AMU Applied Meteorology Unit

Quarterly Report
First Quarter FY-15

31 January 2015

Infusing Weather Technology Into Aerospace Operations

Contract NNK12MA53C/DRL-003 DRD-004

Delta IV Heavy carrying the Orion spacecraft shortly before liftoff. (Image credit: NASA/Kim Shiflett, www.nasa.gov/content/successful-launch-of-orion-heralds-first-step-on-journey-to-mars/)

nasasport.wordpress.com/2014/12/05/applied-meteorology-unit-provides-local-weather-model-using-sport-datasets-for-orion-flight-test/

In this issue:

Launch Support

Dr. Bauman supported the Atlas 5 GPS launch on 29 October .

Ms. Shafer supported the Delta IV Orion EFT-1 launch on 5 December.

This Quarter's Highlights

The AMU team worked on four tasks for their customers:

- Ms. Crawford set up and began running the software needed for the dual-Doppler wind field task at the National Weather Service Melbourne, Florida (NWS MLB) office.
- Ms. Shafer completed the final report describing the implementation and verification of the local high-resolution Weather Research and Forecasting (WRF) model.
- Dr. Bauman began a task to evaluate the AMU-WRF model's ability to forecast the onset, position, and movement of the local sea and river breezes, important elements in the location and timing of lightning.
- Before going on maternity leave in December, Dr. Watson continued work on a task to optimize and run in real time the WRF model she configured to assimilate observational data in a previous task.

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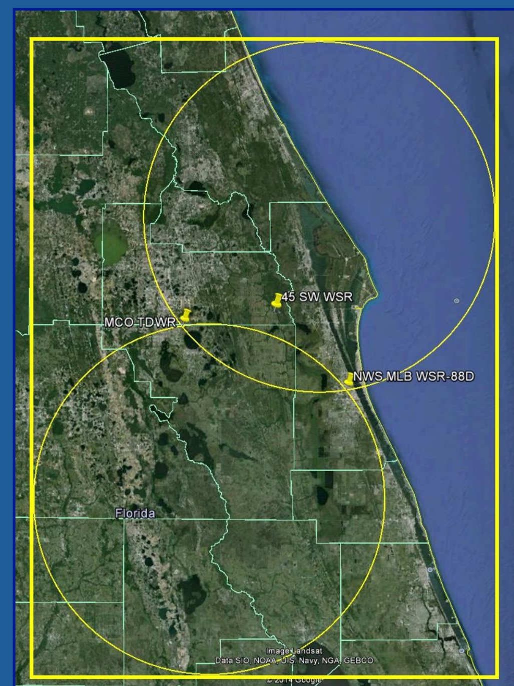
Quarterly Task Summaries

This section contains summaries of the AMU activities for the first quarter of Fiscal Year 2015 (October—December 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 Real-Time Dual-Doppler 3-D Wind Field System (Page 4)

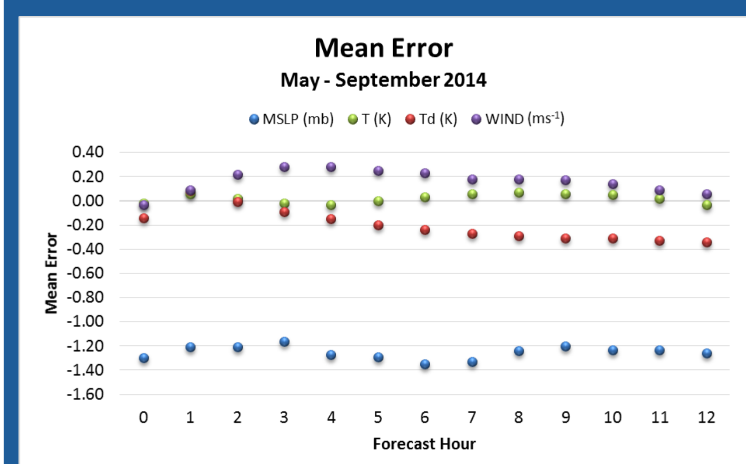


Customers: NASA's Launch Services Program (LSP), Ground Systems Development and Operations (GSDO), and Space Launch System (SLS) programs, and NWS MLB.

Purpose: Develop a real-time dual-Doppler system using freely available software to create a three-dimensional (3-D) wind field over east-central Florida using data from two local Doppler radars. Current LSP and GSDO and future SLS space vehicle operations will be halted when winds exceed defined thresholds and when lightning is a threat. A display of the wind field to reveal areas of high winds or convergence, especially over areas where no observations exist, would be useful to 45th Weather Squadron (45 WS) and NWS MLB forecasters in predicting the onset of vehicle-critical weather phenomena, and can also be used to initialize a local mesoscale numerical weather prediction model to improve the model forecast of these phenomena. A real-time dual-Doppler wind field display will aid in using ground processing and space launch resources more efficiently by stopping or starting work in a timelier manner.

Accomplished: Installed the operational version of the Warning Decision Support System – Integrated Information (WDSS-II) software on a Linux PC at NWS MLB. Tested several commands for running the software in real-time. Using a built-in command that ingests, quality controls (QC), and displays the data.

Real-Time KSC/CCAFS High Resolution Model Implementation and Verification (Page 5)



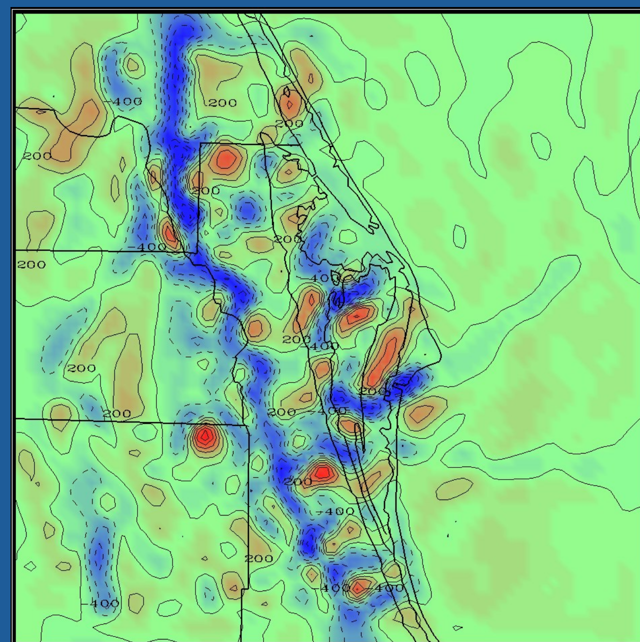
Customers: NASA's LSP, GSDO, and SLS programs.

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 Kennedy Space Center (KSC) and Cape Canaveral Air Force Station (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 made the model output available on the AMU and 45 WS Advanced Weather Interactive Processing System (AWIPS) for real-time subjective analysis.

Accomplished: Determined model verification statistics for the 2014 warm season (May-September) using the Model Evaluation Tools (MET) software. Completed writing the final report, which summarizes the real-time model configuration and availability, the model forecast verification, and how to access the model output via AWIPS.

Quarterly Task Summaries
(continued)

Evaluate Prediction of Local Sea Breeze Fronts from AMU-WRF Model (Page 7)

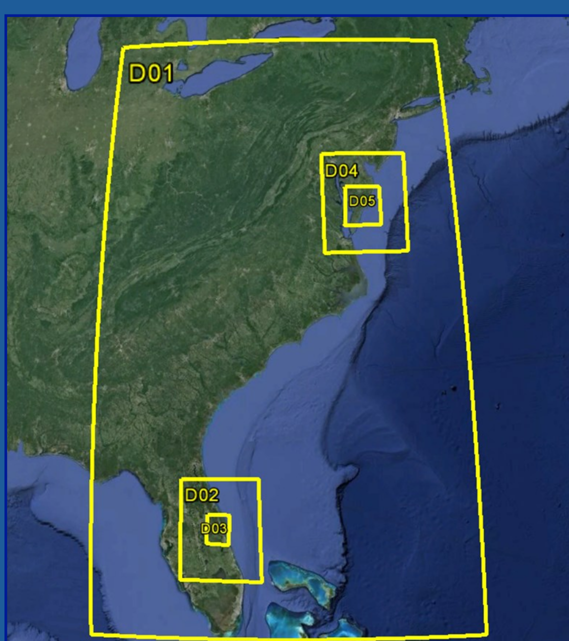


Customers: NASA's LSP, GSDO, and SLS programs.

Purpose: Evaluate the performance of the 1.33- and 4-km horizontal resolution AMU-WRF model's capability to predict the onset, position, and movement of the local sea breeze and river breeze fronts. These sea breeze and river breeze fronts directly influence thunderstorm development at KSC and CCAFS during the warm season months of May to September, which directly affects NASA's SLS, LSP, and GSDO daily and launch operations. The results of this evaluation will provide guidance to the forecasters and launch weather officers (LWOs) when forecasting lightning occurrence, including timing of the first strike of the day, which is difficult to forecast during the warm season.

Accomplished: Acquired and QC-ed the KSC/CCAFS wind tower observations. Assessed three open source software packages for processing and displaying observations and model forecasts. Chose the Integrated Data Viewer (IDV) software and began creating wind tower observation files in IDV format.

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



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

Purpose: Tune the numerical forecast model design for optimal operational performance for the Eastern Range (ER) and Wallops Flight Facility (WFF) to better forecast a variety of unique weather phenomena that affect NASA's SLS, LSP, and GSDO 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: Modified the Gridpoint Statistical Interpolation (GSI)/WRF scripts to run in real-time and completed porting the code from the developmental cluster to the real-time cluster.

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 Real-Time 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 and subsequent lightning occurrence. To provide this wind field, the AMU was tasked to use freely available software to create a real-time dual-Doppler analysis using data from the NWS MLB Weather Surveillance Radar – 1988 Doppler (WSR-88D) and the Federal Aviation Administration (FAA) Terminal Doppler Weather Radar (TDWR) at Orlando International Airport (MCO). This task is a continuation of the AMU's just-completed Configuration and Evaluation of a Dual-Doppler 3-D Wind Field System task (Crawford 2014) in which the WDSS-II software package was tested using archived radar data. WDSS-II has been installed at NWS MLB and dual-Doppler analyses will be created using real-time data from the WSR-88D and MCO TDWR. The AMU will also investigate the ability of WDSS-II to ingest and display data from local lightning detection systems, and how to prepare the dual-Doppler wind fields for ingest to NWS MLB's local WRF model.

Real-Time Operation

Mr. Blottman of NWS MLB acquired a Linux PC that initially had issues with the graphics software. He resolved the graphics issues and completed setting up the PC, including connecting a real-time WSR-88D data feed. Ms. Crawford downloaded and installed WDSS-II on the PC and copied the files needed to run the package in real-time into the appropriate directory.

Ms. Crawford first tested the software for correct installation by processing archived data and displaying the output. She then processed and displayed real-time WSR-88D data successfully using two methods. The first was using a command in a terminal window that runs continuously. This method has the disadvantage of only being able to run one command in a terminal window. The second is a WDSS-II utility that reads a configuration file and runs in the background. It can run several algorithms on the data, including QC and data merge processes. Ms. Crawford edited the configuration file to contain the correct directory structure for the input and output files and the algorithms to be run on the data, which included processing and QC-ing. The utility has been running continuously without interruption since late December 2014. This utility will be used for the dual-Doppler analysis once TDWR data are available.

Status

NWS MLB must get permission from the FAA to ingest the TDWR data. Until that permission is granted and the real-time TDWR feed is connected to the PC, no work can be done to create the dual-Doppler wind fields. In the meantime, Ms. Crawford will investigate how to ingest lightning data into WDSS-II, and how to prepare the output for ingest into NWS MLB's local WRF model.

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

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 implemented the WRF-EMS model on the second of two AMU modeling clusters. The AMU then made the model output available on the AMU AWIPS servers, which allows the 45 WS and AMU staff to customize the model output display on the AMU and Range Weather Operations (RWO) AWIPS client computers and conduct real-time subjective analyses. The AMU also calculated verification statistics to determine model performance compared to observational data.

Warm Season Verification

Ms. Shafer calculated model verification statistics to determine the 1.33-km domain WRF-EMS model performance for the entire 2014 warm season (May–September). To accomplish this, she used two of the statistical verification tools available in the MET software, the Point-Stat and the Method for Object-Based Diagnostic Evaluation (MODE) tools (AMU Quarterly Report Q2 FY14).

Point-Stat was used to compute the mean error (ME) and root mean square error (RMSE) of the mean sea level pressure (MSLP), the 2-m temperature (T) and dewpoint (Td), and 10-m wind speed and direction. The ME is the overall bias of the model parameter during the period of interest. It ranges from negative infinity to infinity with a perfect score equal to 0. The RMSE is the magnitude of the model error. Smaller RMSE values indicate better model performance. It ranges from 0 to infinity with a perfect score equal to 0.

Figure 1 shows the ME for MSLP, T, Td, and wind speed versus model forecast hour for the 2014 warm season. The ME curve for T is close to 0 at all forecast hours, indicating a good forecast for this parameter. The ME values for wind speed and Td are within ±0.4 with wind speed showing a small positive bias and Td showing a slightly negative, or dry, bias. The values for MSLP are all negative ranging from -1.2 to -1.4. Considering the magnitude of MSLP values on the order of 1000 mb, these biases are very small in comparison. Figure 2 is the same but for wind direction. These values increase with forecast hour from just above 25 to 35 degrees.

Figures 3 and 4 are the same as Figures 1 and 2 respectively, but for RMSE. The RMSE values for MSLP, T, Td and wind speed slightly increase with forecast hour but remain between 1 and 1.8 (Figure 3). These values are close to 0 which confirms the magnitude of the model error for these parameters is small. A similar trend exists for wind direction (Figure 4) but the RMSE values range from about 40 to 50 degrees. These values could be due to light and variable

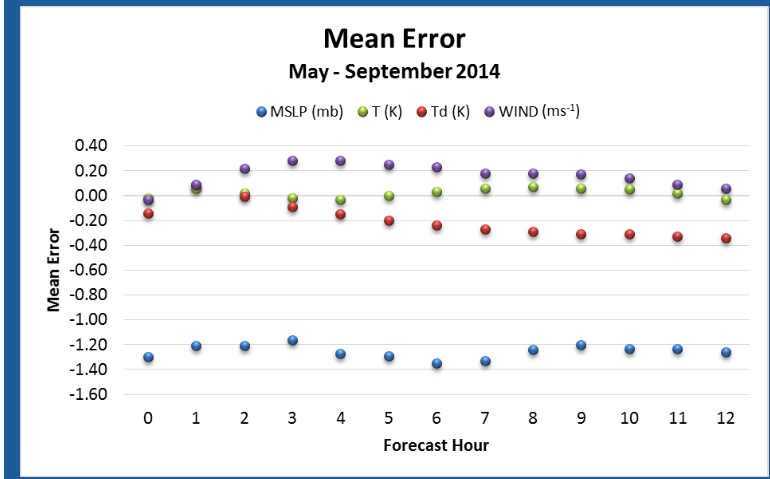


Figure 1. The ME for each parameter versus forecast hour. Surface pressure is in mb (blue dots), temperature in K (green dots), dewpoint temperature in K (red dots) and wind speed in ms^{-1} (purple dots).

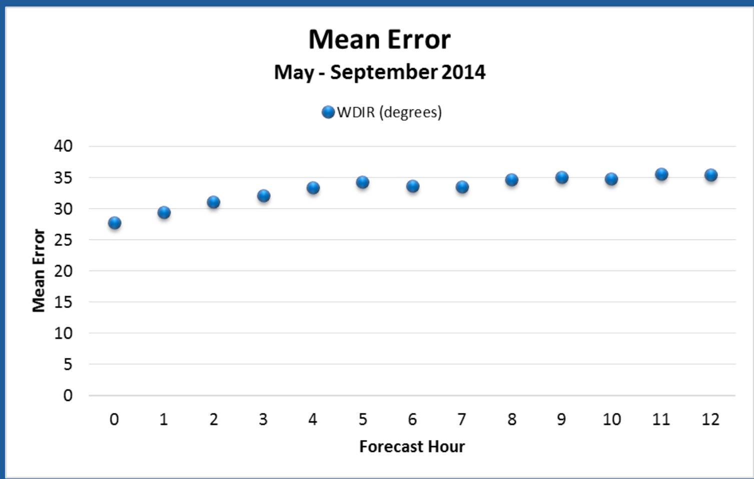


Figure 2. The ME for wind direction in degrees versus forecast hour.

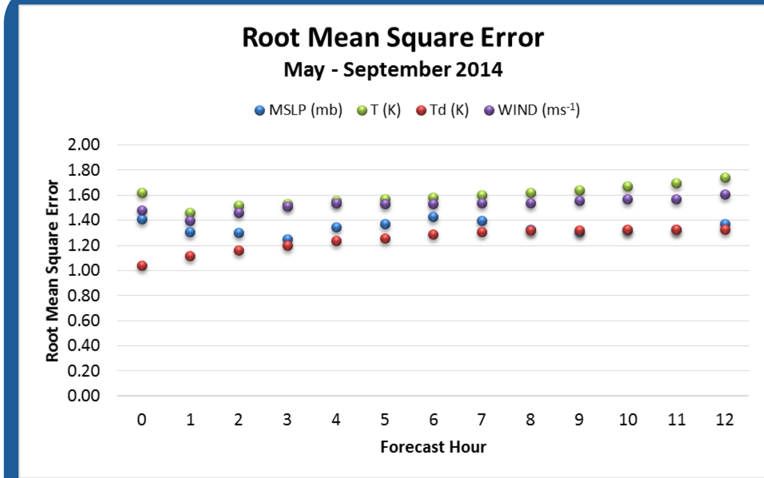


Figure 3. Same as Figure 1 but for RMSE.

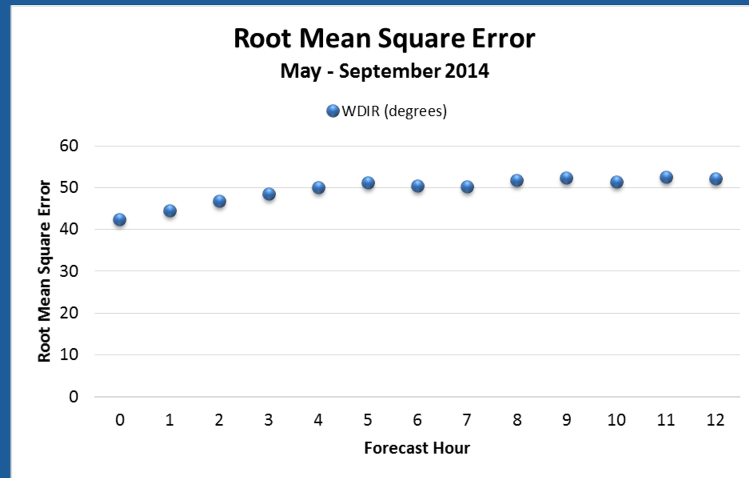


Figure 4. Same as Figure 2 but for RMSE.

winds that are common at night over KSC/CCAFS during the warm season. When winds are light there tends to be a larger variance in the wind direction that would be difficult for the model to forecast. In future work, Ms. Shafer will stratify the warm season results diurnally to determine how the time of day influences the model wind direction forecasts.

Ms. Shafer also used MODE to verify the model precipitation forecasts. MODE applies an object-based verification technique to compare a gridded forecast to a gridded analysis. The technique for defining objects in MODE is discussed in the previous AMU Quarterly Report (Q4 FY14). Table 1 shows the statistics Ms. Shafer used from MODE for the model verification.

The centroid distance is the distance between the centers of two objects: the observed precipitation object and the corresponding forecast precipitation object. A perfect forecast would have a centroid distance equal to 0. Figure 5 shows the centroid distance versus model forecast hour for the warm season verification. As expected, there is a general increase in distance with time although it remains between 35 and 38 grid boxes. The distance in km is equal to the centroid distance in grid boxes multiplied by the domain resolution of 1.33-km, resulting in distances between 46.55 and 50.54 km.

Table 1. List of statistics available in the MODE tool Ms. Shafer used to verify the model.

Statistic Name	Description
Centroid Distance	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)

These location differences may be present because warm season convection remains one of the most poorly forecast meteorological parameters, in part due to dynamic and thermodynamic features that occur on the mesoscale (Watson 2007). Note that MODE does not calculate statistics for the initialization time (Forecast Hour = 0) since the model takes time to spin-up the precipitation forecasts.

The area ratio compares the size of the forecast objects to the observed objects (forecast area/observed area). A perfect forecast would have an area ratio equal to 1. Figure 6 shows the area ratio versus model forecast hour remaining steady at about 0.35. This means the model is consistently under-forecasting the size of the precipitation objects. This could be an artifact of calculating the statistics for each hour rather than for the entire 12-hour period.

Finally, the interest value compares the differences in attributes between the forecast and observed objects, including the centroid distance and area ratio, and gives an indication of the overall quality of the model precipitation forecasts. It ranges from 0 to 1 with a perfect score equal to 1. Figure 7 shows the interest versus model forecast hour. These values consistently remain just above 0.6 regardless of model forecast hour.

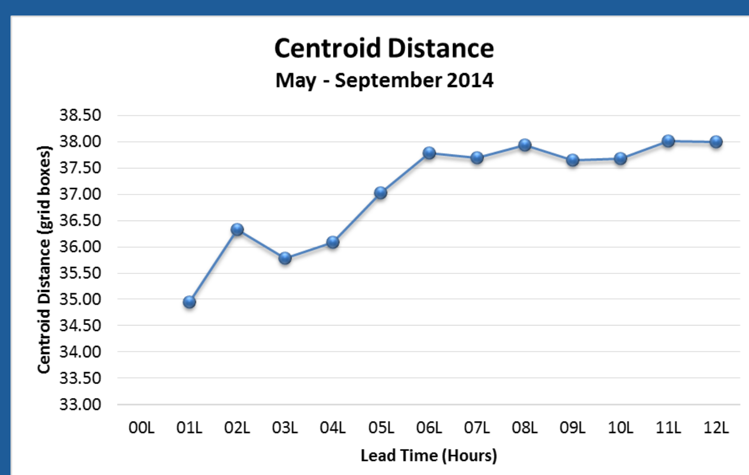


Figure 5. Centroid distance versus model forecast hour for the warm season model verification. Centroid distances are in number of grid boxes.

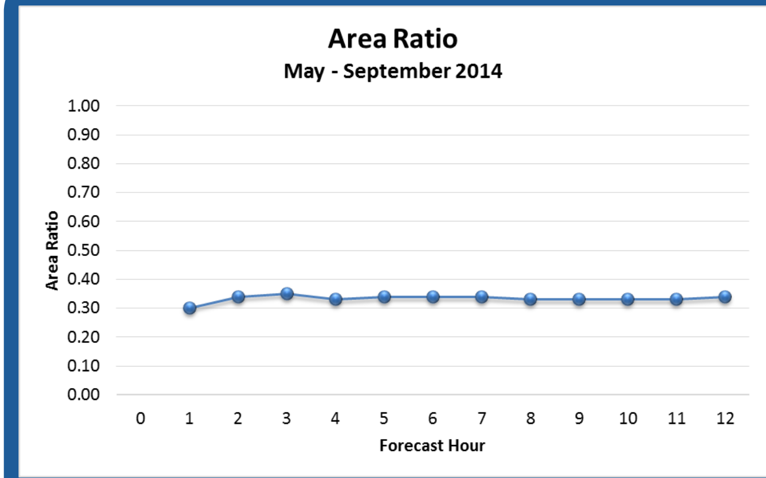


Figure 6. Area ratio versus model forecast hour for the warm season model verification.

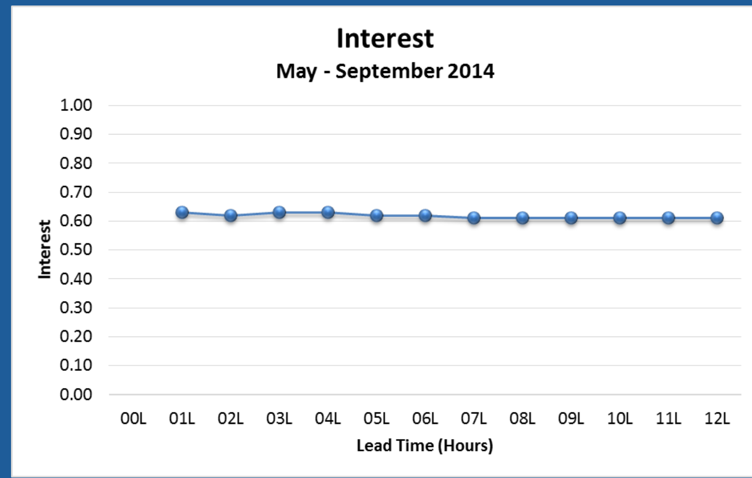


Figure 7. Interest value versus model forecast hour for the warm season model verification.

Summary and Future Work

Ms. Shafer assessed the WRF-EMS 1.33-km model performance for the 2014 warm season. She computed the verification statistics using the MET software, specifically the Point-Stat and MODE tools. The results showed the ME values were close to 0 and the RMSE values were less than 1.8 for MSLP, T, Td, and wind speed, all very small differences between the forecast and observations considering the normal magnitudes of the parameters. The RMSE for wind direction was between 40 and 50 degrees which could be because of the light and variable winds that are common at night over KSC/CCAFS during the warm season. The precipitation forecast verification results showed consistent under-forecasting of the precipitation size.

In future work, Ms. Shafer will stratify the results diurnally to determine how the time of day influences the model wind direction forecasts. Also, she will implement an updated version of the WRF-EMS model incorporates local data assimilation based on work Dr. Watson recently completed (Watson 2014).

Final Report

Ms. Shafer completed writing the final report. It was reviewed internally by the AMU and externally by customers. It was submitted for NASA Export Control approval. Once approval is received the report will be distributed and posted on the AMU website.

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

Evaluate Prediction of Local Sea Breeze Fronts from AMU-WRF Model (Dr. Bauman)

The AMU is producing real time high-resolution AMU-WRF numerical weather prediction model output to provide more accurate and timely forecasts of unique weather phenomena that can affect NASA's SLS, LSP, and GSDO daily operations and space launch activities. One AMU-WRF product developed by the AMU is a depiction of the local sea and river breezes based on the model's forecast of surface convergence and low-level winds. During the warm season months of May to September, daily lightning-producing convection at KSC and CCAFS is highly correlated to the onset, position, and movement of the sea and river breeze fronts. High-confidence, high-precision prediction of the onset of sea and river breezes in the KSC/CCAFS area during the warm season is difficult. However, precise prediction of sea and river breeze onset, position, and movement is important to forecasting the first lightning of the day, lightning progression, and wind flows for toxic corridor prediction by 45 SW Range Safety during launch windows.

Anecdotally, the 45 WS LWOs and forecasters believe the AMU-WRF sea breeze product performed well during the 2014 warm season. In order to quantify the model's capability, the 45 WS tasked the AMU evaluate the performance of the 1.33- and 4-km horizontal resolution AMU-WRF model in predicting the onset, position, movement, and intensity of sea and river breeze fronts in the KSC/CCAFS area during the 2014 warm season.

Data

Dr. Bauman investigated using the 45th Space Wing (45 SW) Meteorological and Range Safety Support (MARSS) system (Figure 8) Total Area Average Divergence (TAAD) product data as ground truth to verify the forecast. The MARSS TAAD is a gridded convergence/divergence analysis based on the 54-ft wind tower observations. He discovered that archived MARSS data are not available and cannot be obtained in real-time. Therefore, gridded convergence fields will have to be created from the KSC/CCAFS wind tower observations.

Figure 8. The MARSS system display of wind tower observations (yellow wind barbs), gridded divergence (cyan and yellow lines), and gridded wind flow vectors (red arrows). Tower locations not reporting are shown by a red x.

The KSC/CCAFS wind tower observations using the 54-ft wind sensors will be used for identifying areas of surface convergence associated with the sea and river breezes. During the 2014 warm season there were 28 wind towers reporting wind speed and direction at the 54-ft level as shown on the map in Figure 9.

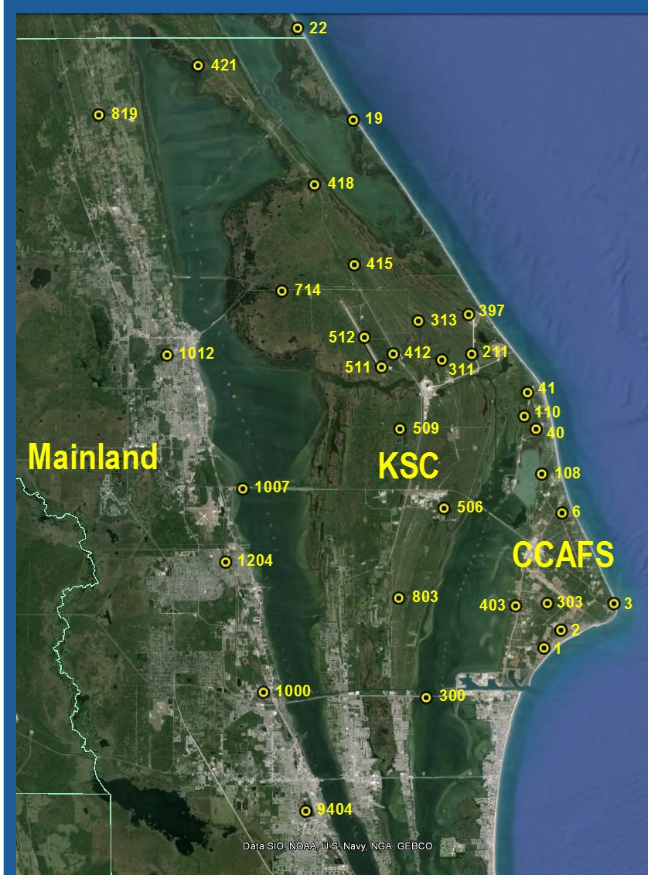


Figure 9. A map showing the locations of the wind towers used in this task.

Four towers have sensors on two sides as shown in Table 2. The redundant sensors at these towers were added in response to the effect of obstructed wind flow around the tower on the downwind sensor (Lambert 2002). Only data from the windward side of each tower are displayed to the forecasters, but data from both sensors at each tower were in the data set. The data from both sensors at the redundant towers were processed and analyzed as separate sensors. Figure 10 shows a photograph of tower 6 with redundant wind sensors at a height of 12 ft.

Dr. Bauman verified the AMU had acquired the 2014 warm season KSC/CCAFS wind tower data from the Eastern Range Technical Services (ERTS) contractor. The ERTS contractor provided the AMU with the wind tower data in the form of 153 ASCII text files from the 45 WS Meteorological Interactive Data Display System (MIDDS). Each file contained one day of 5-minute interval tower observations from all sensor levels for all towers in the network. The metadata in each file include

- year, month, day, hour, minute,
- tower identifier,
- sensor location on the tower, and
- sensor height in feet.

The meteorological variables in each file include

- temperature and dew point temperature in degrees Celsius,
- 5-minute average and 5-minute peak wind speeds in meters per second,
- 5-minute average and 5-minute peak wind direction in degrees,
- deviation of the 5-minute average wind direction in degrees, and
- relative humidity in percent.

The wind speed and direction were sampled every second. The 5-minute average is the mean of all 300 1-second observations in the 5-minute period. The peak wind is the maximum 1-second speed in the 5-minute period and its associated direction. Before processing, the temperatures were converted to degrees Fahrenheit with the equation

$$ºF = 1.8 * ºC + 32,$$

and the wind speeds were converted to knots (kt) with the equation

$$kt = 1.9424 * ms^{-1}.$$

Table 2. Towers with redundant sensors and information about the location of the sensors relative to the towers. Each side of the tower is given a distinct tower identification number.

Tower Number	Side: Number
313	Northeast: 3131 Southwest: 3132
2	Northwest: 0020 Southeast: 0021
6	Northwest: 0061 Southeast: 0062
110	Northwest: 1101 Southeast: 1102

Data Processing

Dr. Bauman first ran the AMU-developed wind tower automated QC program on the wind tower observation data. Erroneous observations were removed from the data using five QC routines developed specifically for the KSC/CCAFS wind tower network (Lambert 2002):

- unrealistic value check (e.g. wind speed < 0),
- standard deviation (σ) check (e.g. temperature not within 5 σ of mean),
- peak-to-average wind speed ratio check in which the peak wind must be within a specified factor of the average wind speed (factor dependent on average speed),
- vertical consistency check between sensor levels at each individual tower, and
- temporal consistency check for each individual sensor.

Figure 10. Photograph of tower 6 showing redundant wind sensors at a height of 12 ft on opposite sides of the tower.

Creating convergence/divergence maps based on the wind tower network observations requires converting the observational data to gridded data, and then performing a Barnes objective analysis (Barnes 1973) on the observational data. Dr. Bauman assessed three open source software programs to do this: the GEneral Meteorology PAcKage (GEMPAK) from Unidata, the Grid Analysis and Display System (GrADS) from the Institute of Global Environment and Society Center for Ocean-Land-Atmosphere Studies, and the Integrated Data Viewer (IDV) from Unidata. Both GEMPAK and GrADS were designed for UNIX/Linux operating systems while IDV includes a Java-based software library allowing it to run on the Microsoft Windows operating system. IDV has the ability to display and work with satellite imagery, gridded, surface, upper-air, and radar data with a unified interface (Murray et al. 2003). It has elements of GEMPAK and the Man computer Interactive Data Access System built into the software. It is for these reasons that Dr. Bauman decided to use IDV to display the gridded observational data and gridded model forecast output. A sample of a gridded AMU-WRF model forecast of surface convergence/divergence displayed in IDV is shown in Figure 11.

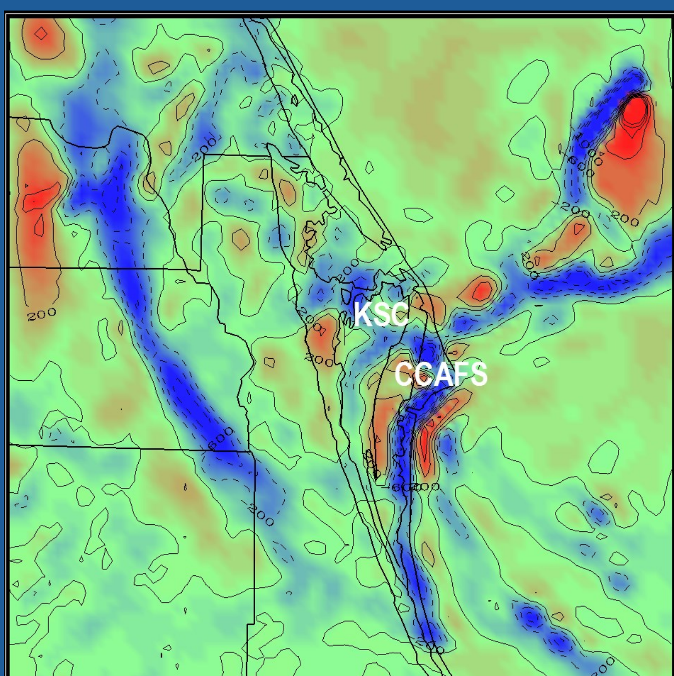


Figure 11. AMU-WRF model 4-hour 15-minute forecast from 31 July 2014 1000 UTC initialization of surface convergence/divergence displayed in IDV. Blue shaded areas show convergence which represents the sea and river breeze fronts in the KSC/CCAFS vicinity.

To create gridded data for use in IDV, a file containing the 54-ft wind speed and direction from all 28 towers in the network must be created for each 15-minute interval to match the 1.33-km horizontal resolution AMU-WRF model forecast frequency. To do so for the entire warm season requires creating 14,688 files starting with 160 QC-ed monthly files. Dr. Bauman wrote an Excel Visual Basic for Applications (VBA) script to first remove all sensor heights except 54 ft from the QC-ed monthly files. Using a second VBA script, he extracted 992 daily files for May 2014 from the monthly files. Using a third VBA script, he extracted 2,976 15-minute files for May from the daily files. He will follow this methodology for the remaining warm season months' files.

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

Range-Specific High-Resolution Mesoscale Model Setup: Optimization (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 SLS, LSP, and GSDO 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 2012 in which the AMU tuned the WRF model for the ER and WFF by determining the best model configuration and physics for the ER and WFF. The task continued in 2013 to provide a recommended local data assimilation (DA) and numerical forecast model design, which is a cycled DA and modeling system using the GSI and WRF software with scripts provided by NASA's Short-term Prediction Research and Transition Center (SPoRT). In this part of the task, the AMU will port GSI/WRF code to the AMU real-time cluster to run every three hours and display real-time output of the GSI/WRF cycled runs on the AMU's AWIPS workstations. The AMU will work with NASA SPoRT to determine if the GSI/WRF can be run in a rapid-refresh mode. If so, the AMU will determine the time needed to set up the rapid-refresh system and will implement it if possible within the time frame of this task. In addition, the AMU will explore ensemble modeling using the WRF model and will determine the level of effort to set up an ensemble modeling system.

Real-time GSI/WRF Scripts

Dr. Watson modified the GSI/WRF scripts to run in real-time and ported the code from the developmental cluster to the real-time cluster. However, she encountered issues while running the scripts using multiple nodes on the real-time cluster. Some components of the scripts either ran extremely slow or did not run at all. She worked with Mr. Magnuson to resolve the issue. Mr. Magnuson upgraded the clusters and reconfigured them for optimum performance so the she could continue running the current real-time AMU-WRF and begin running the real-time GSI/WRF and display them on AWIPS.

Dr. Watson spoke to Mr. Brad Zavodsky of NASA SPoRT regarding running the GSI/WRF system in a rapid-refresh mode. He referred her to Dr. Emily Berndt, also of NASA SPoRT, who has taken the lead on developing a rapid-refresh option for the GSI/WRF scripts. Dr. Berndt indicated that she is working to update the scripts to work with updated GSI and WRF software and is exploring options to acquire observation files for the rapid-refresh mode.

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

Technical Interchange

The AMU team participated in the KSC 2014 Innovation Expo in the lobby of the Operations and Checkout building. They used a laptop and monitors to show AMU technology transition products that are used by the AMU customers, including the AMU-WRF high-resolution computer model forecast loops from KSC/CCAFS and WFF. They also showcased current tasks such as dual-Doppler radar imagery focusing on a tornadic event from 15 April 2014. The AMU team made several contacts with KSC groups that could result in future collaboration on tasks.

Launch Support

Dr. Bauman, Ms. Shafer and Ms. Crawford participated in the 45 WS Delta IV Orion Exploration Flight Test 1 (EFT-1) Launch Readiness Review (LRR) on 1 December. Ms. Shafer and Dr. Bauman participated in the 45 WS Falcon 9 SpaceX Commercial Resupply Services 5 LRR on 17 December.

During the Atlas 5 launch on 29 October, there was no current rawinsonde data in the KSC Weather Archive to support the LSP Upper Winds tool. Dr. Bauman notified Mr. Gemmer of Abacus Technology and requested help to determine the cause of the missing data. Mr. Gemmer was able to manually move a file to the Archive site and began investigating the automatic file transfer issue.

The KSC 50 MHz Doppler Radar Wind Profiler (DRWP) was turned on so the users could look at the data for the Delta IV Orion EFT-1 launch attempt on 4 December. Dr. Bauman discovered the DRWP data was not being displayed on the AMU MIDDS and informed the launch weather team at the weather meeting. The 45 WS LWO, Ms. Winters, was able to display the DRWP data on the LWO MIDDS. Mr. Osier, the CSR Meteorology Manager, took an action to look into the issue, which was quickly resolved by Mr. Madison of CSR.

Two weather issues during the Delta IV Orion EFT-1 launch attempt on 4 December included ground launch wind constraints and fog. The 45 WS launch weather team asked the AMU if AMU-WRF high-resolution model forecast winds could be displayed at a height close to the wind sensors at Complex 37. The wind sensors are at about 300 ft and the AMU-WRF could display forecast winds in a layer from the surface to 1,600 feet. The model was under-forecasting the wind speeds, but it indicated correctly the sustained wind speeds would not change during the launch window. The 45 WS LWO stated that sea fog had developed north of the area and was moving southwest, which could impact the availability of the weather reconnaissance aircraft that operates from Sanford International Airport. She asked Dr. Bauman if the AMU-WRF model could produce forecasts of fog to help determine its movement and dissipation for aircraft operations. Dr. Bauman created a fog product from the model and displayed it on the 45 WS AWIPS. The AMU-WRF correctly forecast the fog location and movement. The AMU's support to the Orion launch is written in a NASA SPoRT blog post at nasasport.wordpress.com/2014/12/05/applied-meteorology-unit-provides-local-weather-model-using-sport-datasets-for-orion-flight-test/.

Forecaster Support

While attending the 45 WS morning briefing on 2 October, Ms. Crawford noted that one of the forecasters thought the K-Index calculated from the sounding in MIDDS was too high given the existence of a large capping inversion above 700 mb. Ms. Crawford suggested verifying the value by doing a manual calculation of K-Index with the sounding tabular data. She looked up the formula and took it to the forecaster, who used it to calculate K-Index from the tabular data and confirmed that the MIDDS code was calculating this value properly. The formula does not take into account moisture above 700 mb. The capping inversion began above 700 mb at 676 mb. One of the pitfalls of K-Index is that it can miss a capping inversion that begins above 700 mb, and confirms the need to look at other indices and data when making a forecast for convective activity.

Dr. Bauman and Ms. Shafer provided two AWIPS user guides to the 45 WS for the forecasters and LWOs to reference as they learn how to use AWIPS. One guide is the official NWS document published by Raytheon and the other was written by the AMU and customized for NASA/AMU AWIPS use. Dr. Bauman and Ms. Shafer added procedures specific to the AWIPS platform and added a section describing how to use the AMU-WRF high-resolution mesoscale model. They deployed the user guide files to each AWIPS client computer and to the 45 WS shared drive.

Ms. Crawford conducted a literature search for articles on waterspouts in Florida to determine if wind direction should be one of the forecast parameters in the 45 WS Weak Waterspout tool. She read the articles and summarized their content, and spoke with forecasters who have experience with waterspout occurrence. From the literature review and conversations, she determined that wind direction has not been proven to be a predictor for waterspout occurrence in the KSC/CCAFS area. She began writing a memorandum containing summaries of the relevant waterspout literature and recommendations for changes to the 45 WS Weak Waterspout tool.

Given the expressed 45 WS interest in expanding the size of the AMU-WRF model domains, Ms. Shafer configured and tested various domain sizes for the AMU-WRF. The goal was to determine a configuration that would keep the model run time less than 60 minutes, capture both coasts of Florida with the 4-km domain, and cover the NWS MLB county warning area (CWA) with the 1.33-km domain. The AMU created a triple-nested configuration that met each of these goals. The new set-up increased the clock time by about 13 minutes over the current configuration, resulting in a total run time of about 36 minutes per model run, which is well under the time needed to produce a new model run every hour. This will help the 45 WS forecasters better track the west coast sea breeze before it impacts KSC/CCAFS and monitor tropical cyclones near the east coast of Florida. It will also provide high-resolution model forecasts for NWS MLB over their entire CWA. This new grid configuration will be implemented in the second quarter of Fiscal Year 2015.

Dr. Bauman provided NWS MLB with details about the proposed AMU-WRF model domain changes made by Ms. Shafer that will include their entire CWA in central Florida within the highest resolution (1.33 km) domain. The current AMU-WRF only covers part of the NWS MLB CWA. The AMU will work with NWS MLB to provide near real-time hourly delivery of the model output files from the AMU modeling clusters at KSC to the NWS MLB AWIPS via a secure file transfer protocol. Having this high-resolution model data will help the NWS MLB forecasters see small scale features such as river and sea breezes to better predict lightning and severe weather threats that can impact the CWA.

Data Access and Display

Maj Sweat, Chief of the 45 WS Systems Division, met with AMU staff on 16 October to discuss providing AMU-WRF output to AFWA at Offutt Air Force Base in Omaha, Nebraska, so AFWA could visualize the model data and make it available on the AFWA web portal for 45 WS forecasters and LWOs. Although the AMU-WRF is available to the forecasters and LWOs via the AMU AWIPS in the RWO, making it available via AFWA would allow the 45 WS to more easily access the model data for daily briefing and forecasting support and allow the LWOs to display the data on closed-circuit television for use during launch support operations. Maj Sweat coordinated a draft email on 20 October with AMU staff outlining requirements for AFWA. The AMU staff provided sample AMU-WRF files that Maj Sweat emailed to AFWA to ensure they could ingest them and create products, which they verified they could do.

The CCAFS rawinsonde data had stopped updating on the KSC Weather Archive site causing the AMU-developed Excel Waterspout and LSP Upper Winds tools to produce invalid results. Mr. Gemmer corrected the problem, which was related to a filename component being hard coded. The filename was changed to match the 45 SW Range External Interface Network (REIN) naming convention instead of the existing naming convention for MIDDS. Upon testing the tools after this fix, another error was identified in the rawinsonde file – the format had changed, which resulted in the Excel code reading in the wrong data strings. The issue was resolved and the tools were updated in time to support the Atlas 5 launch on 29 October. The failure of both tools was related to an operating system change during the recent MIDDS upgrade. On 27 October, the AMU code in both tools was updated to account for the change. The tools were tested and then delivered to the 45 WS.

In order to assimilate near real-time observations into the AMU-WRF model initialization from the KSC/CCAFS network of weather sensors, the AMU needs a script to automatically retrieve the observations from the 45 SW REIN, which recently became operational. The REIN website is a secure site requiring credentials using a Department of Defense (DoD) Common Access Card for manual access or by purchasing an External Certification Authority digital certificate for automated access. The AMU received two scripts used by the KSC Weather Archive and SpaceX for accessing the observations. After reviewing the scripts and discussing the complexity of automatically accessing REIN to retrieve the files, Mr. Lockshine of Abacus Technology suggested that the AMU access the files from the KSC Weather Archive similar to what is done for the LSP Upper Winds tool. This would require much less effort to retrieve the files from within the NASA network between two computers on the NDC network. Dr. Huddleston agreed and asked Mr. Gemmer consider this option.

Since the National Oceanic and Atmospheric Administration (NOAA) increased bandwidth for users of the NOAAPort Receive System (NRS) Satellite Broadcast Network in September, the AMU AWIPS has been experiencing data dropouts of large files such as satellite imagery and model data. Working with the NRS vendor, Mr. Magnuson determined the issue is pervasive for all NRS's with satellite dishes more than 5 years old. The AMU dish is about 20 years old. The solution is to replace the Low Noise Block (LNB) located on the feed horn of the satellite dish. The LNB receives the very low level microwave signal from the satellite, amplifies it, changes the signals to a lower frequency band, and sends them down the cable to ultimately be displayed in AWIPS. Dr. Bauman submitted a request to the KSC Weather Office to purchase the LNB ($250). In the meantime, Mr. Magnuson setup alternate feeds from ENSCO's NRS until the AMU LNB is replaced. The AMU-WRF model products in AWIPS are not affected by this issue.

IT

The AMU received notification that they could install an upgrade to their VMware software running on three of their PCs. Mr. Davis of KSC's Ground Systems Division (GP-G) worked with Dr. Huddleston to acquire the upgraded software, which is required by KSC IT Security. The AMU staff completed the software upgrade and Mr. Weiss of KSC IT Security verified the upgrade removed any potential vulnerabilities on the PC's.

On 10 November, Mr. Manning from GP-G notified Dr. Huddleston that all AMU files stored on their current GP file share need to be moved to a Center Operations (TA)/ Spaceport Integration server due to the KSC Reorganization. All AMU files created since 1991 are stored on the file share and occupy about 1.15 TB of space. Ms. Burch, the Agency Consolidated End-User Services (ACES) TA representative, stated she will work with KSC Information Management and Communications Support staff and Mr. Mack of GP-G to ensure all of the files are moved. She will coordinate with the AMU staff when the files are ready to be moved.

AMU modeling cluster 1 became unresponsive via network connections on 22 November. The issue was related to the head node (1 of 13 nodes that make up the cluster), which required an on-site visit to the KSC Data Center by Ms. Shafer, Dr. Bauman, and Mr. Magnuson to reboot it. After rebooting the head node and the other 12 nodes, the cluster began functioning normally and was once again accessible via the network.

The 45 SW Range Technical Services Contractor (RTSC) was tasked to move a switch connected to the NASA/AMU AWIPS servers from an RTSC-managed cabinet into the AWIPS rack that houses the servers. To make room for the switch, Ms. Shafer and Dr. Bauman removed all unused equipment and cabling from the AWIPS rack that had been previously used for a 45 WS modeling cluster, which was removed several years ago.

Mr. Magnuson performed required maintenance on both AMU modeling clusters that run the real-time and developmental AMU-WRF model by updating the operating systems to the current version, installing software to optimize system performance, and updating the security software.

Dr. Bauman provided KSC 50-MHz DRWP test files from the 45 WS MIDDS to Mr. Wilfong of DeTect, Inc. so he could compare the MIDDS files with those sent from the DRWP to ensure they were identical. This is part of the acceptance testing of the new DRWP.

Visitor Briefings

Personnel from NWS MLB and Brevard County Emergency Management received a briefing on the AMU-WRF capabilities. After the briefing, Mr. Scott Spratt from NWS MLB asked if was possible for his office to receive the AMU-WRF output in support of the forecasting operations. The AMU agreed to help determine the best method to provide the files.

Dr. Bauman, Ms. Crawford, and Ms. Shafer gave an AMU overview briefing to Ms. Launa Maier on 9 December to familiarize her with the AMU as she begins work in the KSC Weather Office.

Training

Dr. Bauman completed two IT Security System for Administration, Training, and Educational Resources for NASA courses: "Elevated Privileges on NASA IT Systems" and "IT Security for System Administrators - Intermediate Level". Both courses were required to attain long-term elevated privileges for administration of AMU non-ACES computers to ensure timely implementation of patches and updates.

Dr. Bauman completed two COMET MetEd courses: "Using the WRF Mesoscale Model" and "Effective Use of High-Resolution Models" so he can better assist the 45 WS with choosing appropriate products to request from the AFWA output of the AMU-WRF model. MetEd is a free collection of learning resources for the geoscience community sponsored by COMET (www.meted.ucar.edu). It uses innovative methods to disseminate and enhance scientific knowledge in the environmental sciences, particularly meteorology, but also including diverse areas such as oceanography, hydrology, space weather and emergency management.

Ms. Crawford completed the annual DoD Cyber-Awareness Training course through the Air Force Advanced Distributed Learning System needed to maintain her Air Force account.

Ms. Crawford completed an introductory Python programming language course through Coursera (http://www.coursera.org/course/pythonlearn). She took this course to prepare for the comparison of the 50-MHz DRWP data to the daily CCAFS soundings. The code to do this comparison is being written by Marshall Space Flight Center Natural Environments personnel using Python.

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LIST OF ACRONYMS

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
ACES	Agency Consolidated End-User Services
AFSPC	Air Force Space Command
AFWA	Air Force Weather Agency
AMU	Applied Meteorology Unit
AWIPS	Advanced Weather Information Processing System
CCAFS	Cape Canaveral Air Force Station
CSR	Computer Sciences Raytheon
CWA	County Warning Area
DA	Data Assimilation
DoD	Department of Defense
DRWP	Doppler Radar Wind Profiler
EFT-1	Exploration Flight Test 1
ER	Eastern Range
ERAU	Embry-Riddle Aeronautical University
ERTS	Eastern Range Technical Services
ESRL	Earth System Research Laboratory
FAA	Federal Aviation Administration
FSU	Florida State University
GEMPAK	GEneral Meteorology PAcKage
GP-G	Ground Systems Division
GrADS	Grid Analysis and Display System
GSDO	Ground Systems Development and Operations program
GSI	Gridpoint Statistical Interpolation
IDV	Integrated Data Viewer
JSC	Johnson Space Center
KSC	Kennedy Space Center
LNB	Low Noise Block
LRR	Launch Readiness Review
LSP	Launch Services Program
LWO	Launch Weather Officer
MARSS	Meteorological and Range Safety Support
MCO	Orlando International Airport
ME	Mean Error
MET	Model Evaluation Tools
MIDDS	Meteorological Interactive Data Display System
MODE	Method For Object-Based Diagnostic Evaluation
MSFC	Marshall Space Flight Center
MSLP	Mean Sea Level Pressure
NCAR	National Center for Atmospheric Research
NOAA	National Oceanic and Atmospheric Administration
NRS	NOAAPort Receive System
NSSL	National Severe Storms Laboratory
NWS MLB	National Weather Service in Melbourne, Florida
QC	Quality Control
REIN	Range External Interface Network
RMSE	Root Mean Square Error
RTSC	Range Technical Services Contractor
RWO	Range Weather Operations
SLS	Space Launch System
SMC	Space and Missile Center
SPoRT	Short-term Prediction Research and Transition Center
TA	KSC Center Operations Directorate
TAAD	Total Area Average Divergence
TDWR	Terminal Doppler Weather Radar
USAF	United States Air Force
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-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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