AMU Applied Meteorology Unit

Infusing Weather Technology Into Aerospace Operations

Quarterly Report
Second Quarter FY-14
30 April 2014

Contract NNK12MA53C/DRL-003 DRD-004

In this issue:

Falcon 9 carrying the Thaicom 6 broadcast satellite on 6 January 2014 (Image credit: Walter Scriptunas II www.scriptunasimages.com, also on Spaceflight Now www.spaceflightnow.com/falcon9/008/remotes/)

Launch Support

Ms. Shafer and Dr. Huddleston supported the Falcon 9 Thaicom 6 launch on 6 January.

Dr. Watson and Dr. Huddleston supported the Atlas 5 TDRS L launch on 23 January.

Dr. Bauman and Dr. Huddleston supported the Delta 4 GPS 2F-5 launch on 20 February

This Quarter's Highlights

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

- Ms. Crawford processed data from two local radars to create a merged reflectivity display.
- Dr. Bauman completed researching software packages for their ability to display radar and lightning data for use in evaluating lightning launch commit criteria.
- 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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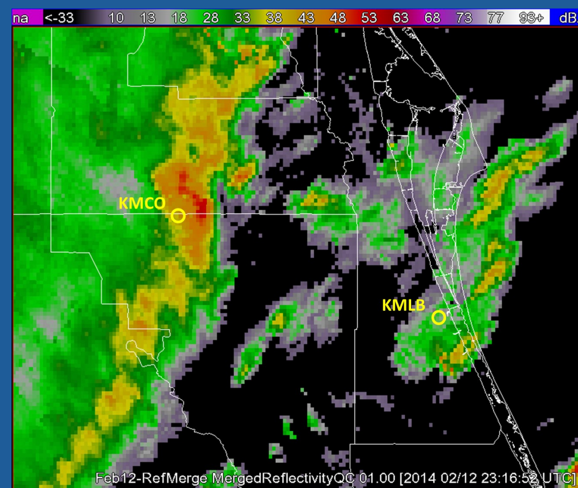
Quarterly Task Summaries

This section contains summaries of the AMU activities for the second quarter of Fiscal Year 2014 (January-March 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 4)

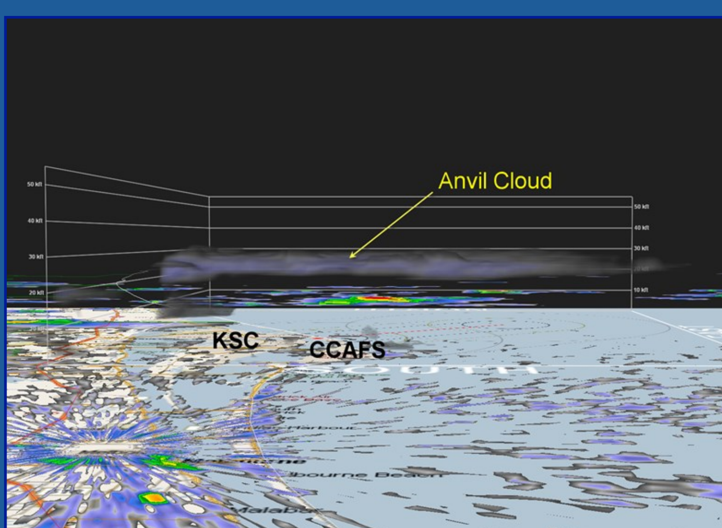
Customers: NASA's Launch Services Program (LSP), Ground Systems Development and Operations (GSDO), and Space Launch System (SLS) programs; and the National Weather Service in Melbourne, Florida (NWS MLB).



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: .Processed and quality controlled (QC-d) the NWS MLB Weather Surveillance Radar 1988-Doppler (WSR-88D) and Orlando International Airport (MCO) Terminal Doppler Weather Radar (TDWR) data, and successfully merged the reflectivity data from both radars. Downloaded Linux tools to edit Network Common Data Form (netCDF) files in order to change the incorrect Nyquist velocity value in the 45th Space Wing (45 SW) Doppler radar (WSR).

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



Customers: NASA's LSP and SLS program.

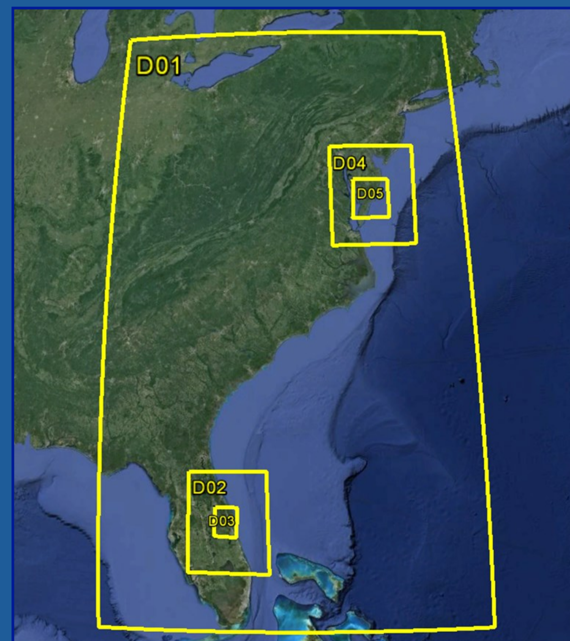
Purpose: NASA's LSP customers and the future SLS program cannot launch if lightning is within 10 NM of the predetermined flight path of a launch vehicle. The 45 WS Launch Weather Officers (LWOs) evaluate this lightning launch commit criteria (LLCC) to ensure the safety of the vehicle in flight. The AMU 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 Internet searches using keywords applicable to the data types and software required and cataloged the results. Completed discussions with several software developers in government and private companies to discuss the capabilities of their software. Began writing the final report.

Quarterly Task Summaries
(continued)

Range-Specific High-Resolution Mesoscale Model Setup (Page 9)

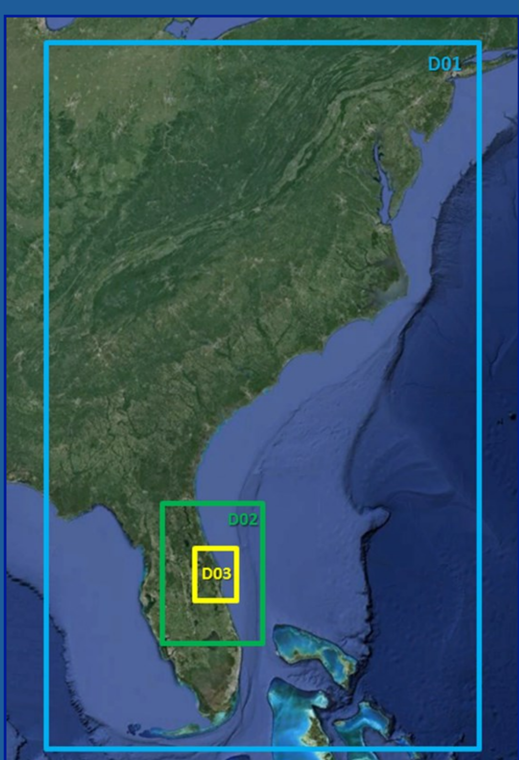
Customers: NASA's LSP, GSDO, and SLS programs.



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: Modified updated scripts to run the Gridpoint Statistical Interpolation (GSI)/Weather Research and Forecasting (WRF) model in real-time from NASA's Short-term Prediction Research and Transition Center (SPoRT). Finished running GSI/WRF archive cases for two more domain configurations over the ER and WFF. Obtained and began processing observation data that will be used to validate the WRF forecasts.

Real-Time KSC/CCAFS High Resolution Model Implementation and Verification (Page 10)



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 (AWIPS) for real-time subjective analysis.

Accomplished: Set up data connections to the AMU cluster and wrote scripts to automatically receive observational data from the National Centers for Environmental Prediction (NCEP). Finished writing Perl scripts to automate the Model Evaluation Tools (MET) software statistical output routines, which will be used to verify the WRF-EMS runs. Began working to get real-time WRF-EMS output into AWIPS II.

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 WSR, NWS MLB WSR-88D, and the Federal Aviation Administration (FAA) TDWR at MCO.

MCO TDWR Data

Mr. Blottman of NWS MLB provided MCO TDWR (KMCO) data from 21 November 2013 downloaded from their KMCO Supplemental Product Generator (SPG). Ms. Crawford was unsuccessful in processing the data received from the FAA and was unable to get advice from the Warning Decision Support System Integrated Information (WDSS-II) forum on how to process the FAA data. She used the SPG data set to determine if it could be processed by the WDSS-II algorithms.

After gleaning information from the WDSS-II forum and researching TDWR data formats, Ms. Crawford was finally able to process the data with some errors. She described the data, the tools she used, and the errors to the WDSS-II forum and received assistance from Mr. Ben Herzog of the Cooperative Institute for Mesoscale Meteorological Studies at the University of Oklahoma. He pointed her to another WDSS-II tool that processed the SPG data with no errors. Once processed, she QC-d the reflectivity data using a WDSS-II QC tool and prepared the data for input to the WDSS-II graphical user interface (GUI).

Merged Reflectivity

Ms. Crawford researched the WDSS-II forum for how to merge data from two or more radars. Through trial and error, she was able to glean enough information about which tools to use and which options in the commands were needed to merge the reflectivities and velocities from the TDWR and WSR-88D.

The merging process takes several steps. First, a 3-D grid area must be created for the merge command to access. It is defined by a northwest latitude/longitude (lat/lon) and grid top height, a southeast lat/lon and grid bottom height, and the horizontal and vertical grid spacing. Next, a simulator tool is started that reads the processed data from two or more radars and reorders it according to time. The beginning and end time of the simulation is defined in this tool. The merger tool can then be started in another terminal window. This tool uses the output from the simulator as input, processes the data using the merging procedure described in Lakshmanan et al. (2006), and then outputs the merged data.

Ms. Crawford followed this process using the 21 November KMCO and associated NWS MLB WSR-88D (KMLB) data downloaded from the National Climatic Data Center (NCDC), and was able to create a merged reflectivity field. However, there was no weather during the data time period and, thus, no precipitation echoes.

On 12 February 2014, a severe weather event occurred in central Florida with winds in excess of 50 kt and quarter-size hail reported in some locations. Mr. Blottman collected two hours of KMCO and KMLB data during that event and sent the files to Ms. Crawford. She processed and QC-d the KMCO data, but WDSS-II could not process the KMLB data collected directly from the radar product generator (RPG). She downloaded the KMLB data from NCDC, which WDSS-II was able to process and QC.

For these two radars, Ms. Crawford defined a grid with a northwest corner lat/lon of 29.5 N/82 W and top of 10 km, a southeast corner lat/lon of 27 N/80 W and bottom of 0 km, and grid spacing of 0.009x0.009 degrees horizontal and 0.5 km vertical. There are approximately 111 km per degree latitude and approximately 97–99 km per degree longitude at the latitudes in the grid. The horizontal grid spacing of 0.009 is roughly equal to 1 km in both dimensions, slightly shorter in the east-west dimension than north-south. This resolution can be changed depending on operational or numerical model needs.

Figure 1 shows the reflectivity from the KMCO 0.3 degree elevation scan at 2316 UTC. The location of each radar is surrounded by a yellow circle. Note the small cone of silence, the black circle inside the yellow circle, at the KMCO radar. Figure 2 shows the reflectivity from the KMLB 0.5 degree elevation scan at 2318 UTC, the closest KMLB scan in time to the KMCO scan in Figure 1. The cone of silence at the KMLB radar is larger than that of KMCO.

Figure 3 shows the merged reflectivities at 2316 UTC. Note the reflectivities over the cones of silence seen in Figures 1 and 2. The resolution is more coarse than for either radar, KMLB has a gate spacing of 0.25 km and KMCO has a gate spacing of 0.15 km, but the 1-km grid spacing may be more appropriate for the merged wind field, which is the ultimate goal of this task. It is required in WDSS-II that reflectivities be merged before velocities. Ms. Crawford is now testing options in the merge tool to create merged velocities after being successful in merging the reflectivities.

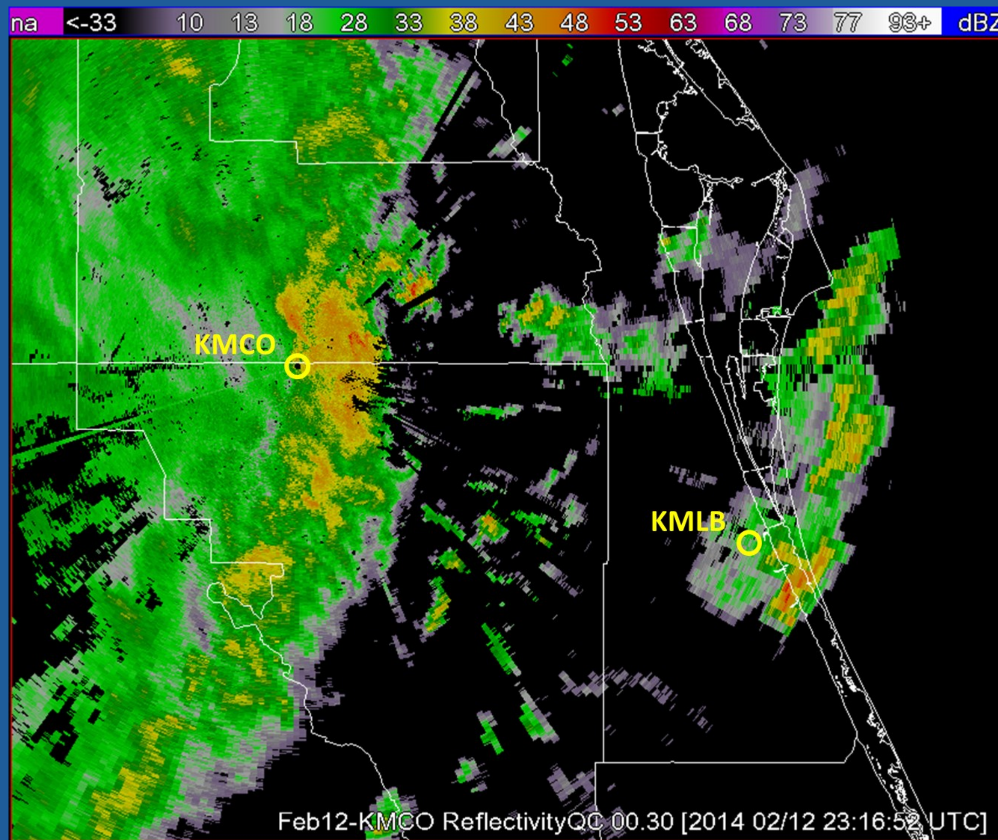


Figure 1. The KMCO reflectivity at 2316 UTC 12 February 2014, elevation angle 0.3 degrees. The yellow circles show the locations of the KMCO and KMLB radars.

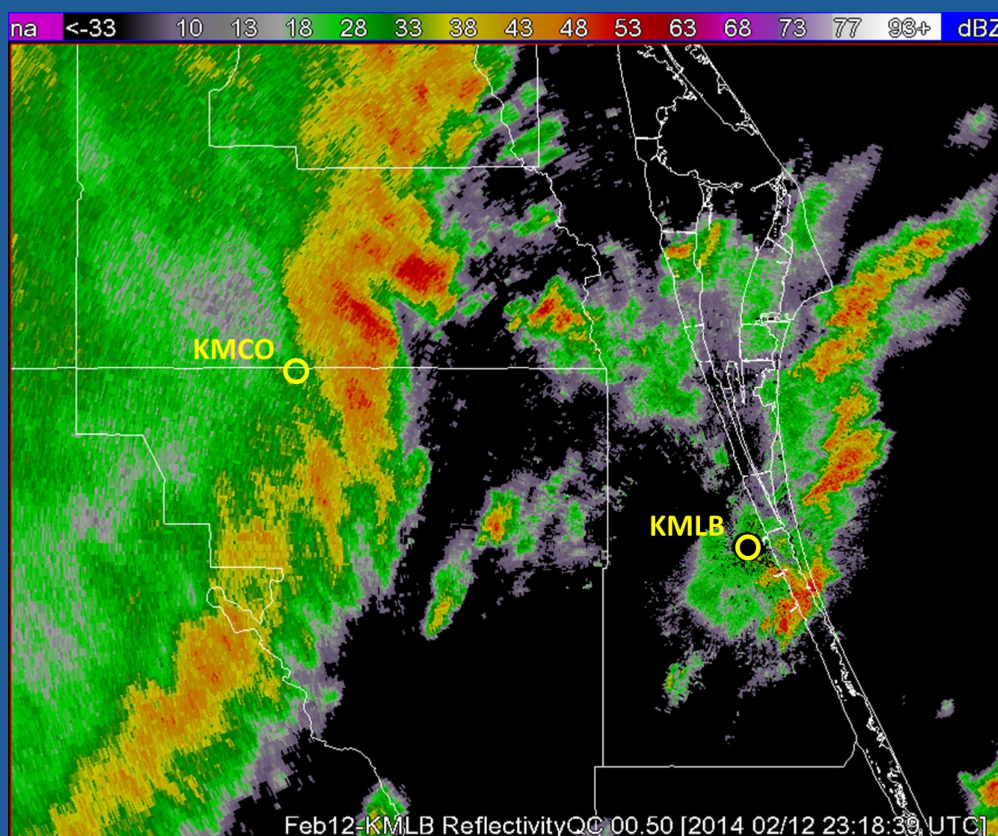


Figure 2. The KMLB reflectivity at 2316 UTC 12 February 2014, elevation angle 0.5 degrees. The yellow circles show the locations of the KMCO and KMLB radars.

NWS MLB WSR-88D data

As stated in the previous section, WDSS-II could not process the KMLB data collected from the NWS MLB RPG, but was able to process the data from NCDC. Ms. Crawford compared the file content from both sources and found differences in the file header information. If WDSS-II is to be run in real-time at NWS-MLB, it must be able to ingest data from the RPG. Ms. Crawford will investigate this issue in the WDSS-II forum.

45 SW WSR Data

In the last AMU Quarterly Report (Q1 FY14), Ms. Crawford described the Nyquist velocity issue with the WSR data. She installed Linux tools that can edit netCDF files, and began working with them to change the incorrect Nyquist velocity value in the WSR netCDF files. This may allow the WDSS-II velocity de-aliasing algorithm to use the correct value.

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

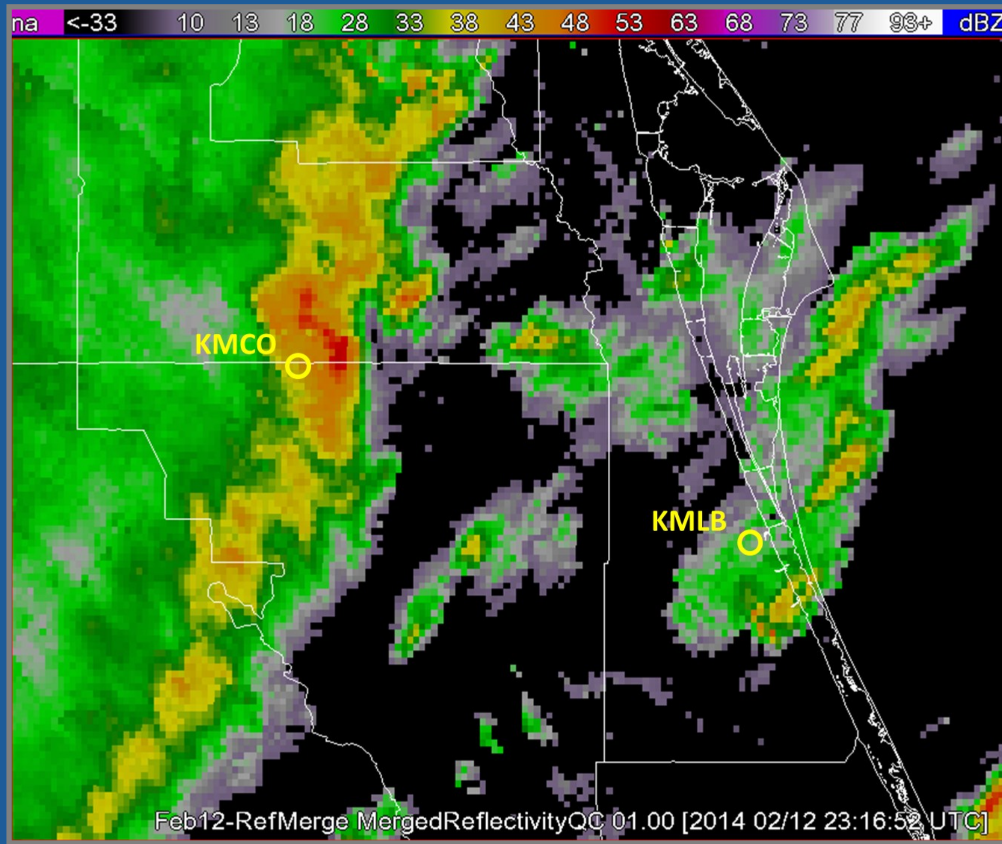


Figure 3. The KMCO and KMLB merged reflectivity at 2316 UTC 12 February 2014, height of 1 km. The yellow circles show the locations of the KMCO and KMLB radars.

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 WSR, the NWS MLB WSR-88D, and the vehicle flight path data so that all can be visualized together. To accomplish this, the AMU will conduct Internet searches for potential software candidates and interview software developers. The AMU will also need to determine the format of each data type.

Software Search

Dr. Bauman completed the keyword Internet searches for software that could potentially ingest and display the data types. In addition to the summary of candidate software shown in Table 2 in the previous AMU Quarterly Report (Q4 FY13), he found other candidate software from Weather Decision Technologies and NASA/University of Alabama in Huntsville.

Upon completion of Internet searches, Dr. Bauman contacted software developers via e-mail or talked to them directly while attending the 94th American Meteorological Society (AMS) Annual Meeting in Atlanta, Ga., from 2–6 February 2014. He found that none of the candidate software could meet the data display requirement without some development.

The two most likely candidate software packages include Omni®, developed and sold by Baron Services, Inc. (hereafter Baron), and the Real Time Mission Monitor (RTMM), developed by NASA Marshall Space Flight Center (MSFC), to track and monitor assets during Earth science research airborne field deployments (Goodman et al. 2011).

Omni Software

Baron states that Omni is "Capable of depicting multiple layered datasets from any available source simultaneously" and that "Omni enables full integration of meteorological observations, from radar and satellite imagery to live sensors, cameras, forecast modeling and much more." Omni is also capable of displaying 3-D volumetric radar imagery, integrating almost any kind of native sensor format, and tracking mobile assets equipped with GPS-enabled devices.

Dr. Bauman talked to Baron Executive Vice President and Chief Development Officer Bob Dreisward at the AMS meeting about the requirements and he stated that Omni could possibly display the data but not without development. He recommended NASA contact him to request a quote for the development costs.

RTMM Software

The RTMM is described as "a situational awareness tool that integrates satellite, airborne and surface data sets; weather information; model and forecast outputs; and vehicle state data (e.g., aircraft navigation, satellite tracks and instrument field-of-views) for field experiment management" (Blakeslee et al. 2007). Dr. Bauman could not find any references to a 3-D version of RTMM but, in its current state, it is capable of displaying the required data types: WSR-88D reflectivity images, C-band weather radar reflectivities (e.g., the 45 SW WSR), multiple lightning strike networks including LMAs, and vehicle tracks (aircraft or vertical launch). The RTMM uses a Google Earth plug-in application programming interface (API) giving it an intuitive and familiar user interface (Figure 4). Using the API allows users to run the RTMM application in a web browser instead of having to install the Google Earth standalone application on their computer.

KSC Lightning Mapping Array

At this time, the KSC LMA is still under construction and no data are available. Dr. Bauman was told by KSC Ground Processing Directorate personnel that once the LMA network is complete the data will terminate in the KSC Data Center and will not be provided to the 45 SW. The data will, therefore, not be available to populate a computer system in Range Weather Operations at CCAFS. It would be up the 45 SW to coordinate and fund the infrastructure to get the data to CCAFS.

Recommendations

Dr. Bauman recommends following-up with Baron and NASA/MSFC to request more information on these two candidate software packages to determine the development costs needed to meet the full 3-D data display requirements required by the 45 WS LWOs.

Final Report

Dr. Bauman started writing the final report.

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

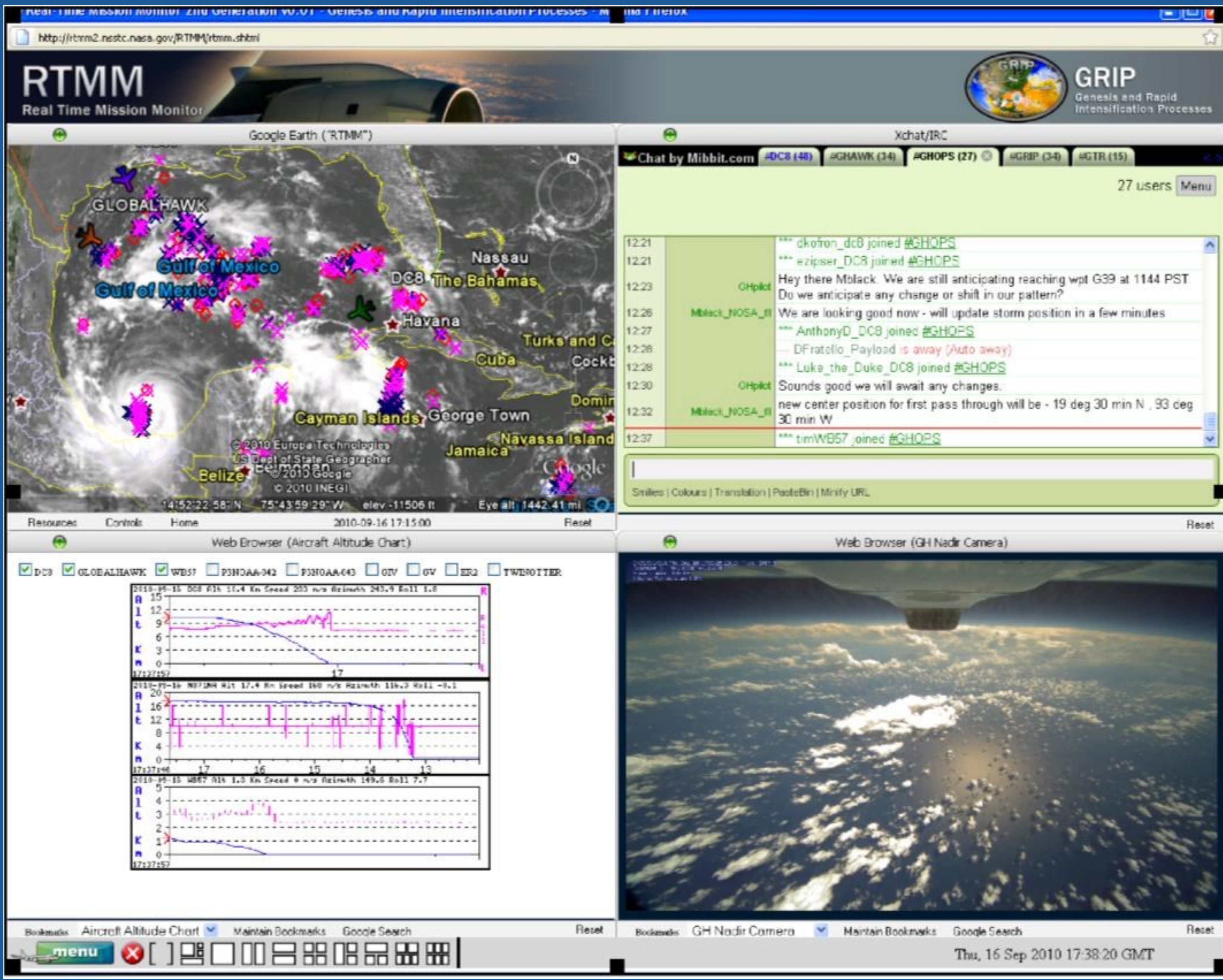


Figure 4. Four-panel RTMM screen depicting (upper left): three aircraft with lightning strikes in magenta; (upper right): XChat discussion of Global Hawk waypoint timing; (lower left): aircraft altitude charts; (lower right): nadir camera view from the belly of the Global Hawk (From Goodman et al. 2011)

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.

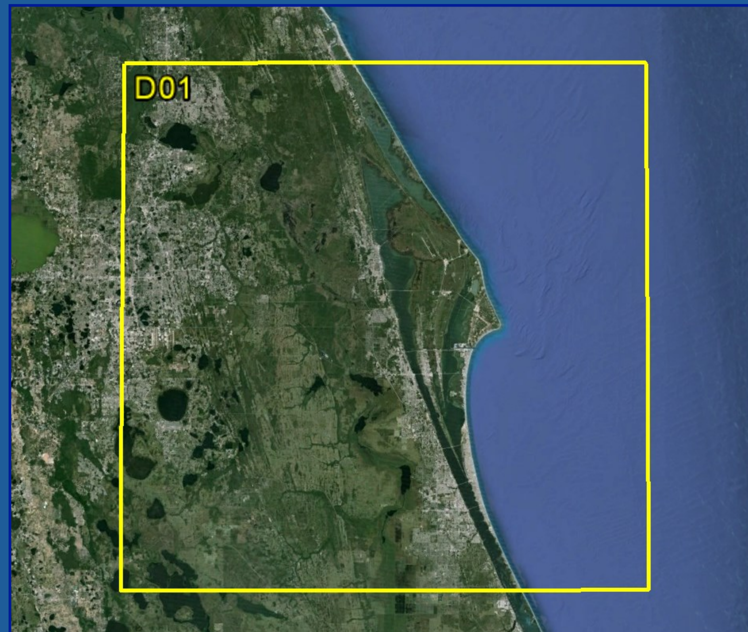


Figure 5. Map of the ER showing 1-km (D01) model domain boundary.

GSI/WRF Scripts and Running Archive Cases

Dr. Watson received an updated set of scripts to run GSI/WRF in real-time from Mr. Brad Zavodsky of SPoRT. She modified the new scripts based on the changes she made to the original set of scripts. Once that was complete, Dr. Watson ran two new domain configurations for the ER and WFF, a 1-km single domain over ER (Figure 5) and a 9/3/1-km triple nest domain over the ER and WFF (Figure 6). The period of record for both configurations was 27 August to 11 November 2013. She ran the GSI/WRF scripts four times per day, with each run producing a 12-hour forecast. For the triple-nested configuration, the data assimilation was run on the outer 9-km domain with the innermost domains used to create the high-resolution forecasts.

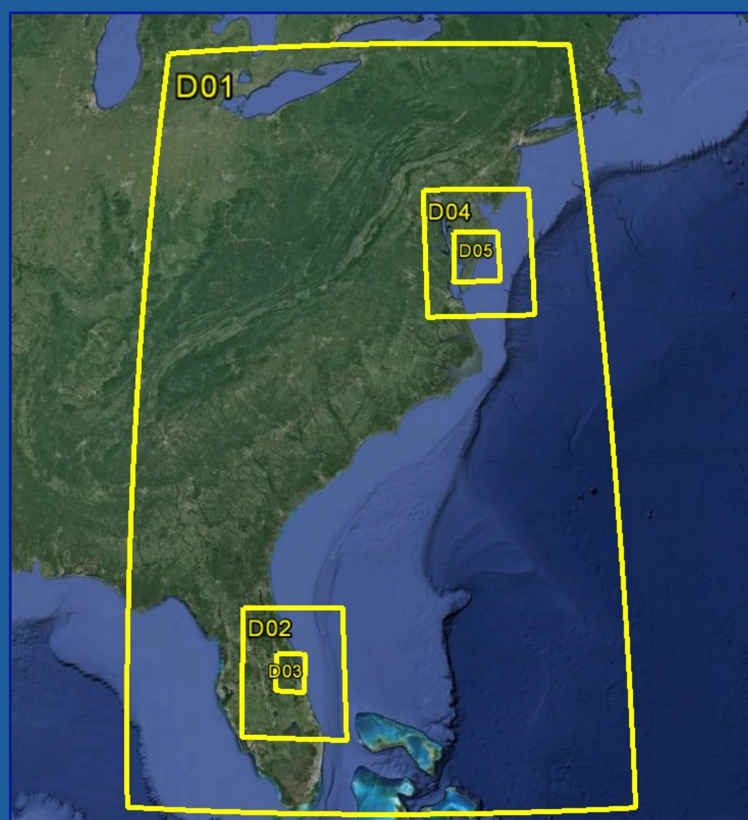


Figure 6. Map of the triple nested configuration showing the 9-km outer (D01), 3-km middle (D02 and D04), and 1-km inner (D03 and D05) model domain boundaries over the ER and WFF.

Validation of WRF Forecasts

Dr. Watson downloaded METAR data, a part of the Meteorological Assimilation Data Ingest System (MADIS), that will be used to validate the WRF forecasts. METAR is the international standard code format for hourly surface weather observations. Dr. Watson will compare the METAR observation to the WRF forecasts using the MET verification package. MET was developed by the National Center for Atmospheric Research (NCAR) Developmental Testbed Center through the support of AFWA and the National Oceanic and Atmospheric Administration (NOAA) and was designed to be a highly-configurable, state-of-the-art suite of verification tools.

After downloading the data, she reformatted the METAR data for use in the MET software. Although METAR is a good verification dataset, there are not many METAR reports available within the inner ER and WFF domains. Therefore, Dr. Watson decided to include mesonet data, also part of MADIS, for validation. The mesonet is a network of automated weather stations designed to observe mesoscale meteorological phenomena and report conditions in time intervals anywhere from 1 to 15 minutes. The locations of some of the METAR and mesonet stations over the ER are shown in Figure 7 in the next task description. The MET package did not include an option for forecast validation using mesonet data, so Dr. Watson worked with Mr. John Halley Gotway, from the NCAR Research Applications Laboratory, to update the MET source code to include the mesonet as a point observations source in MET. Dr. Watson reformatted the mesonet data after the MET source code was updated.

Dr. Watson also downloaded the NCEP Stage IV precipitation data that she will use to validate the WRF forecasts. She re-gridded the precipitation data to match the innermost domain of each WRF configuration for the ER and WFF.

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 servers, which will allow the 45 WS and AMU staff to customize the model output display on the AMU and Range Weather Operations AWIPS 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.

Observational Data

In order to verify the WRF-EMS model performance, Ms. Shafer required surface weather observations of temperature, dewpoint, relative humidity (RH), wind speed and direction, and atmospheric pressure. Based on Dr. Watson's previous model verification work, Ms. Shafer will use NCEP's MADIS and Stage IV precipitation data for the observational datasets.

MADIS

Last quarter, Mr. Erik Magnuson, a system and software engineer with ENSCO, Inc., set up and configured the second AMU modeling cluster for AMU use. Once this was complete, Mr. Magnuson worked with Ms. Shafer and Dr. Watson to coordinate with NCEP and set up a data connection to the cluster. With this connection the AMU automatically receives MADIS observational data via NCEP's local data manager in real-time. MADIS includes multiple data types including METAR and mesonet files. METAR is the international standard code format for hourly surface weather observations. Mesonet refers to a network of automated weather stations designed to observe mesoscale meteorological phenomena and report conditions in time intervals anywhere from 1 to 15 minutes. These data will be used to verify hourly 2-m temperature (K), dewpoint (K), RH (%), 10-m wind speed (m/s) and direction, and surface pressure (mb). Figure 7 shows the locations of the METAR and mesonet weather stations (https://madis-data.noaa.gov/sfc_display/) that will be used to verify the performance of the WRF-EMS inner-most domain.

Stage IV

In addition to the MADIS data, Ms. Shafer will use gridded NCEP Stage IV precipitation data to verify the hourly WRF-EMS precipitation forecasts. The Stage IV data combines radar data and rain gauge reports to produce hourly rainfall accumulation on a 4-km grid. It is a manually quality-controlled mosaic from the regional 1-hour precipitation analyses produced by 12 National Weather Service River Forecast Centers (Lin and Mitchell 2005). Ms. Shafer wrote a Perl script to automatically download and archive the necessary Stage IV data to the AMU cluster.

MET Software Automation

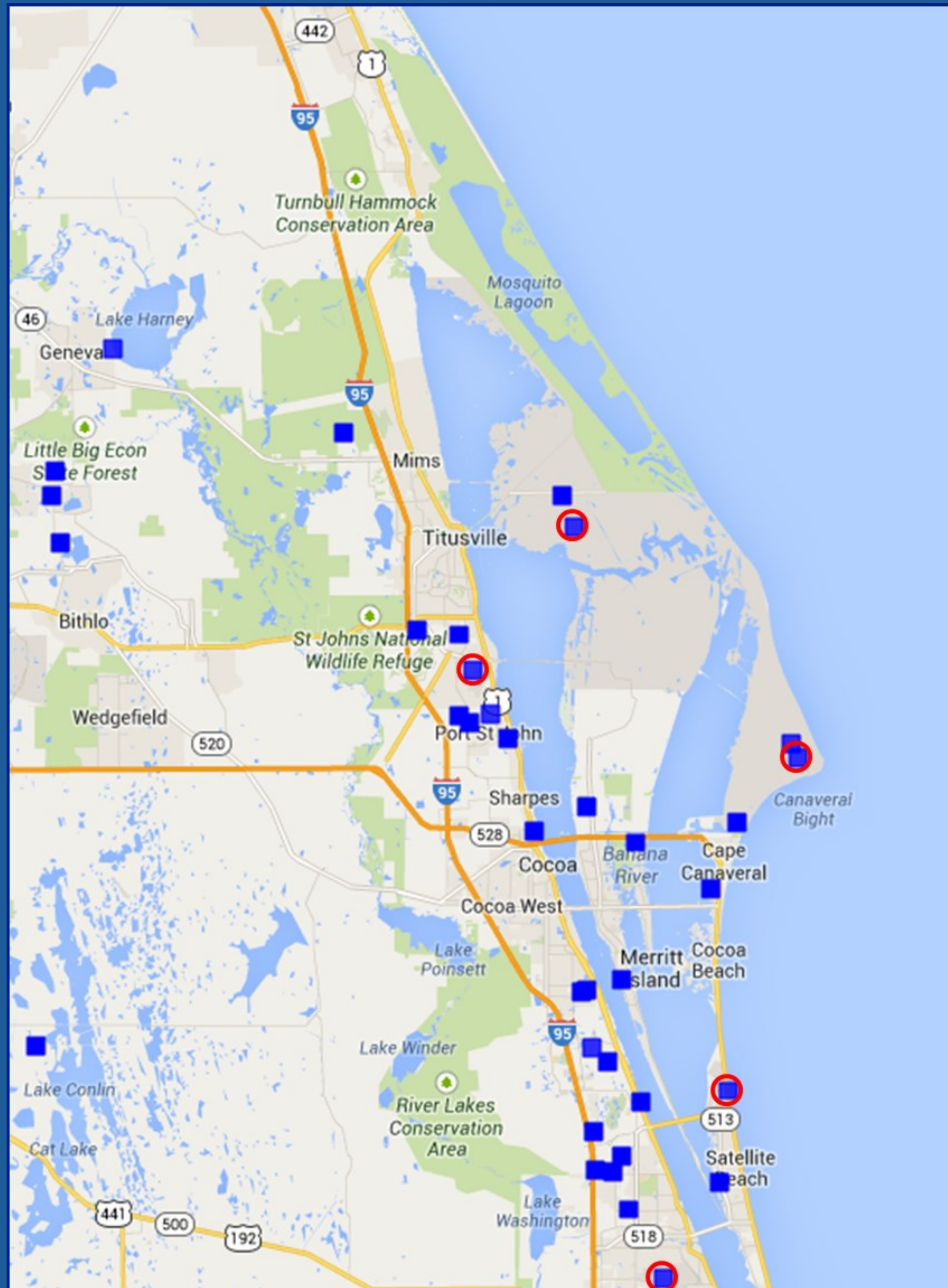


Figure 7. Map of the mesonet (blue squares) and METAR (blue squares with red circles) weather station locations from MADIS. Ms. Shafer will use the data from these sites to calculate verification statistics for the inner-most WRF-EMS domain.

Ms. Shafer will calculate verification statistics to determine the WRF-EMS model performance using the MET software. MET was developed by the NCAR Developmental Testbed Center through the support of AFWA and NOAA and was designed to be a highly-configurable, state-of-the-art suite of verification tools. Ms. Shafer will use two of the statistical verification tools available in MET, the Point-Stat Tool and the Method For Object-Based Diagnostic Evaluation (MODE) Tool. Ms. Shafer wrote Perl scripts to automatically run the MET statistical routines and archive the output on the AMU cluster.

Point-Stat Tool

The Point-Stat Tool computes traditional verification scores by comparing the gridded WRF-EMS forecast to the corresponding MADIS point observations. Some of the statistics include mean error, standard deviation, multiplicative bias, mean absolute error, mean squared error, and root mean squared error. Point-Stat is run on each hourly forecast and outputs a text file. Ms. Shafer will consolidate these text files in Microsoft Excel to help determine the overall model performance.

MODE Tool

The MODE Tool applies an object-based verification technique in comparing a gridded forecast to a gridded analysis. Ms. Shafer will use this tool to compare the WRF-EMS precipitation forecasts to the NCEP Stage IV observations. Table 1 shows some of the statistics included in the MODE output that she will use for model verification.

In order to use the MODE Tool for verification, the timing and grid spacing of the forecast must match the observational data. Since the WRF-EMS produces precipitation forecasts every 15 minutes on a 1.33-km grid and the Stage IV data is available hourly on a 4-km grid, Ms. Shafer had to reformat the WRF-EMS output to match the observations. Dr. Watson reformatted each of the 15-minute WRF-EMS files from the 1.33-km grid spacing to a 4-km grid. Then, she combined the new 15-minute 4-km files and created a 1-hour 4-km WRF-EMS forecast. Ms. Shafer wrote a Perl script to repeat this process and then run the MODE Tool for each hour each day. Similar to the Point-Stat Tool, Ms. Shafer will consolidate these MODE output text files in Microsoft Excel to determine the overall model performance for precipitation forecasts.

WRF-EMS Output into AWIPS II

In addition to verifying the model's performance, the AMU also agreed to make the WRF-EMS output available in AWIPS II for the 45 WS forecasters and AMU staff. Ms. Shafer contacted Dr. Geoffrey Stano, an ENSCO meteorologist and member of SPoRT, for assistance and provided a sample output file for his review.

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

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

Statistic Name	Description
ACC	Accuracy
FBIAS	Frequency Bias
PODY	Probability of Detecting Yes
PODN	Probability of Detecting No
POFD	Probability of False Detection
FAR	False Alarm Ratio
CSI	Critical Success Index
GSS	Gilbert Skill Score
HSS	Heidke Skill Score

The AMU staff started working fewer hours on the AMU contract due to reduced funding in the current contract year. Each of the four ENSCO AMU staff worked 3-4 days per week on the contract during the quarter.

Range Weather

Dr. Bauman provided input to Dr. Huddleston for the TA13 Technology Roadmap, a NASA-generated document that identifies technologies needed over a 20-year term. He suggested adding an assessment of new ground-based remote sensing technology to supplement/replace aging meteorological observing systems at KSC/CCAFS.

Dr. Watson and Ms. Shafer participated in the 45 WS Severe Weather Forecast discussion on 6 March. The 45 WS conducts these special discussions when there is the potential for severe weather to occur at KSC/CCAFS, and solicit input from the AMU meteorologists as part of their decision-making process.

Dr. Bauman contacted Mr. Jay Dorney of Exelis at Patrick Air Force Base to reopen the issue of accessing 45 SW weather sensor data via the Range External Interface Network (REIN). The AMU staff need the data automatically delivered to the AMU modeling clusters to assimilate into the local WRF model. Dr. Huddleston noted that Mr. Gemmer at KSC also needs this capability and requested we work this as a joint effort from the KSC Weather Office.

Documents

Ms. Crawford and Dr. Bauman continued to work with Dr. Huddleston to solve Document Availability Authorization (DAA) form issues with the KSC Scientific and Technical Information office. KSC switched to an electronic DAA form several months ago and the AMU staff had not been able to complete the form because the AMU no longer has a KSC mail code. Dr. Huddleston took steps to solve this issue, which will be tested with the next DAA. Additionally, two DAA's were submitted for AMU final reports in November 2013 prior to implementation of the electronic form and Dr. Huddleston has been working to track down the status.

Dr. Bauman updated the manuscript he submitted to the National Weather Association (NWA) Journal of Meteorology (JOM) based on reviewers' comments and it was approved for publication by the NWA JOM associate editor. It was evaluated by an NWA JOM technical editor and provided to Dr. Bauman for further review. Mr. Roeder of the 45 WS is co-author on the paper 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" completed in 2013.

Meetings

Dr. Bauman attended the 94th AMS Annual Meeting in Atlanta, Ga., from 2-6 February. His travel was funded by ENSCO, Inc., and he represented the AMU and NASA by presenting a poster titled "A Sounding-based Severe Weather Tool to Support Daily Operations at Kennedy Space Center and Cape Canaveral Air Force Station" with co-author Mr. Roeder from the 45 WS. He and Dr. Huddleston were co-authors on a paper presented by Dr. Jedlovec from NASA SPoRT titled "Lessons Learned in Transitioning Research to Operations: Applications to Space Weather." Dr. Bauman represented NASA and ENSCO as a member of the Aviation, Range, and Aerospace Meteorology committee and participated in their annual meeting.

The AMU staff participated in the NASA/MSFC Natural Environments Day of Launch Working Group at KSC on 19 and 20 March.

Dr. Watson and Ms. Crawford attended the 45 WS Launch Readiness Review for the Falcon 9 launch on 16 March.

IT

Ms. Shafer and Dr. Huddleston met with Ms. Maureen Sides of Yang Enterprises (KSC/ISC) to review NASA equipment inventory in the Morrell Operations Center (MOC) and KSC Central Instrumentation Facility. Ms. Shafer showed Ms. Sides the location of each item and confirmed the NASA tag numbers agreed with inventory records. Ms. Sides provided Dr. Huddleston written confirmation that the inventory was processed with no discrepancies and no further action is required.

Ms. Shafer and Dr. Bauman updated Adobe Flash Player software on all non-ACES AMU Windows computers per directive from the KSC IT Security Office under KAITS Actions IT(CIO)/2014-00003., IT (CIO)/2014-00007, IT(CIO)/2014-00010, IT(CIO)/2014-00014.

Ms. Shafer and Dr. Bauman updated Adobe Reader and Adobe Acrobat software on all non-ACES AMU Windows computers per directive from the KSC IT Security Office under KAITS Action IT(CIO)/2014-00005.

Ms. Shafer and Dr. Bauman updated Java software on all non-ACES AMU Windows computers per directive from the KSC IT Security Office under KAITS Actions IT (CIO)/2014-00004 and IT(CIO)/2014-00017

Mr. Saul of the 45 WS requested AMU help to determine the meteorological products available via the NOAAPort Receive System (NRS) that the AMU and 45 WS use to populate their weather analysis and display systems. The NRS consists of a satellite ground station located at the MOC and NRS servers to process the data. The 45 WS NRS feeds their Meteorological Interactive Data Display System (MIDDS) and the AMU NRS feeds the KSC AWIPS. While there is no product list available from NOAA, Mr. Magnuson of ENSCO provided Mr. Saul a product list he had developed from multiple sources. Mr. Saul stated that Mr. Magnuson provided what he needed to support the 45 SW MIDDS upgrade.

Ms. Shafer and Dr. Bauman began working with Mr. Magnuson to upgrade the AMU AWIPS to its latest version, AWIPS II. The AMU has three AWIPS client computers and two servers that require Linux operating system (OS) upgrades to CentOS 6 in order to run AWIPS II. Ms. Shafer and Dr. Bauman first upgraded the OS on each system and then installed the AWIPS II software on both servers and the AWIPS II visualization software all three clients. They load-balanced the servers for optimum performance and then started testing the graphical user interface on the client computers.

Dr. Bauman and Ms. Shafer started the process to setup the grids for retrieval of the 1.67 km WRF model files from the AFWA Consolidated Dissemination Capability. The 45 WS requested the AMU archive the model files for the 2014 warm season of May- September in preparation for a possible AMU task to assess the model's capability to forecast convection over KSC/CCAFS. Since AFWA does not archive any of the model files, they will automatically deliver the files to one of the AMU modeling clusters in the KSC Data Center once the setup is complete.

Ms. Shafer and Dr. Bauman continued testing the graphical user interface on the NASA AWIPS client computers as part of the upgrade to AWIPS II.

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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
AFSPC	Air Force Space Command
AFWA	Air Force Weather Agency
AMS	American Meteorological Society
AMU	Applied Meteorology Unit
API	Application Programming Interface
AWIPS	Advanced Weather Information Processing System
CCAFS	Cape Canaveral Air Force Station
CI	Convection Initiation
CSR	Computer Sciences Raytheon
DAA	Document Availability Authorization
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
GUI	Graphical User Interface
JOM	Journal of Operational Meteorology
JSC	Johnson Space Center
KMCO	MCO TDWR
KMLB	NWS MLB WSR-88D
KSC	Kennedy Space Center
LLCC	Lightning Launch Commit Criteria
LMA	Lightning Mapping Array
LSP	Launch Services Program
LWO	Launch Weather Officer
MADIS	Meteorological Assimilation Data Ingest System
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
NCDC	National Climatic Data Center
NCEP	National Centers for Environmental Prediction
netCDF	Network Common Data Form
NOAA	National Oceanic and Atmospheric Administration
NRS	NOAAPort Receive System
NSSL	National Severe Storms Laboratory
NWA	National Weather Association
NWS MLB	National Weather Service in Melbourne, Florida
OS	Operating System
QC	Quality Control
REIN	Range External Interface Network
RH	Relative Humidity
RPG	Radar Product Generator
RTMM	Real Time Mission Monitor
SLS	Space Launch System
SMC	Space and Missile Center
SPG	Supplemental Product Generator
SPoRT	Short-term Prediction Research and Transition Center
TDWR	Terminal Doppler Weather Radar
USAF	United States Air Force
VAFB	Vandenberg Air Force Base
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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