AMU Applied Meteorology Unit

Quarterly Report
Third Quarter FY-14
31 July 2014

Infusing Weather Technology Into Aerospace Operations

Contract NNK12MA53C/DRL-003 DRD-004

In this issue:

Atlas 5 carrying a payload for the National Reconnaisssance Office on 22 May 2014 (Image credit: Spaceflight Now www.spaceflightnow.com/atlas/av046/launch/)

Launch Support

Ms. Crawford supported the Atlas 5 NROL-67 launch on 10 April.

Ms. Shafer supported the Falcon 9 CRS 3 launch on 18 April.

Dr. Watson supported the Delta 4 GPS launch on 16 May.

Dr. Bauman supported the Atlas 5 NROL-33 launch on 22 May.

This Quarter's Highlights

The AMU team continued work on five tasks for their customers:

- Ms. Crawford continued working to create a merged velocity display and began writing the final report.
- Dr. Bauman completed the final report for the task to find software packages that could display radar and lightning data for use in evaluating lightning launch commit criteria (LLCC).
- Dr. Bauman began transitioning the 915-MHz and 50-MHz Doppler Radar Wind Profiler (DRWP) splicing algorithm developed at Marshall Space Flight Center (MSFC) into the AMU Upper Winds Tool.
- Dr. Watson continued working to assimilate data into model configurations for Wallops Flight Facility (WFF) and Kennedy Space Center/Cape Canaveral Air Force Station (KSC/CCAFS).
- Ms. Shafer continued setting up a local high-resolution model that she will evaluate for its ability to forecast weather elements that affect launches at KSC/CCAFS.

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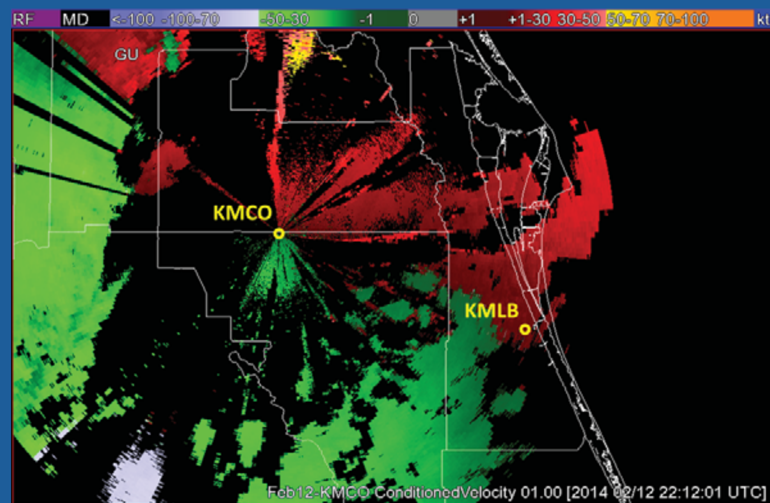
Quarterly Task Summaries

This section contains summaries of the AMU activities for the third quarter of Fiscal Year 2014 (April—June 2014). 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.

Configuration and Evaluation of a Dual-Doppler 3-D Wind Field System (Page 5)

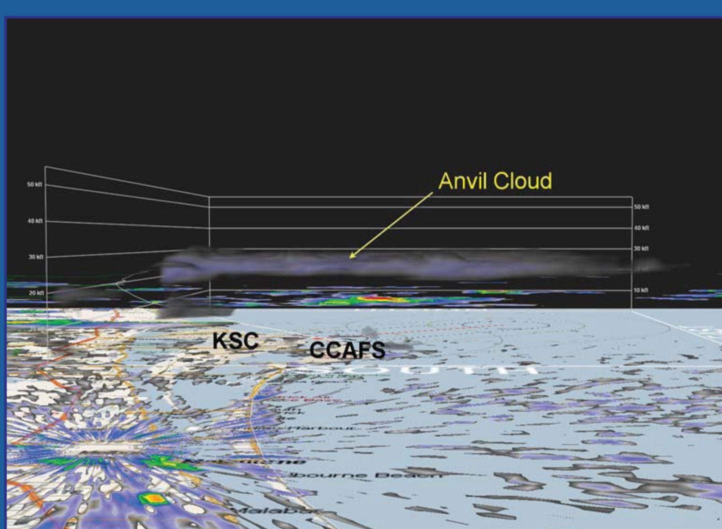
Customers: NASA's Launch Services Program (LSP), Ground Systems Development and Operations (GSDO), and Space Launch System (SLS) programs; and the National Weather Service in Melbourne, Florida (NWS MLB).

Purpose: Current LSP and GSDO and future SLS operations will be halted when winds exceed defined thresholds or when lightning is a threat. A wind field display showing areas of high winds or convergence, especially over areas with no observations, would be useful to 45th Weather Squadron (45 WS) and NWS MLB forecasters in predicting the onset of vehicle-critical weather phenomena, and can be used to initialize a local numerical weather prediction model to improve forecasts of these phenomena. Having a three-dimensional (3-D) wind field over the KSC/CCAFS area using freely available software and data from the three local Doppler weather radars will aid in using ground processing and space launch resources more efficiently by stopping or starting work in a timely manner.



Accomplished: Used the tools in the Weather Decision Support System—Integrated Information (WDSS-II) to create a merged velocity field with the NWS MLB Weather Surveillance Radar 1988-Doppler (WSR-88D) and Orlando International Airport (MCO) Terminal Doppler Weather Radar (TDWR) data, but was unsuccessful. Began writing the final report.

Three-Dimensional Lightning Launch Commit Criteria Visualization Tool Market Research (Page 7)



Customers: NASA's LSP and SLS program.

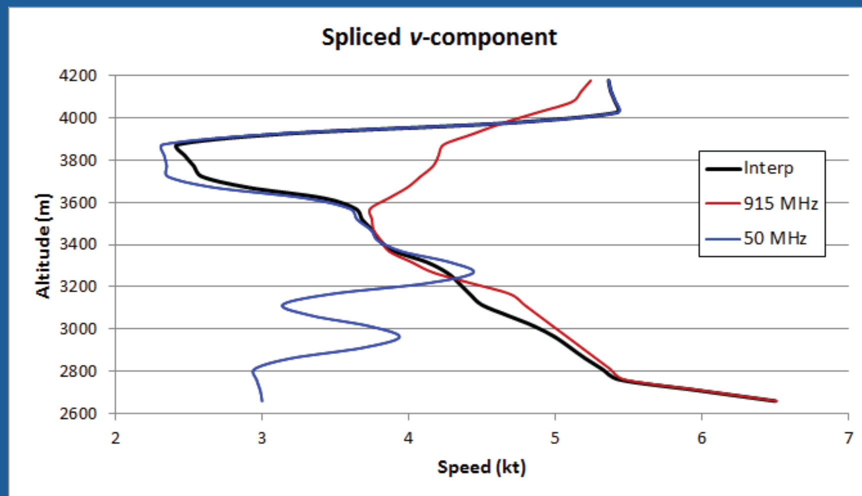
Purpose: NASA's LSP customers and the future SLS program cannot launch if lightning is within 10 NM of the pre-determined flight path of a launch vehicle. The 45 WS Launch Weather Officers (LWOs) evaluate this LLCC to ensure the safety of the vehicle in flight. The AMU will conduct a market research of commercial, government, and open source software that might be able to ingest and display 3-D lightning data from the KSC Lightning Mapping Array (LMA), local weather radar, and the vehicle flight path so that all can be visualized together. Currently, the LWOs analyze distance between lightning and the flight path subjectively using data from different display systems. Having the lightning data, weather radar reflectivity, and flight path are together in one 3-D display would greatly reduce the ambiguity in evaluating this LLCC.

Accomplished: Completed writing the final report. It was reviewed internally and externally by customers before distribution and is awaiting NASA approval for posting on the AMU website.

Quarterly Task Summaries
(continued)

Transition MSFC Wind Profiler Splicing Algorithm to LSP Upper Winds Tool (Page 7)

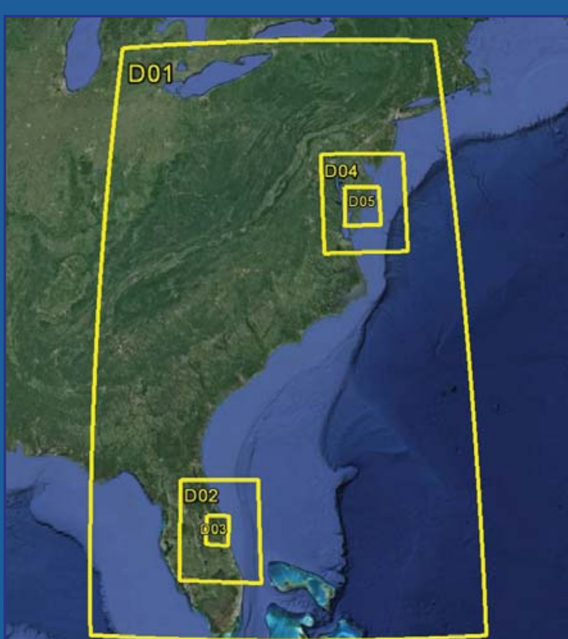
Customers: NASA's LSP and SLS program.



Purpose: NASA's LSP customers and the future SLS program rely on observations of upper-level winds for steering, loads, and trajectory calculations for the launch vehicle's flight. On the day of launch, the 45 WS LWOs monitor the upper-level winds and provide forecasts to the launch team via the AMU-developed LSP Upper Winds tool. The goal of this task is to splice the wind speed and direction profiles from the 45th Space Wing (45 SW) 915-MHz DRWPs and KSC 50-MHz DRWP at altitudes where the wind profiles overlap to create a smooth profile. In the first version of the LSP Upper Winds tool, the top of the 915-MHz DRWP wind profile and the bottom of the 50-MHz DRWP were not spliced, creating a discontinuity in the profile. The MSFC Natural Environments Branch (NE) created algorithms to splice the wind profiles from the two sensors to generate an archive of vertically complete wind profiles for the SLS program. The AMU worked with MSFC NE personnel to implement these algorithms in the LSP Upper Winds tool to provide a continuous spliced wind profile.

Accomplished: Reviewed the MSFC NE splicing algorithm documentation. Transitioned the MATLAB® functions used to develop the splicing algorithms into Excel Visual Basic for Applications (VBA) for interpolating altitudes, filling data gaps, and splicing the wind observations.

Range-Specific High-Resolution Mesoscale Model Setup (Page 10)



Customers: NASA's LSP, GSDO, and SLS programs.

Purpose: Establish a high-resolution model with data assimilation for the Eastern Range (ER) and WFF to better forecast a variety of unique weather phenomena that affect NASA's LSP, GSDO, and future SLS programs daily and launch operations. Global and national scale models cannot properly resolve important local-scale weather features due to their coarse horizontal resolutions. A properly tuned model at a high resolution would provide that capability and provide forecasters with more accurate depictions of the future state of the atmosphere.

Accomplished: Reran Gridpoint Statistical Interpolation (GSI)/ Weather Research and Forecasting (WRF) archive cases for two domain configurations over the ER and WFF that were found to have errors in the output. Began validating WRF forecasts against local observation data using the Model Evaluation Tools (MET) verification package.

Quarterly Task Summaries
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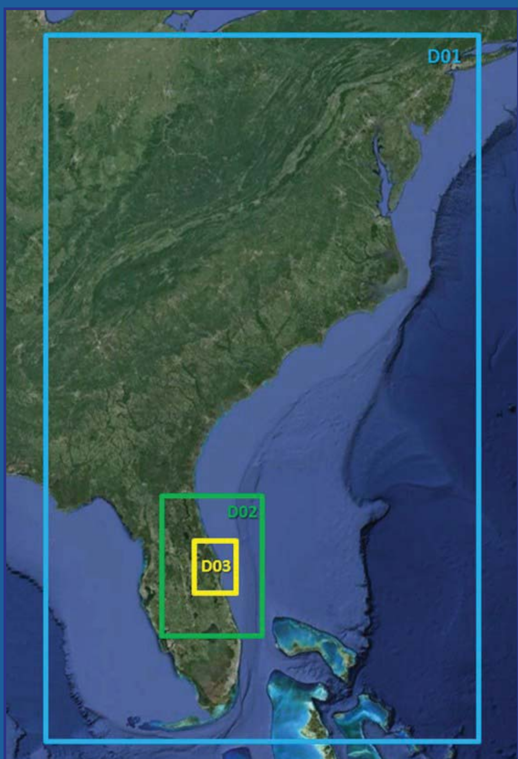
Real-Time KSC/CCAFS High Resolution Model Implementation and Verification (Page 11)



Customers: NASA's LSP, GSDO, and SLS programs.

Purpose: Implement a real-time version of the AMU high-resolution WRF Environmental Modeling System (WRF-EMS) model developed in a previous AMU task and determine its ability to forecast the unique weather phenomena that affect NASA's LSP, GSDO, and SLS daily and launch operations on KSC and CCAFS. Implementing a real-time version of WRF-EMS will create a larger database of model output than in the previous task for determining model performance compared to observational data. The AMU will also make the model output available on the AMU and 45 WS Advanced Weather Interactive Processing System II (AWIPS II) for real-time subjective analysis.

Accomplished: Set up Perl scripts to run automatically on the NASA/AMU cluster and generate the MET software statistical output routines, which will be used to verify the WRF-EMS runs. Customized the real-time WRF-EMS output to continually ingest and display each model domain separately in AWIPS II. Made the model output available in the AWIPS II volume browser to make the model fully accessible to users.

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.

INSTRUMENTATION AND MEASUREMENT

Configuration and Evaluation of a Dual-Doppler 3-D Wind Field System (Ms. Crawford)

Current LSP, GSDO, and future SLS space vehicle operations will be halted when wind speeds from specific directions exceed defined thresholds and when lightning is a threat. Strong winds and lightning are difficult parameters for the 45 WS to forecast, yet are important in the protection of customer vehicle operations and the personnel that conduct them. A display of the low-level horizontal wind field to reveal areas of high winds or convergence would be a valuable tool for forecasters in assessing the timing of high winds, or convection initiation (CI) and subsequent lightning occurrence. This is especially important for areas where no other weather observation platforms exist, such as inland west of the KSC/CCAFS area or east over the Atlantic Ocean. Developing a dual-Doppler capability would provide such a display to assist the 45 WS and NWS MLB forecasters in predicting high winds and CI. The wind fields can also be used to initialize a local mesoscale numerical weather prediction model to help improve the model forecast winds, CI, and other phenomena. Finally, data combined from two or more radars will lessen radar geometry problems such as the cone of silence and beam blockage. This display will aid in using ground processing and space launch resources more efficiently by stopping or starting work in a timelier manner. The AMU was tasked by the 45 WS and NWS MLB to develop a dual-Doppler display using data from three local Doppler radars and freely available software to derive the wind field over east-central Florida, especially over the KSC/CCAFS area to support the safety of ground and launch operations. The radars include the 45 SW Weather Surveillance Radar (WSR), NWS MLB WSR-88D, and the Federal Aviation Administration TDWR at MCO.

Merged Velocity

In the last AMU Quarterly Report (Q2 FY14), Ms. Crawford described the method to create a merged reflectivity field from two radars, the MCO TDWR (KMCO) and NWS MLB WSR-88D (KMLB), in WDSS-II. The process is similar in creating merged velocities, with some differences in the inputs to the routines. The merged reflectivity must be created first as it is used as input to the velocity merger routine. The same simulator tool used for the reflectivity merger is used to access the input data for the velocity merger, but it has the merged reflectivity as input. The simulator is started first, and then the velocity merger tool is started in another terminal window.

Ms. Crawford followed this process, but was unsuccessful in creating a merged velocity field as shown in Lakshmanan et al. (2006). She searched the WDSS-II forum for ideas on what input to use in the simulator and merger tools, and asked questions on the forum when those ideas did not work. She also searched the WDSS-II website for documentation on using the merger tool for velocity and tried several configurations of input to the tool, but was still unsuccessful in creating a merged velocity field.

Figure 1 shows the velocity from the KMCO 1.0 degree elevation scan at 2212 UTC on 12 February 2014. The radar locations are indicated by yellow circles. Figure 2 shows the velocity from the KMLB 1.3 degree elevation scan at 2211 UTC, the closest KMLB scan in time to the KMCO scan in Figure 1.

Figure 3 shows the 2211 UTC merged velocity field at 3 km above ground. The text at the bottom of the image states that this is merged aliased velocity, but Ms. Crawford also used de-aliased velocity with the same results. The data field is uniformly purple, in the RF range of the scale at the top. The pattern of black concentric rings around KMCO is unique to this height and time, other heights and times exhibit different patterns of black rings and purple background.

NWS MLB WSR-88D data

In the last AMU Quarterly Report (Q2 FY14), Ms. Crawford reported being unable to process the KMLB data collected directly from the radar in WDSS-II. If WDSS-II is to be run in real-time at NWS-MLB, it must be able to ingest data from the local Radar Product Generator (RPG). Dr. Lakshmanan of the University of Oklahoma suggested an option to try in the processing tool, which worked. The data directly from the KMLB RPG can be processed by the code.

Status

Part of the task was to determine the time delay between ingesting the data and creating the output. Based on a preliminary analysis, Ms. Crawford determined that the radar data can be input, processed and displayed in near real-time for operational support.

Ms. Crawford began writing the final report while continuing to make attempts at creating merged wind fields in WDSS-II without success. She is now focusing only on finishing the final report.

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

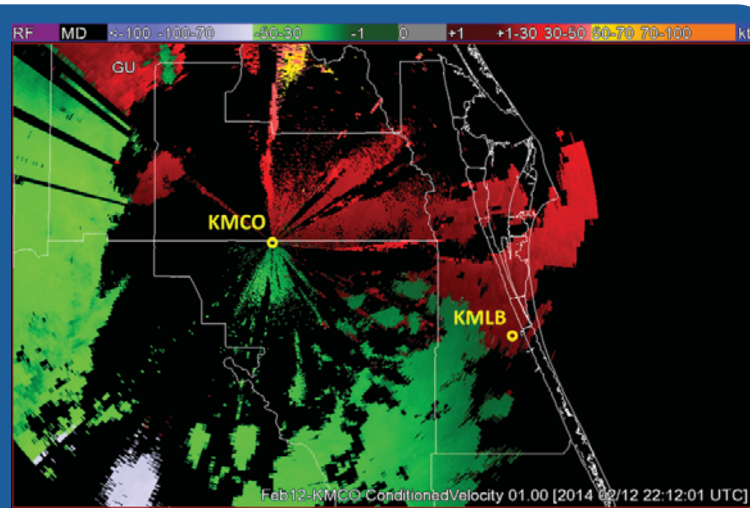


Figure 1. The KMCO velocity at 2212 UTC 12 February 2014, elevation angle 1.0 degrees. The yellow circles show the locations of the KMCO and KMLB radars.

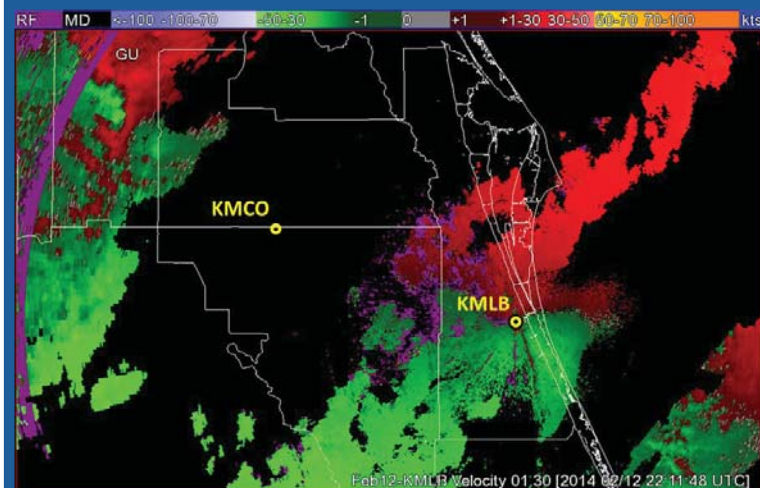


Figure 2. The KMLB velocity at 2211 UTC 12 February 2014, elevation angle 1.3 degrees. The yellow circles show the locations of the KMCO and KMLB radars.

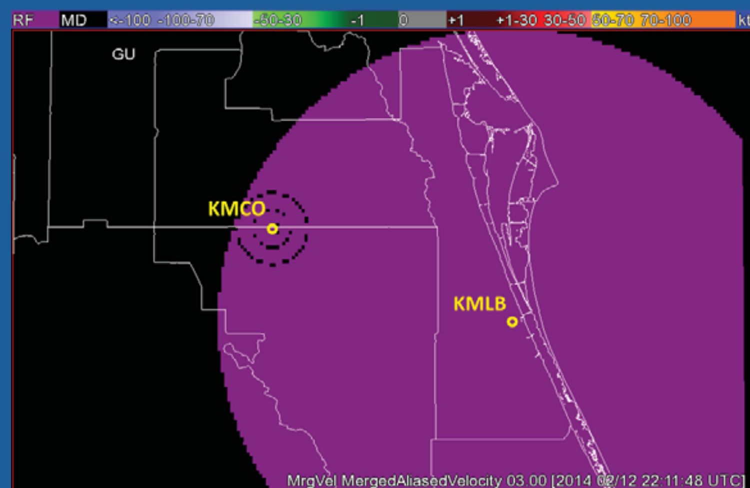


Figure 3. The KMCO and KMLB merged velocity at 2211 UTC 12 February 2014, height of 3 km. The yellow circles show the locations of the KMCO and KMLB radars.

Three Dimensional Lightning Launch Commit Criteria Visualization Tool (Dr. Bauman)

Lightning occurrence too close to a NASA LSP or future SLS program launch vehicle in flight would have disastrous results. The sensitive electronics on the vehicle could be damaged to the point of causing an anomalous flight path and ultimate destruction of the vehicle and payload. According to 45 WS LLCC, a vehicle cannot launch if lightning is within 10 NM of its pre-determined flight path. The 45 WS LWOs evaluate this LLCC for their launch customers to ensure the safety of the vehicle in flight. Currently, the LWOs conduct a subjective analysis of the distance between lightning and the flight path using data from different display systems. A 3-D display in which the lightning data and flight path are together would greatly reduce the ambiguity in evaluating this LLCC. It would give the LWOs and launch directors more confidence in whether a GO or NO GO for launch should be issued. When lightning appears close to the path, the LWOs likely err on the side of conservatism and deem the lightning to be within 10 NM. This would cause a costly delay or scrub. If the LWOs can determine with a strong level of certainty that the lightning is beyond 10 NM, launch availability would increase without compromising safety of the vehicle, payload or, in the future, astronauts. The AMU was tasked by their customers to conduct a market research of commercial, government, and open source software that might be able to ingest and display the 3-D lightning data from the KSC LMA, the 45 SW WSR, the NWS MLB WSR-88D, and the vehicle flight path data so that all can be visualized together. To accomplish this, the AMU conducted Internet searches for potential software candidates, interviewed software developers, and determined data availability. The AMU recommended the NASA KSC Weather Office request more information on the candidate software packages to determine the development costs needed to meet the full 3-D data display requirements required by the 45 WS LWOs.

LAP Consultation

Dr. Bauman provided a summary of work completed on this task to Dr. Huddleston so she could present it at the Lightning Advisory Panel (LAP) meeting. The LAP requested a status of their recommendations for upgrades to weather displays in Range Weather Operations (RWO).

Dr. Bauman talked to Dr. Ken Cummins, a member of the NASA LAP and a research professor in the Department of Atmospheric Sciences at the University of Arizona about this task and the findings thus far. Dr. Cummins believes the NASA Real Time Mission Monitor (RTMM; http://rtmm.nsstc.nasa.gov/) software may be capable of meeting the requirements with some development. During his market research, Dr. Bauman confirmed RTMM does not yet have true 3-D capability. It can display 3-D data in two dimensions, but this does not meet the LWOs requirements. Dr. Cummins recommended the AMU and KSC Weather Office contact the RTMM developers at MSFC to determine if they can add the 3-D capability.

Final Report

Dr. Bauman completed writing the final report describing the candidate software packages and data needed for the display. It was reviewed internally by the AMU and externally by customers before distribution. He is waiting for NASA Export Control approval before posting the report on the AMU website.

Figure 4. Lightning observations on 11 July 2007 at 2300 UTC from the Vaisala Network displayed in RTMM. Figure 13 from the RTMM Tutorial at http://rtmm.nsstc.nasa.gov/tutorial.html.

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

Transition MSFC Wind Profiler Splicing Algorithm to LSP Upper Winds Tool (Dr. Bauman)

NASA's LSP customers and the future SLS program rely on observations of upper-level winds for steering, loads, and trajectory calculations for the launch vehicle's flight. On the day-of-launch, the 45 WS LWOs monitor the upper-level winds and provide forecasts to the launch team management via the AMU-developed Upper Winds tool. The 45 SW 915-MHz DRWPs and KSC 50-MHz DRWP observations of wind speed and direction can be combined to create one continuous vertical wind profile of speed and direction. The 915-MHz DRWPs measure the winds at altitudes ranging from 285 to 14,560 ft (87–4,438 m) while the 50-MHz DRWP measures winds at altitudes ranging from 8,747 to 61,024 ft (2,700–18,600 m). Even though the nominal altitudes of the sensor's measurements overlap at the top of the 915-MHz DRWPs and bottom of the 50-MHz DRWP, the wind speeds and directions do not necessarily match at that interface. To compensate for this variation, the MSFC NE developed algorithms to splice concurrent measurements from both profilers. The AMU-developed LSP Upper Winds tool uses both DRWP sources to create a continuous profile of winds from approximately 427 to 61,024 ft (130–18,600 m). In the original LSP Upper Winds tool, the 915-MHz DRWP wind profile was cut off to match the bottom altitude of the 50-MHz DRWP wind profile or the wind profiles were connected via a straight line interpolation from the top of the 915-MHz data to the bottom of the 50-MHz data. The straight line interpolation was implemented due to time constraints levied on the task but it does not provide the smoothed profile that can be realized by splicing the data together among overlapping altitudes from both sensors.

Transitioning the Algorithms

The MSFC NE splicing technique was developed using functions available in the MATLAB software. Since the LSP Upper Winds tool was written in Excel using VBA, Dr. Bauman had to manually recreate the MATLAB functions in VBA. Being unfamiliar with MATLAB, he received help from Mr. Barbré of the Jacobs Engineering and Science Services and Skills Augmentation Group at MSFC NE, who developed the splicing algorithms.

Data Gap Analysis

The preprocessing performed on individual 50- and 915-MHz DRWP profiles before splicing entails filling data gaps in the original profile before performing any interpolation. MSFC NE performed an analysis that quantified the maximum tolerable data gap size from the 50- and 915-MHz DRWP profiles (Barbré 2013). Figure 5 shows the root mean square (RMS) of the maximum wind component differences versus gap size for

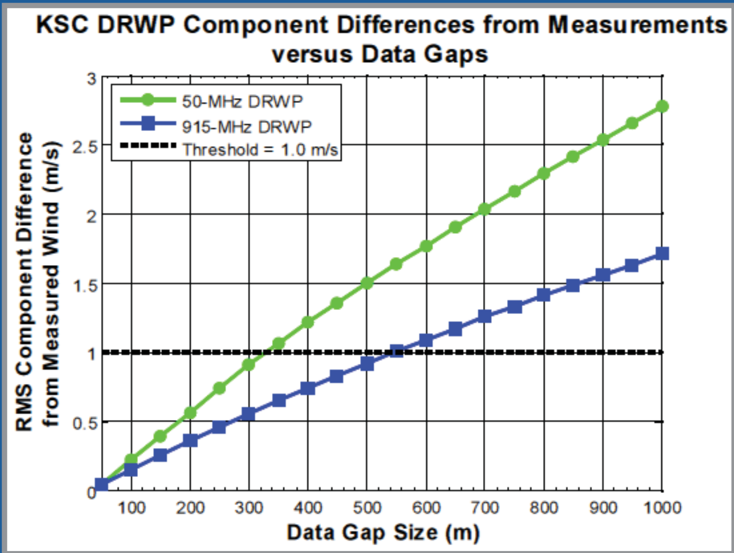


Figure 5. RMS component difference from the measured wind (ms^{-1}) as a function of data gap size (m) for the 50-MHz DRWP (green line) and the 915-MHz DRWP (blue line). The analysis uses the thresholds to determine how many consecutive gaps to tolerate when splicing 50- and 915-MHz DRWP profiles. Figure B2.3 from Barbré (2013).

each sensor. The analysis compared these results with a selected threshold of 1.0 ms^{-1} RMS, which is the 50-MHz DRWP acceptable measurement error (Pinter et al. 2006). No such quantification exists for the 915-MHz measurement error, but the NASA meteorological community considers the 915-MHz DRWP errors to resemble the 50-MHz DRWP errors (Barbré 2013). MSFC NE used the largest gap size that did not exceed the threshold as the criteria. Figure 5 depicts the gap sizes as 300 m for the 50-MHz DRWP analysis and 500 m for the 915 -MHz DRWP analysis.

The 50-MHz DRWP reports observations at 145 m altitude intervals while the 915-MHz DRWP reports observations at 101 m altitude intervals. For the 50-MHz DRWP, Dr. Bauman wrote VBA code to fill data gaps ≤ 290 m by linearly interpolating the wind components through the gap. For the 915-MHz DRWP, he wrote VBA code to fill data gaps ≤ 505 m by linearly interpolating the wind components through the gap. Dr. Bauman chose these values instead of 300 and 500 m because they are multiples of the DRWP altitude intervals.

Interpolating Altitudes

MSFC NE used a MATLAB function called *interp1* to interpolate the 915-MHz and 50-MHz observations from 101 m and 145 m, respectively, to 50-m intervals. Since the AMU does not have a copy of MATLAB, Dr. Bauman was not able to see the code within the MATLAB function but Mr. Barbré was able to outline how the function worked so Dr. Bauman could write the code in VBA. The process requires computing a weighted value, w, for each altitude, actual and interpolated, and applying w to the u- and v-components at each interpolated 50-m altitude. The VBA code computes w by finding the highest altitude (z_{blw}) that is below the altitude of interest, z_i, and the lowest altitude (z_{abv}) that is above the altitude of interest, z_i, using all the observed 145-m interval altitudes, z. The equations for these quantities are

$z_{blw} = \max(z\ (z \le z_i))$

$z_{abv} = \min(z\ (z \ge z_i))$

$w = (z_i - z_{blw}) / (z_{abv} - z_{blw})$. If $z_{abv} = z_{blw}$ then w = 1.

For example, given altitudes at z = 2,666 m and 2,811 m, z_i would include altitudes at 2,666 m, 2,716 m, and 2,766 m, resulting in three values for w at each z_i.

w at z_i = 2,666:

z_{blw} = max ([2,666 ≤ 2,666]) = 2,666

z_{abv} = min ([2,666 ≥ 2,666, 2,811, 2,956, 3,101…]) = 2,666

w = 1 since $z_{abv} = z_{blw}$

w at z_i = 2,716:

z_{blw} = max ([2,666, 2,811, 2,956… ≤ 2,716]) = 2,666

z_{abv} = min ([2,666, 2,811, 2,956… ≥ 2,716]) = 2,811

w = (2,716-2,666)/(2,811-2,666) = 0.34483

w at z_i = 2,766:

z_{blw} = max ([2,666, 2,811, 2,956… ≤ 2,766]) = 2,666

z_{abv} = min ([2,666, 2,811, 2,956… ≥ 2,766]) = 2,811

w = (2,766-2,666)/(2,811-2,666) = 0.68966

To compute the u-component at each interpolated altitude, u_i, use the equation:

$$u_i = (1-w) * u\,(z_{blw}) + w * (z_{abv})$$

Therefore, if u = 6.8 kt at 2,666 m and u = 7.9 kt at 2,811 m, the u-components at the interpolated altitudes are:

At 2,666 m:

u_{2666} = (1-1) * 6.8 + 1 * 6.8 = 6.8 kt

At 2,716 m:

u_{2716} = (1-0.34483) * 6.8 + 0.34483 * 7.9 = 7.2 kt

At 2,766 m:

u_{2766} = (1-0.68966) * 6.8 + 0.68966 * 7.9 = 7.6 kt

Weighting Scheme for Splicing

Once the 915-MHz and 50-MHz DRWPs winds were interpolated to 50-m intervals, MSFC NE used the MATLAB function *gausswin* as a Gaussian weighting function to determine which profiler will have more influence on the resulting wind component values at each height. This function, w(z), is defined by the equation:

$$w(z) = e^{-\frac{1}{2}\left(\alpha \frac{n}{N/2}\right)^2}$$

Where

α = 2.5 (MathWorks 2014)

N = L-1 where L is the number of overlapping altitudes from the 915-MHz and 50-MHz DRWPs

n = (0:N)-N/2

Dr. Bauman ported this equation to Excel and tested it with the 31 overlapping altitudes from 2,666 m to 4,117 m from both DRWPs on 2 January 2014 at 1515 UTC. The resulting Gaussian distribution of w(z) is shown in Figure 6. The cumulative sum of w is normalized by its maximum to produce the chart in Figure 3, which is a plot of the weights used to compute the spliced wind components at the 31 altitudes where the 915-MHz DRWP profile overlaps the 50-MHz DRWP profile. In this case, w starts at 0.0 at 2,666 m, transitions from 0.0-1.0 from 2,666 to 4,117 m, and remains at 1.0 above 4,117 m.

To compute the spliced DRWP wind components, Dr. Bauman used Equation (12) from Barbré (2013) for the u- and v-components, where $w_n(z)$ is the normalized weight shown in Figure 7:

$u(z) = w_n(z) * u_{50}(z) + [1 – w_n(z)] * u_{915}(z)$

$v(z) = w_n(z) * v_{50}(z) + [1 – w_n(z)] * v_{915}(z)$

Applying this equation with the appropriate w_n at each z produces the spliced profile, which fares the 915-MHz DRWP winds into the 50-MHz DRWP winds within the transition region. Figure 8 shows the spliced v-component profile for 1515 UTC 2 January 2014. Note the spliced profile significantly resembles the 915-MHz DRWP profile below approximately 3,400 m and the 50-MHz DRWP profile above 3,400m, which shows the weighting scheme's effect.

Status

Dr. Bauman finished transitioning the MATLAB® functions used to develop the splicing algorithms into VBA for interpolating altitudes, filling data gaps, and splicing the wind observations from the 915-MHz and 50-MHz DRWPs. Next he will copy the VBA code into the LSP Upper Winds Tool and test it to ensure it functions properly with the sounding and model data wind profiles also used in the tool.

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

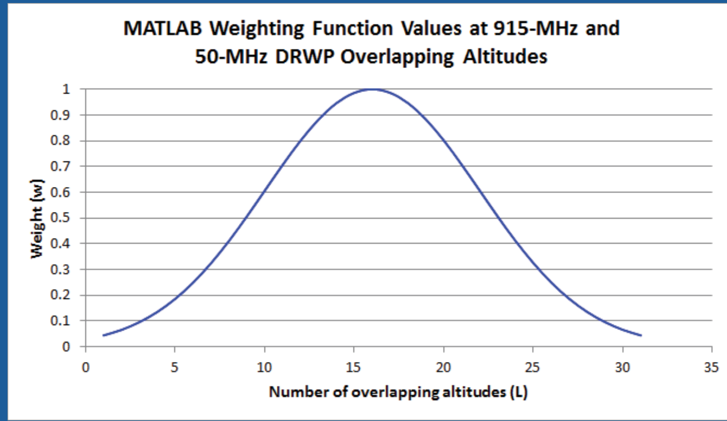


Figure 6. Results after applying the MATLAB Gaussian weighting function to the 31 overlapping altitudes from the 31 concurrent 915-MHz and 50-MHz DRWP profiles. The x- and y-axes denote the number of overlapping altitudes (L) and the weight (w; dimensionless), respectively.

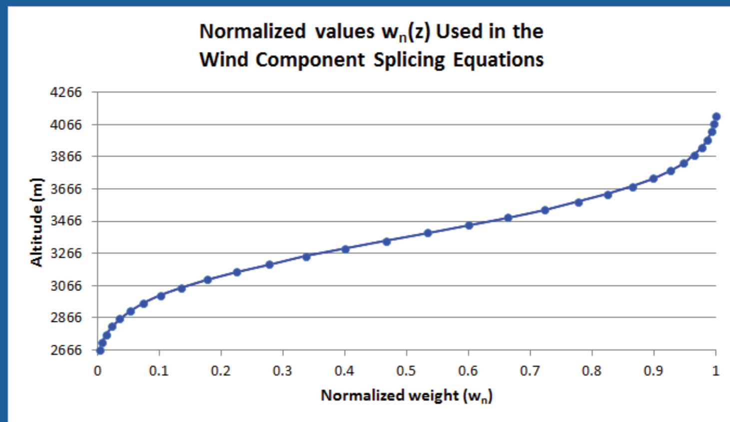


Figure 7. Normalized $w_n(z)$ values used to compute the spliced DRWP wind components for the overlapping altitude region extending from 2,666 to 4,117 m. The x- and y-axes denote the weight (w; dimensionless) and altitude (m), respectively.

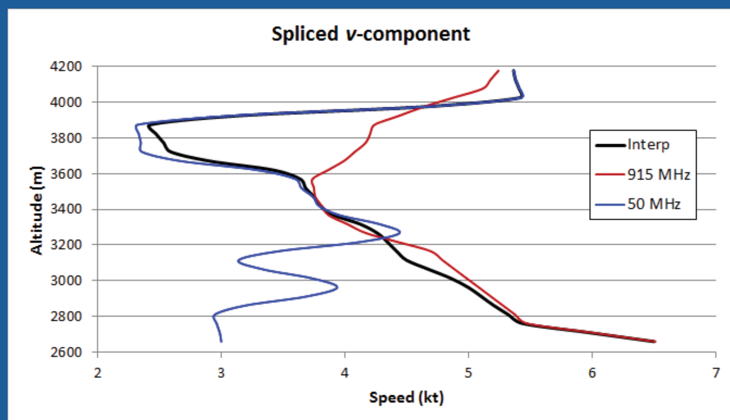


Figure 8. Example v-component (kt) profile versus altitude (m) for 1515 UTC 2 January 2014. Red, blue, and black lines stand for the concurrent 915-MHz, 50-MHz, and spliced DRWP profiles, respectively.

Range-Specific High-Resolution Mesoscale Model Setup: Data Assimilation (Dr. Watson)

The ER and WFF require high-resolution numerical weather prediction model output to provide more accurate and timely forecasts of unique weather phenomena that can affect NASA's LSP, GSDO, and future SLS daily operations and space launch activities. Global and national scale models cannot properly resolve important mesoscale features due to their horizontal resolutions being much too coarse. A properly tuned high-resolution model running operationally will provide multiple benefits to the launch community. This is a continuation of a previously customer-approved task that began in FY12 in which the WRF model was tuned for the ER and WFF (Watson 2013). This task will provide a recommended local data assimilation and numerical forecast model design optimized for the ER and WFF to support space launch activities. The model will be optimized for local weather challenges at both ranges.

Running Archive Cases

Dr. Watson found some errors in previous GSI/WRF model runs after examining the model output. She determined that two domain configurations, the 1-km single domain over the ER (Figure 9) and the 9/3/1-km triple nest domain over the ER and WFF (Figure 10), needed to be rerun. She finished rerunning both sets of domain configurations.

Validation of WRF Forecasts

Dr. Watson began validating the GSI/WRF forecasts against the local observations using the MET verification package. She used two of the statistical verification tools available in MET, the Point-Stat tool and the Method For Object-Based Diagnostic Evaluation (MODE) tool. Point-Stat computes traditional verification scores by comparing the gridded GSI/WRF forecast to the corresponding local point observations. Dr. Watson will compute hourly statistics for mean error, root mean squared error, and correlation coefficient with this tool. The MODE tool applies an object-based verification technique in comparing a gridded forecast to a gridded analysis. The GSI/WRF accumulated precipitation forecasts were compared to the National Centers for Environmental Prediction's Stage IV precipitation data. Both the forecast and observed precipitation data were first re-gridded so that the innermost domain of each WRF configuration for the ER and WFF matched the gridded Stage-IV precipitation data. Once the grids matched, Dr. Watson ran the MODE tool to compute hourly statistics. Dr. Watson is currently analyzing the statistics and putting them into graphical form for the final report.

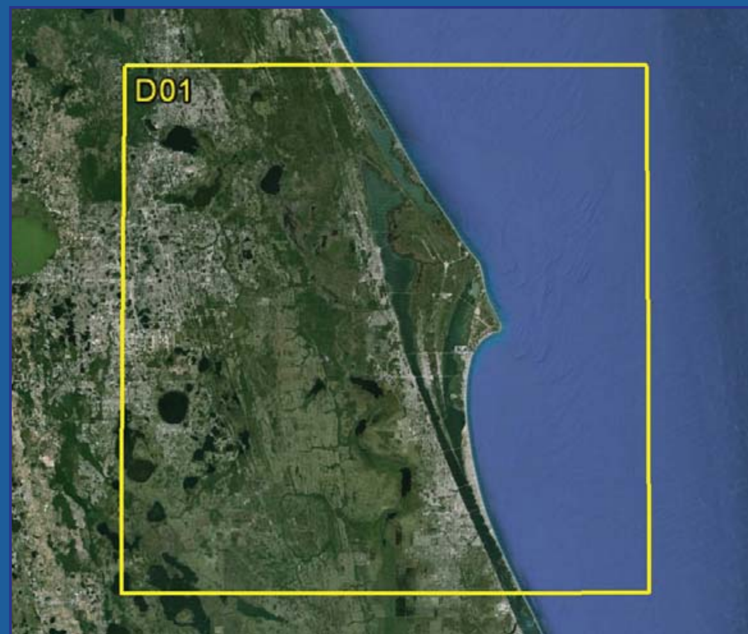


Figure 9. Map of the ER showing 1-km (D01) model domain boundary that was rerun.

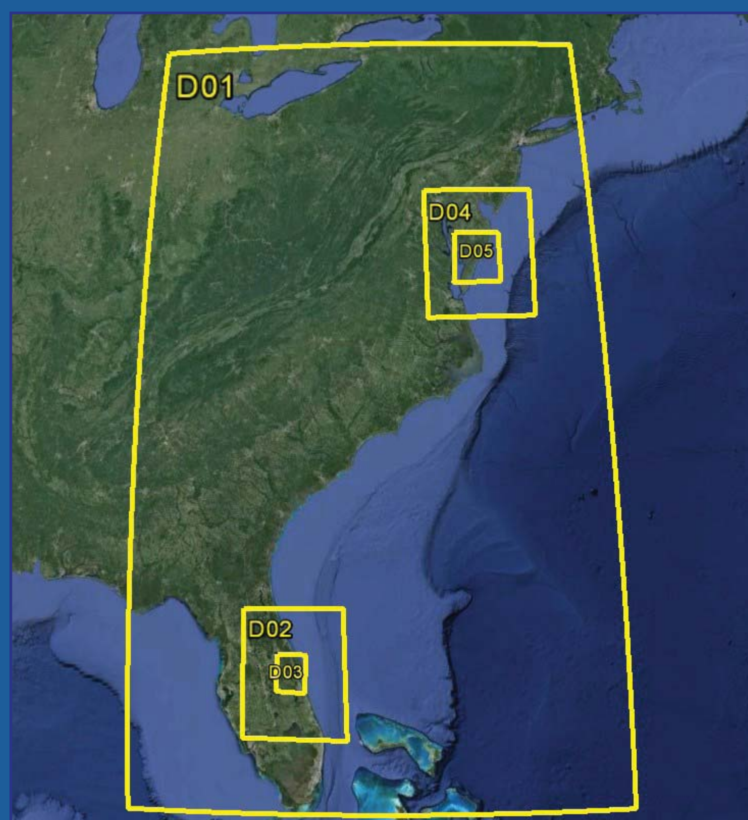


Figure 10. Map of the triple nested configuration showing the 9-km outer (D01), 3-km middle (D02 and D04), and 1-km inner (D03 and D05) model domain boundaries over the ER and WFF that were rerun.

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

Real-time KSC/CCAFS High Resolution Model Implementation and Verification (Ms. Shafer and Dr. Watson)

NASA's LSP, GSDO, SLS and other programs at KSC and CCAFS use the daily and weekly weather forecasts issued by the 45 WS as decision tools for their day-to-day and launch operations on the ER. For example, to determine if they need to limit activities such as vehicle transport to the launch pad, protect people, structures or exposed launch vehicles given a threat of severe weather, or reschedule other critical operations. The 45 WS uses numerical weather prediction models, such as the Air Force Weather Agency (AFWA) 1.67 km WRF model, as a guide for their daily and weekly weather forecasts. Considering the 45 WS forecasters' and LWOs' extensive use of the AFWA model, the 45 WS proposed a task at the September 2013 AMU Tasking Meeting requesting the AMU verify this model. Due to the lack of archived model data available from AFWA, verification is not yet possible. The AMU then proposed to implement and verify the performance of an ER version of the AMU high-resolution WRF-EMS model (Watson 2013) in real-time. The tasking group agreed to this proposal and therefore the AMU will implement the WRF-EMS model on the second of two AMU modeling clusters. The AMU will make the model output available on the AMU AWIPS II servers, which will allow the 45 WS and AMU staff to customize the model output display on the AMU and RWO AWIPS II client computers and conduct real-time subjective analyses. The AMU will also calculate verification statistics to determine model performance compared to observational data. Implementing a real-time version of WRF-EMS will generate a larger database of model output than in the previous task for determining model performance, and will allow the AMU more control over and access to the model output archive.

MET Software Automation

As mentioned in the previous AMU Quarterly Report (Q2 FY14), Ms. Shafer will calculate verification statistics to determine the 1.33-km domain WRF-EMS model performance using the MET software. She will use two of the statistical verification tools available, the Point-Stat Tool and the MODE tool.

The Point-Stat Tool computes traditional verification scores by comparing the WRF-EMS forecast to the corresponding observations. Ms. Shafer will use the mean error, multiplicative bias, and RMS error of the 2-m temperature and dewpoint (K), surface pressure (mb), 10-m wind speed (m/s) and wind direction (degree) as part of the model verification. The MODE tool applies an object-based verification technique in comparing a gridded forecast to a gridded analysis. Table 1 shows the statistics Ms. Shafer will use for the model verification.

Ms. Shafer and Dr. Watson configured the MET tools to input the observation and model output data and produce the desired statistics. Perl scripts run the MET tools and archive the verification statistics output automatically on the NASA/AMU cluster. These scripts are run once a day to produce hourly statistics for the previous day model runs. Ms. Shafer began consolidating the May and June output text files in Microsoft Excel.

WRF-EMS Output into AWIPS II

The AMU agreed to make the WRF-EMS output available in AWIPS II for the 45 WS forecasters and AMU staff. Last quarter, Ms. Shafer contacted Dr. Geoffrey Stano, an ENSCO meteorologist and member of the Short-term Prediction Research and Transition Center (SPoRT), for assistance. Dr. Stano suggested working with Mr. Kevin McGrath, a member of SPoRT and AWIPS II expert, to get the model output into AWIPS II. Ms. Shafer began working with Mr. McGrath and provided him two sample model output files. He was able to successfully ingest these files on the SPoRT AWIPS II system. Ms. Shafer provided Mr. McGrath additional AMU AWIPS II environment information and he generated ingest instructions for the AMU.

After minimal troubleshooting with Mr. McGrath, Ms. Shafer successfully displayed the real-time AMU WRF-EMS output running on the NASA/AMU modeling clusters via the Common AWIPS Visualization Environment (CAVE) on the AWIPS II workstations. She was able to customize the WRF-EMS runs and ingest the three domains separately in order to display each in AWIPS II. Example CAVE screen shots of the 12-, 4- and 1.33-km AMU WRF-EMS model frontogenesis forecast product are shown in Figures 11, 12, and 13, respectively.

Table 1. List of statistics available in the MODE Tool Ms. Shafer will use to verify the model.

Statistic Name	Description
Centroid Distance (km)	Distance between two objects centroids (in grid units)
Area Ratio	Ratio of the areas of two objects defined as the lesser of the forecast area divided by the observation area or its reciprocal (unitless)
Interest	Total interest value computed for a pair of simple objects (unitless)

Ms. Shafer wrote a Perl script that automates the ingest process and updates the model in AWIPS II every hour. She was also able to get the outputs into the Volume Browser in AWIPS II, which makes the model fully accessible to users.

Contact Ms. Shafer at 321-853-8200 or shafer.jaclyn@ensco.com for more information.

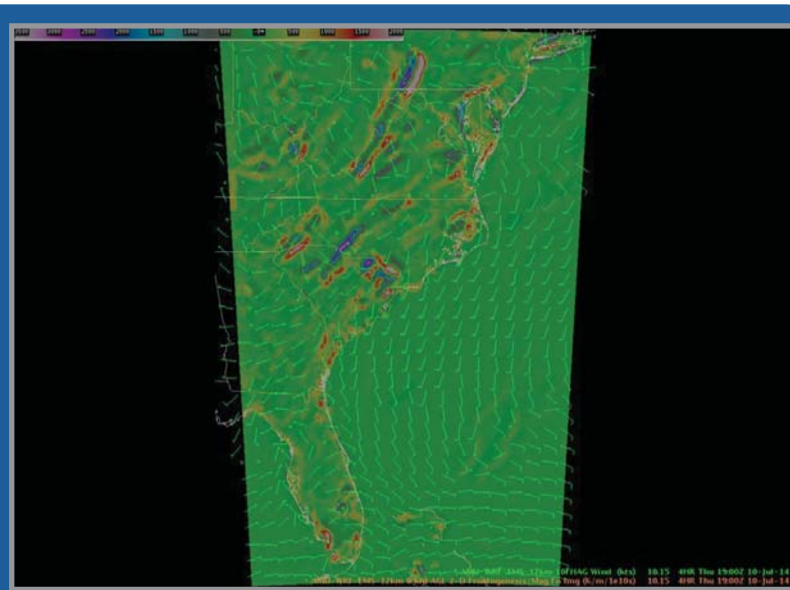


Figure 11. CAVE screen shot of the AMU WRF-EMS 12-km frontogenesis output valid at 1900 UTC on 10 July 2014. The warm colors are frontogenesis and the cool colors are frontolysis.

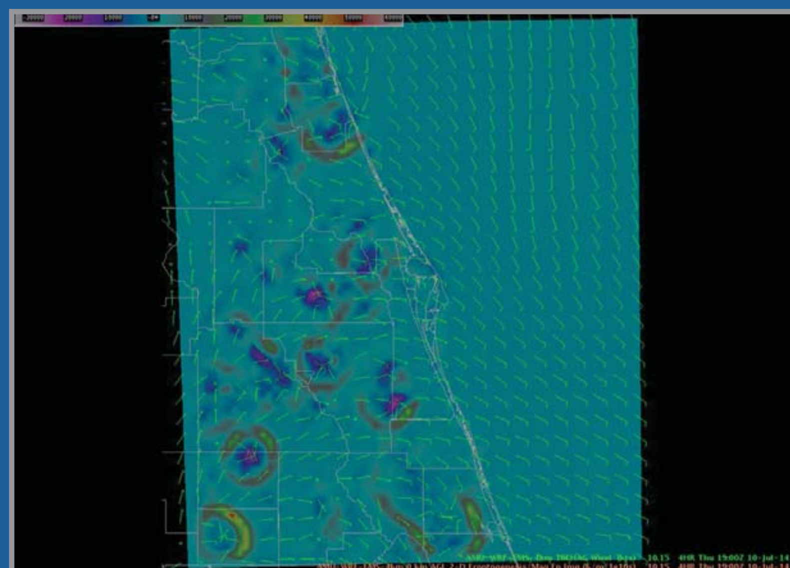


Figure 12. CAVE screen shot of the AMU WRF-EMS 4-km frontogenesis output valid at 1900 UTC on 10 July 2014.

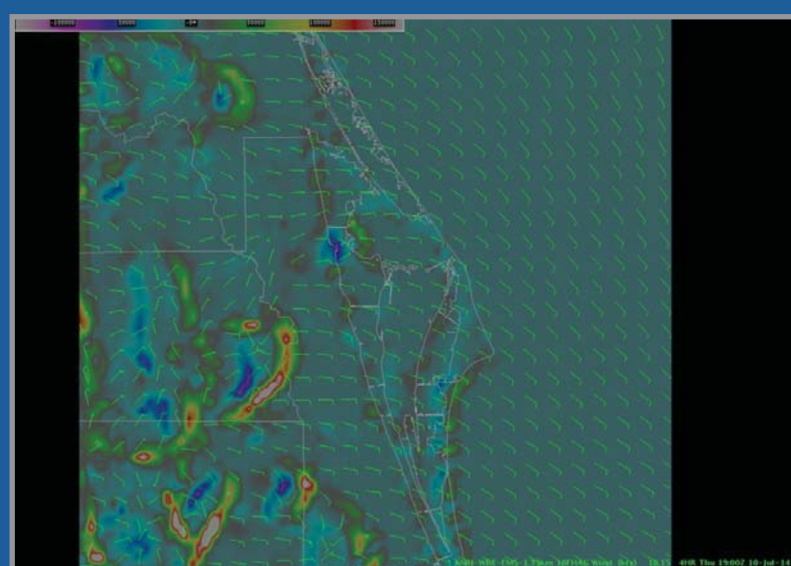


Figure 13. CAVE screen shot of the AMU WRF-EMS 1.33-km frontogenesis output valid at 1900 UTC on 10 July 2014.

The 45 SW Commander, Brig. Gen. Armagno, sent a letter of appreciation for the AMU on behalf of the 45 SW to the KSC Center Director, Mr. Cabana, "…for the outstanding work of the Applied Meteorology Unit (AMU) in improving weather support to America's space program." She also stated that "Their role throughout the past 23 years has been significant with many noteworthy contributions to our wing." She closed her letter by noting the AMU is an irreplaceable force multiplier and that if we were to lose the AMU, it would take years to reestablish.

Meetings

Ms. Crawford attended the inaugural meeting of the KSC Lightning Coordination and Validation Working Group at KSC on 4 April. Dr. Bauman, Ms. Crawford, and Ms. Shafer attended the Launch Commit Criteria Working Group kickoff meeting on 19 June.

Ms. Crawford attended the initial demonstration for the smartphone app WxReport!, an app designed to be used by storm spotters when sending tweets through Twitter about observed severe weather. She assisted Mr. Marc Seibert of NASA in developing the requirements for the initial version with her knowledge of how the NWS uses social media and storm reports. The tool was developed by NASA programmers to make it easier and faster for spotters to get their information to the NWS.

The AMU staff submitted technical proposals in response to Dr. Huddleston's call for proposals for the upcoming AMU tasking meeting. They also completed responses to the AMU customers' technical proposals for the meeting and emailed them to Dr. Huddleston for distribution to the AMU tasking team.

On 18 June, Dr. Bauman visited NASA SPoRT in Huntsville, Alabama. He talked to the SPoRT principal investigator, Dr. Gary Jedlovec, about some of the work the AMU and SPoRT have coordinated on and future cooperation between the two groups. Recently, SPoRT assisted the AMU with modifying configuration files to successfully import the AMU-WRF model into the NASA/AMU AWIPS II. The AMU is learning how to use AWIPS II plug-in software, which SPoRT has expertise developing. Dr. Jedlovec agreed to have a teleconference with key AMU/ENSCO staff to discuss plug-in development with his staff.

Dr. Bauman, Ms. Shafer, Mr. Magnuson and Ms. Crawford participated in a Videocon with meteorologists at SPoRT on 27 June to discuss methodologies to transition the AMU-developed Anvil Cloud Threat Sector tool into the NASA/AMU AWIPS II. The goal of the Videocon was to strengthen the AMU-SPoRT partnership for scientific collaboration and to share knowledge about the Anvil Threat Sector tool and the potential to port the software code into the NASA/AMU AWIPS II using the SPoRT AWIPS II plug-in technology. Dr. Jedlovec agreed to have his staff send the AMU training materials, which they did on 30 June. Mr. Burks, a SPoRT research meteorologist, emailed PowerPoint presentations from several Experimental Products Development Team training sessions.

Launch Support

Dr. Watson and Ms. Crawford attended the 45 WS Launch Readiness Reviews (LRR) on 7 April for the Atlas 5 and Falcon 9 launches scheduled on 10 and 18 April, respectively. Ms. Shafer supported the LRR on 6 May for the Falcon 9 launch scheduled for 10 May. Ms. Crawford and Ms. Shafer attended the dual LRR for the Delta 4 launch scheduled on 15 May and the Atlas 5 launch scheduled on 22 May.

During the Falcon 9 launch attempt on 14 April, Dr. Bauman assisted the LWO with the AMU-developed LSP Upper Winds tool since this was the first launch attempt to use the tool since the KSC 50-MHz DRWP was powered down for the replacement project. Dr. Bauman had created a custom version of the tool to use only rawinsonde data during the profiler replacement and the LWO was not sure how to execute the software and manage the graphical user interface. He also answered LWO questions concerning model output on AWIPS II that displayed forecast positions of the sea breeze convergence and associated surface winds. Dr. Bauman explained the model being displayed was the Rapid Refresh model and that it was updated hourly with one-hour forecast intervals.

During the Delta IV launch on 16 May, Dr. Bauman helped the 45 WS weather/range safety officers display surface winds on the NASA/AMU AWIPS II from three national forecast models and the newly implemented AMU high-resolution WRF model running on the NASA/AMU modeling clusters at KSC. There was a concern about surface wind direction affecting the opening of the NASA causeway immediately following the launch. Overlaying the surface winds from the four models in AWIPS II showed that three of the four models were forecasting north winds and one was forecasting northeast winds. This gave the forecaster and LWO confidence that the winds would be northerly, therefore allowing the causeway to open safely without any threat from rocket exhaust. He also assisted the 45 WS launch team lead with the LSP Upper Winds tool to determine why the tool was indicating there were no rawinsonde data available even though two balloons were released in the morning. Dr. Bauman discovered numerous empty files on the KSC Weather Archive site that the tool was attempting to access. Within 30 minutes the files updated and the tool was able to access and display the rawinsonde data by accessing the new files.

During the Atlas 5 launch on 22 May, the LSP Upper Winds tool was not plotting the rawinsonde data on the forecast charts for the three models. Dr. Bauman investigated the issue and tracked it down to difference in the filename on the KSC Weather Archive server and the filename the tool was looking for. The KSC Weather Archive site saves files with a zero in the filename for each hour <10 (e.g. 01, 02, etc.). The tool was looking for the hour without a zero in the name. Dr. Bauman updated the code, tested it, and provided a new version of the tool to the 45 WS.

Forecaster Support

Mr. Dave Craft, the Lead LWO for training with the 45 WS, requested the AMU provide instructions on how to load procedures in AWIPS II to aid the forecasters when they run the AMU-developed Severe Weather and Objective Lightning tools in Meteorological Interactive Data Display System (MIDDS). Ms. Shafer authored an AMU Standard Operating Procedure that she provided to the 45 WS to keep on the operations floor near the RWO AWIPS II terminal.

Mr. Brock from the 30th Operational Support Squadron Weather Flight at Vandenberg Air Force Base (AFB) contacted Dr. Bauman to discuss errors he was encountering when running the AMU-developed LSP Upper-level Winds tool. Initially Mr. Brock thought the error was due to the code improperly discerning between standard and daylight saving time, but Dr. Bauman discovered that was not the case. The time issue disappeared when Mr. Brock reran the tool, but he also stated the upper winds plot did not display properly when he ingested several recent rawinsonde files. He sent the files to Dr. Bauman, who could not duplicate the error. Mr. Brock stated they recently received all new Windows PC's and he would continue to troubleshoot the issue.

The AMU received an email from Mr. Joseph Mounts at the KSC Space Station Processing Facility via the AMU website asking if there was a KSC website that could provide real-time weather data to calculate plume analysis for ammonia operations. Dr. Bauman recommended he contact the KSC Weather Office for support. After reviewing several emails about Mr. Mounts' requirements, Dr. Bauman suggested that he look at the KSC wind towers map webpage produced by the Spaceflight Meteorology Group at Johnson Space Center and the KSC Weather Archive website for wind tower data.

Dr. Watson contacted Mr. Wilz of Exelis, Inc., the Senior Meteorologist at WFF, about displaying WRF model data that is being produced from the NASA/AMU modeling cluster on their local systems. Mr. Wilz indicated that they are interested in getting the model data displayed on their Leading Environmental Analysis & Display (LEADS®) weather system provided by MeteoStar and proposed coordinating the effort through their system administrator.

In 2010, at the request of the 45 WS, the AMU transitioned the waterspout checklist into a MIDDS tool. During the 16 June 45 WS daily weather briefing, Mr. Taylor asked Dr. Bauman if the waterspout checklist implemented by the AMU on MIDDS included wind direction as one of the parameters assessed to determine the probability of waterspout activity. The waterspout forecast for 16 June was "moderate". Mr. Taylor thought this was not accurate because the winds in the CCAFS sounding were offshore from the northwest and the 45 WS training guide indicates offshore winds reduce the likelihood of waterspout development. Dr. Bauman notified Mr. Taylor that the MIDDS waterspout tool does not use wind direction, only wind speed, and those parameters were provided by Mr. Roeder of the 45 WS. Mr. Roeder stated that when he developed the checklist in 2003, the LWOs determined wind direction was not needed. Studies have shown that onshore winds are important for waterspout development and it might be worthwhile to consider the local climatology of waterspouts to add wind direction to the tool.

Ten days later on 26 June, the forecaster stated that the waterspout threat for the day was again "moderate" with a score of 14.2. Dr. Bauman thought the threat should not be that high based on the weather scenario, so he ran the waterspout tool on the AMU MIDDS and got the same score of 14.2. He then ran the AMU-developed Excel version of the tool, which produced a score of 8.2. Dr. Bauman discovered the MIDDS tool was using wind speeds from the CCAFS sounding in ms^{-1} instead of knots. He notified the 45 WS Flight Commander to instruct the forecasters not to use the tool until it could be fixed. Ms. Winters, 45 WS LWO who last updated the tool in MIDDS, is most familiar with the code and worked with the AMU to fix the error.

During the 45 WS morning briefing on 25 June, the forecasters stated the Air Force's version of the WRF 1.67-km model convection forecasts have not been reliable. Mr. Craft stated that a study needs to be done to show how well the model forecasts convection. After the briefing, Ms. Crawford and Ms. Shafer told Mr. Craft that the AMU is still trying to get WRF 1.67-km model data from AFWA in anticipation of being tasked to evaluate it, but there are still communications issues between AFWA and KSC. They also reminded Mr. Craft that the AMU's locally tuned WRF 4- and 1.33-km output is available on the AWIPS II workstation in RWO, and Ms. Shafer is preparing a memorandum describing its performance during a recent convective event. Mr. Craft asked that the AMU give a presentation on the local WRF model performance at the July training meeting if the results will be useful to forecasters.

Reports and Publications

The National Weather Association Journal of Meteorology (JOM) published the paper that Dr. Bauman co-authored with Mr. Roeder of the 45 WS on 17 April. The JOM is a peer-reviewed scientific publication and the paper is titled "A Tool to Predict the Probability of Summer Severe Weather in East Central Florida", which is based on the AMU task "Severe Weather Tool using 1500

UTC Cape Canaveral Air Force Station Soundings”.

Dr. Bauman and Dr. Watson responded to a request from Ms. Cummings of the KSC Weather Office to update the AMU input for the KSC annual Office of Federal Coordinator for Meteorology Report. Dr. Bauman updated the FY2014 AMU task summaries and wrote the section on projected tasks for FY2015. Dr. Watson reviewed and provided input on the AMU modeling efforts for FY2014 and FY2015.

The new electronic NASA Document Availability Authorization (DAA)/ Export Control review system continues to cause issues for the AMU staff to distribute reports in a timely manner. A completed NASA Form 1676, or DAA, is required for the AMU to publish reports. Ms. Crawford has been working with Ms. Johnson and Ms. Chan in the KSC Scientific and Technical Information Program because she discovered that the new system is not automatically notifying people when it’s their turn to sign/ approve the DAA. Also, in order for AMU staff members to originate the form, they must have a current KSC mail code, which some AMU team members still do not have with their NASA information.

IT

Ms. Shafer and Dr. Bauman, with assistance from ENSCO system engineer Mr. Magnuson, upgraded both of the NASA AWIPS II NOAAPort Receive System (NRS) servers. The upgrade included installing the latest version of the CentOS 6.5 Linux operating system and the latest Local Data Manager (LDM) software. The NRS required the upgrade for compatibility with the AWIPS II LDM servers and to prevent data ingest failures that had plagued the system since the upgrade to AWIPS II several weeks prior. Both NRS servers are now upgraded and functioning properly.

Ms. Shafer and Dr. Bauman updated the AMU Contingency Test Plan on 27 May by verifying the continuous backup of the AMU server to an off-site external hard drive as part of the AMU IT Security Plan. Ms. Shafer updated the Contingency Test Plan Worksheet and uploaded it to the NASA Risk Management System production server that stores all of the AMU IT Security Plan files.

Ms. Shafer and Dr. Bauman upgraded AWIPS II to the most recent release on 27 June. They tested all servers and clients and verified the data ingest and product display is updating normally.

Dr. Bauman updated Adobe Flash Player, Reader, and Acrobat when required on all AMU non-ACES Windows computers. He also ran Windows Update when required, and updated all AMU non-ACES Windows computers with security updates that are critical to protect KSC systems from hostile activity.

Security

Ms. Crawford received an email from a foreign entity requesting information about a procedure used in an AMU study. She forwarded the email to Dr. Bauman and the KSC Weather Office and asked if she should respond to it. Dr. Huddleston forwarded the email to the KSC Counterintelligence/Counterterrorism office, who determined that the email should not get a response. They further stated that unsolicited emails like this should always be reported to them.

Ms. Crawford and Dr. Bauman conducted the annual Industrial Security self-inspection on 27 May in preparation for the 45 SW annual visit scheduled for 5 June. They processed the self-inspection checklists, verified the Visit Authorization Letters (VALs) were current with the 45 WS Security Officer, Mr. Flinn, and notified the ENSCO Security Officer, Ms. Yockey, that the VALs were due to expire 17 June so she could update them.

The 45 WS Chief of Industrial Security, Mr. Chambers, visited the AMU on 5 June to conduct the annual industrial security review with Ms. Crawford and Dr. Bauman. They gave Mr. Chambers the required documentation certifying they conducted the annual self-inspection on 27 May in preparation for the review and emailed him a copy of the ENSCO annual training briefing conducted in April 2014. Mr. Chambers verified the ENSCO personnel VALs on file with the Air Force were current. Based on this review, the 45 SW Chief of Information Protection stated that ENSCO/AMU “… is in compliance with the National Industrial Security Program” in a 6 June letter to ENSCO.

Data Access and Display

Mr. Ken Colvin from Exelis, contacted Dr. Bauman concerning AMU data acquisition from the 45 SW MIDDS after the upgrade is implemented in mid-June 2014. Dr. Bauman discussed the data requirement with Mr. Colvin and explained the observational data from KSC/CCAFS is required on the AMU clusters to initialize the local high-resolution forecast models. Mr. Colvin explained this can be accomplished if NASA purchases an External Certification Authority (ECA) that will allow the AMU clusters to pull the observational data from MIDDS via the Range External Interface Network. Mr. Colvin emailed a document to Dr. Bauman containing instructions on how to setup the interface. In addition to purchasing an ECA, the AMU will write a script on the clusters to pull the data at required intervals.

Ms. Crawford and Dr. Bauman tested the AMU-developed warm season MIDDS tools, Objective Lightning, Severe Weather, and Waterspout, on the new MIDDS with Mr. Witherow of Space Lift Range Systems Contract. They discovered none of the tools functioned properly due to missing files and an incorrect Forecast menu. Mr. Witherow notified Mr. Madison of CSR who will install the missing files and update the Forecast menu. According to Mr. Madison, these issues discovered by the AMU were likely pervasive in the RWO MIDDS.

On 2 May, Ms. Shafer discovered the Objective Lightning and Severe Weather tools were not working on the AMU MIDDS, but they were working on the 45 WS operational

MIDDS client computers. Dr. Bauman notified Mr. Madison and they worked together to review the code and the files on the AMU MIDDS client computer. They discovered the sounding file from the CCAFS rawinsonde was missing on the AMU system. The impact to the AMU is the staff does not have the opportunity to maintain proficiency with the MIDDS tools and the output from the tools, used for verification, is not being saved on the AMU MIDDS. On 30 May, Mr. Madison worked with Dr. Bauman to fix the issue with the AMU warm season tools. The issue turned out to be a shortage of memory on the workstation. Mr. Madison turned off the automated loading of satellite imagery to free-up memory, rebooted the computer, and tested each tool. Dr. Bauman confirmed the tools were working properly.

The 45 WS tasked the AMU to archive high-resolution model forecast data from AFWA on the AMU modeling clusters beginning 1 May 2014. In December 2013, Dr. Bauman contacted Mr. Sean Nicholson, a system administrator with Abacus Technology at KSC, to open a KSC firewall with the AMU cluster's IP addresses to allow AFWA to push the data files to the clusters. Mr. Nicholson completed the action to open the firewall, but AFWA has been unable to contact either of the AMU clusters. Mr. Nicholson worked with the KSC firewall group and they stated the border firewall was open. AFWA tried again to connect, but the KSC servers just hung without sending a response to AFWA. Dr. Bauman put the AFWA point-of-contact, Mr. Kevin Alger, a software support specialist with Harris IT at Offutt AFB, in direct communication with Mr. Nicholson so they could troubleshoot the issue directly. The networks team at AFWA could not resolve the issue, so Ms. Lois Rife of AFWA opened an AFWA Operations ticket as the next level of support after she received a summary of the work done by KSC, which Dr. Bauman provided after getting it from Mr. Phil Gemmer from Abacus Technology. The data push has not yet started due to unknown technical issues.

Ms. Shafer successfully displayed the real time AMU WRF-EMS output running on the NASA/AMU modeling clusters on the AWIPS II workstations. She is running the version of WRF that resulted from Dr. Watson's AMU task to determine the best WRF model configuration for east-central Florida. The model runs every hour, has a 12-hour forecast period, the 1.33-km domain is output every 15 minutes and the 4- and 12-km domains are output every hour. This capability allows the 45 WS personnel to graphically display the local high resolution model output in near real-time on their AWIPS II workstation with one immediate goal of improving convection initiation forecasts and lightning timing at KSC and CCAFS. Mr. Clay Flinn, a 45 WS LWO, requested a demonstration of the model output. Ms. Shafer demonstrated how to access the AMU WRF and display some of the products. Ms. Shafer then provided a written review of the demonstration to Mr. Flinn via email per his request.

On 17 June, a thunderstorm developed on south Merritt Island west of CCAFS on the sea breeze/river breeze boundary around 1500 UTC (1100 EDT). The AMU-WRF-EMS 1.33- and 4-km output clearly forecast this feature. Ms. Shafer provided Mr. Roeder of the 45 WS screen captures of both domains along with the corresponding image from the NWS MLB WSR-88D per his request.

Visitors

Third-year Air Force Academy Cadet Timothy DesRoches visited the Morrell Operations Center (MOC) for a tour of the RWO and AMU on 18 June. Ms. Shafer provided an introductory AMU briefing and showed examples of some of the AMU-developed tools.

Air Force Institute of Technology student Captain Travis also visited the MOC for a tour of the RWO and AMU on 23 June. Ms. Shafer and Ms. Crawford provided the same briefing and examples to him as to Cadet DesRoches.

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LIST OF ACRONYMS

14 WS	14th Weather Squadron
30 SW	30th Space Wing
30 OSS	30th Operational Support Squadron
3-D	Three Dimensional
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
AFB	Air Force Base
AFSPC	Air Force Space Command
AFWA	Air Force Weather Agency
AMU	Applied Meteorology Unit
AWIPS	Advanced Weather Information Processing System
CAVE	Common AWIPS Visualization Environment
CCAFS	Cape Canaveral Air Force Station
CI	Convection Initiation
CSR	Computer Sciences Raytheon
DAA	Document Availability Authorization
DRWP	Doppler Radar Wind Profiler
ECA	External Certification Authority
ER	Eastern Range
ESRL	Earth System Research Laboratory
FAA	Federal Aviation Administration
FSU	Florida State University
GSDO	Ground Systems Development and Operations program
GSI	Gridpoint Statistical Interpolation
JOM	Journal of Operational Meteorology
JSC	Johnson Space Center
KMCO	MCO TDWR
KMLB	NWS MLB WSR-88D
KSC	Kennedy Space Center
LAP	Lightning Advisory Panel
LDM	Local Data Manager
LLCC	Lightning Launch Commit Criteria
LMA	Lightning Mapping Array
LRR	Launch Readiness Review
LSP	Launch Services Program
LWO	Launch Weather Officer
MCO	Orlando International Airport
MET	Model Evaluation Tools
MIDDS	Meteorological Interactive Data Display System
MODE	Method For Object-Based Diagnostic Evaluation
MSFC	Marshall Space Flight Center
NCAR	National Center for Atmospheric Research
NE	Natural Environments Branch at MSFC
NOAA	National Oceanic and Atmospheric Administration
NRS	NOAAPort Receive System
NSSL	National Severe Storms Laboratory
NWS MLB	National Weather Service in Melbourne, Florida
RMS	Root Mean Square
RPG	Radar Product Generator
RTMM	Real Time Mission Monitor
RWO	Range Weather Operations
SLS	Space Launch System
SMC	Space and Missile Center
SPoRT	Short-term Prediction Research and Transition Center
TDWR	Terminal Doppler Weather Radar
USAF	United States Air Force
VAFB	Vandenberg Air Force Base
VAL	Visit Authorization Letters
VBA	Visual Basic for Applications in Excel
WDSS-II	Warning Decision Support System Integrated Information
WFF	Wallops Flight Facility
WRF	Weather Research and Forecasting Model
WRF-EMS	WRF Environmental Modeling System
WSR	45 SW Weather Surveillance Radar
WSR-88D	Weather Surveillance Radar 1988-Doppler

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

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