NOAA “W/NP”/L. Uccellini
NOAA/OAR/SSMC-I/J. Golden
NOAA/NWS/OST12/SSMC2/ J. McQueen
NOAA Office of Military Affairs/ M. Babcock
NWS Melbourne/B. Hagemeyer
NWS Melbourne/D. Sharp
NWS Melbourne/S. Spratt
NWS Melbourne/P. Blottman
NWS Melbourne/M. Volkmer
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NWS Southern Region HQ/“W/ SR3”/D. Billingsley
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