



**Applied
Meteorology
Unit**

**Quarterly Report
First Quarter FY-14
31 January 2014**

Infusing Weather Technology Into Aerospace Operations

Contract NNK12MA53C/DRL-003 DRD-004



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Launch Support

Dr. Bauman and Dr. Huddleston supported the Atlas 5 MAVEN launch on 18 November.

Ms. Shafer and Dr. Huddleston supported the Falcon 9 SES-8 launch on 3 December.

Atlas 5 carrying NASA's MAVEN on 18 November 2013 (image credit Spaceflight Now www.spaceflightnow.com/atlas/av038/launch/)

This Quarter's Highlights

The AMU team completed four, began two, and continued work on two tasks for their customers:

- Ms. Shafer completed a climatology for the Vandenberg Air Force Base (VAFB) wind towers.
- Dr. Huddleston completed the final report describing a tool to forecast the time of the first lightning strike in the Kennedy Space Center (KSC)/Cape Canaveral Air Force Station (CCAFS) area.
- Dr. Bauman completed the upper-winds analysis tools for VAFB and Wallops Flight Facility (WFF).
- Ms. Crawford processed and displayed radar data to create a dual-Doppler analysis over KSC/CCAFS.
- Dr. Bauman began researching software packages for their ability to display radar and lightning data for use in evaluating lightning launch commit criteria.
- Mr. Decker completed the final report describing the wind pairs database that the Launch Services Program will use to evaluate upper-level winds for launch vehicles.
- Dr. Watson continued assimilating data into model configurations for WFF and KSC/CCAFS.
- Ms. Shafer began 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

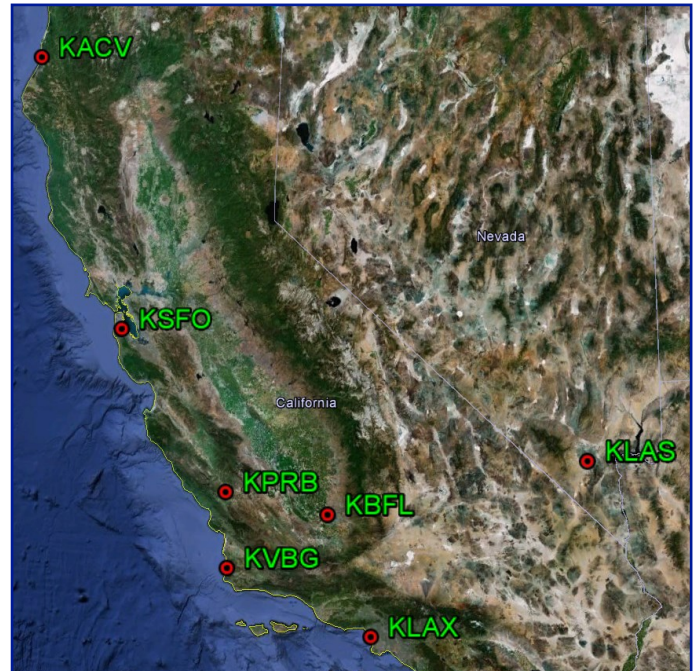
This section contains summaries of the AMU activities for the first quarter of Fiscal Year 2014 (October-December 2013). The accomplishments on each task are described in more detail in the body of the report starting on the page number next to the task name.

Vandenberg AFB Pressure Gradient Wind Study ([Page 6](#))

Customers: NASA's Launch Services Program (LSP)

Purpose: NASA's LSP and other programs at Vandenberg Air Force Base (VAFB) use wind forecasts issued by the 30th Operational Support Squadron (30 OSS) to determine if they need to limit activities or protect property such as a launch vehicle due to the occurrence of warning level winds at VAFB in California. The 30 OSS tasked the AMU to provide a wind forecasting capability to improve wind warning forecasts and enhance the safety of their customers' operations. This would allow 30 OSS forecasters to evaluate pressure gradient thresholds between pairs of regional observing stations to help determine the onset and duration of warning category winds. Development of such a tool will require that solid relationships exist between wind speed and the pressure gradient of one or more station pairs. As part of this task, the AMU will also create a statistical climatology of meteorological observations from the VAFB wind towers.

Accomplished: Completed and delivered the Microsoft Access VAFB climatology database and the final report to the 30 OSS, which was reviewed internally by the AMU and externally by customers before distribution. It is awaiting NASA approval for posting on the AMU website.



First Cloud-to-Ground Lightning Timing Study ([Page 8](#))

<http://spaceweather.com/swpod2009/31may09/Schaefers1.jpg>



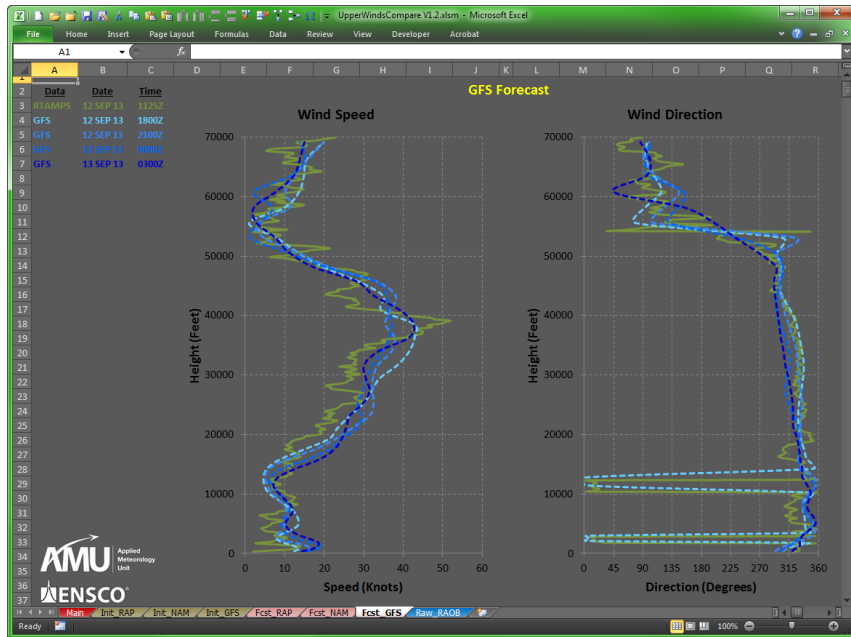
Customers: NASA's LSP, Ground Systems Development and Operations (GSDO), and Space Launch System (SLS) programs

Purpose: Develop a tool that provides the distribution of first cloud-to-ground (CG) lightning times in the KSC/CCAFS lightning warning circles to assist LSP, GSDO, the future SLS program, and other 45th Weather Squadron (45 WS) customers when planning potentially hazardous outdoor activities, including launch operations. Due to small data sample sizes, the AMU could not determine a statistical relationship between speed-stratified flow regimes and the time of the first CG strike. However, the AMU developed a tool with input from the 45 WS that allows forecasters to visualize the climatological frequencies of the timing of the first lightning strike.

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

Quarterly Task Summaries (continued)

Assessing Upper-level Winds on Day-of-Launch at Vandenberg Air Force Base and Wallops Flight Facility ([Page 8](#))



Customers: NASA's LSP and SLS program

Purpose: Provide the NASA launch directors and launch weather teams at VAFB and WFF with the same capability to assess upper-level wind observations and forecasts on day-of-launch as at KSC and CCAFS. The 45 WS Launch Weather Officers (LWOs) use the AMU-developed tool to monitor the upper-level wind observations and forecasts to keep their launch customers at KSC/CCAFS informed about forecast changes in upper-level winds during launch operations. The AMU modified the tool, an Excel graphical user interface (GUI), to include upper-air observations and model point forecast data for VAFB and WFF. The VAFB and WFF GUIs have the same appearance as the KSC version.

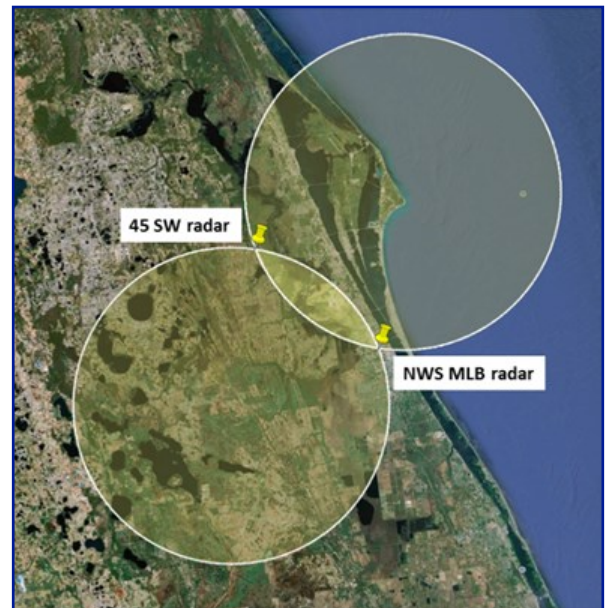
Accomplished: Modified, tested and delivered the tool to the launch weather team at WFF.

Configuration and Evaluation of a Dual-Doppler 3-D Wind Field System ([Page 9](#))

Customers: NASA's LSP, GSDO, and SLS programs; and the National Weather Service in Melbourne, Florida (NWS MLB).

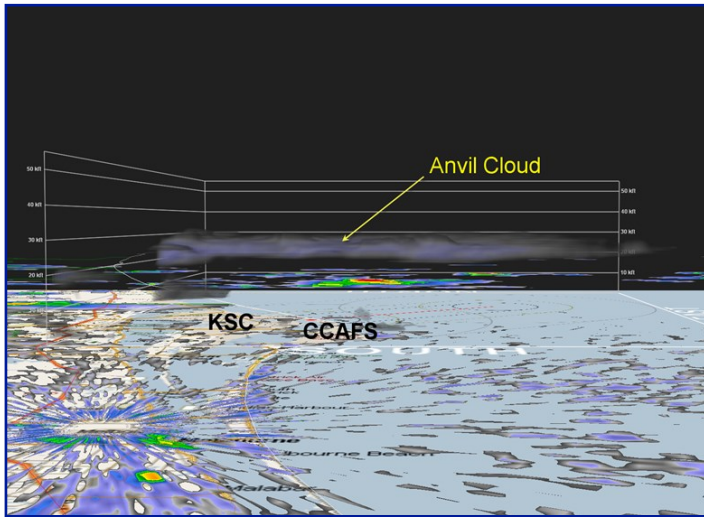
Purpose: Current LSP and GSDO and future SLS space vehicle operations will be halted when winds exceed defined thresholds and when lightning is a threat. A wind field display showing areas of high winds or convergence, especially over areas with no observations, would be useful to 45 WS and NWS MLB forecasters in predicting the onset of vehicle-critical weather phenomena, and can be used to initialize a local mesoscale numerical weather prediction model to improve the model forecast of these phenomena. Developing 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 timelier manner.

Accomplished: Processed and quality controlled (QC) the NWS MLB Weather Surveillance Radar 1988-Doppler (WSR-88D) and 45th Space Wing (45 SW) Doppler radar (WSR) radar data. Discovered issues in the way the Weather Decision Support System – Integrated Information (WDSS-II) software processed the WSR data. After a rebuild of WDSS-II, the WSR data were processed and displayed successfully, but issues remain with the velocity data QC.



Quarterly Task Summaries (continued)

Three-Dimensional Lightning Launch Commit Criteria Visualization Tool Market Research ([Page 12](#))



Customers: NASA's LSP and SLS program.

Purpose: NASA's LSP customers and the future SLS program cannot launch if lightning is within 10 NM of the pre-determined flight path of a launch vehicle. The 45 WS 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: Started conducting Internet searches using keywords applicable to the data types and software required and cataloged the results. Opened a dialogue with several software developers in government and private companies to discuss the capabilities of their software.

Wind Pairs Database for Persistence Modeling ([Page 14](#))

Customers: NASA's LSP and SLS program.

Purpose: Develop upper-level wind profile temporal pair databases and conduct a statistical analysis of wind changes at the ER, Western Range (WR) and WFF for use by NASA's LSP space launch vehicle teams in their commit-to-launch decisions. Their current assessments are based on upper-level wind data obtained earlier in the launch count, which may not represent the winds the vehicle will ascend through. This uncertainty can be mitigated by a statistical analysis of wind change over time periods of interest using historical data from the launch range. The intent of these databases is to help LSP improve the accuracy of launch commit decisions by applying wind change statistics based on measured historical data, as opposed to modeled data, into upper-level wind assessments.

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



Quarterly Task Summaries

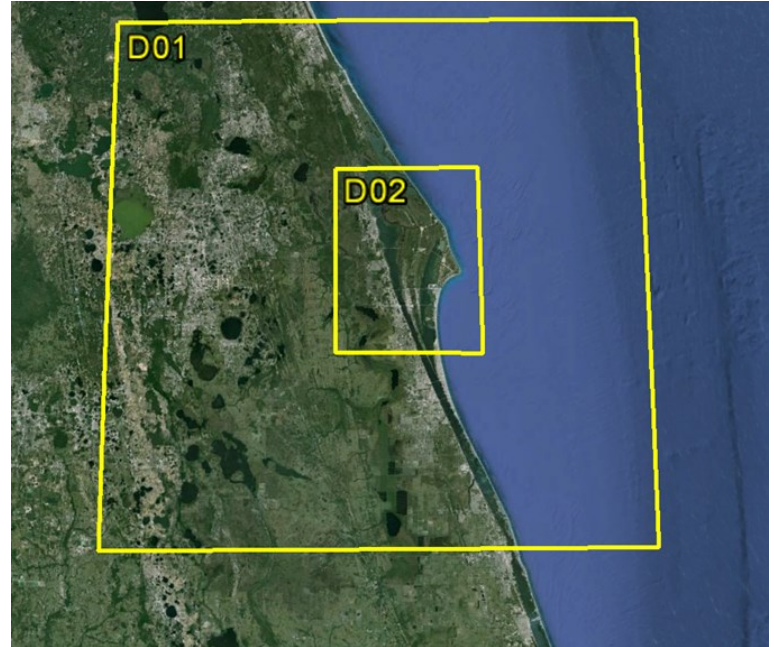
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Range-Specific High-Resolution Mesoscale Model Setup ([Page 15](#))

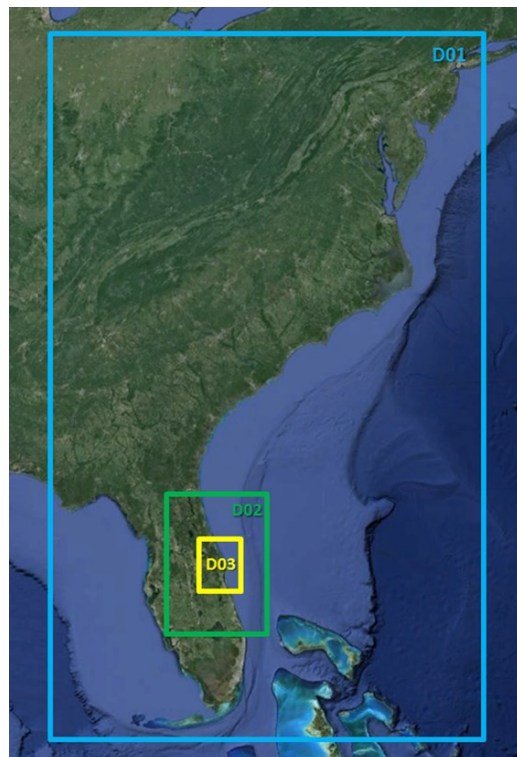
Customers: NASA's LSP, GSDO, and SLS programs.

Purpose: Establish a high-resolution model with data assimilation for the 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: Continued to modify scripts to run the Weather Research and Forecasting (WRF)/ Gridpoint Statistical Interpolation (GSI) in real-time from NASA's Short-term Prediction Research and Transition Center (SPoRT). Finished running GSI/WRF archive cases for one domain over the ER.



Real-Time KSC/CCAFS High Resolution Model Implementation and Verification ([Page 16](#))



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: Completed the configuration and set up of the second NASA AMU cluster. Installed and configured WRF-EMS, completed a successful test run and set up the model to run automatically every hour. Installed and compiled the National Center for Atmospheric Research Model Evaluation Tools (MET) software which will be used to verify the WRF-EMS runs.

AMU ACCOMPLISHMENTS DURING THE PAST QUARTER

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

SHORT-TERM FORECAST IMPROVEMENT

Vandenberg AFB Pressure Gradient Wind Study (Ms. Shafer)

Warning category winds can adversely impact day-to-day space lift operations at VAFB in California. NASA's LSP and other programs at VAFB use wind forecasts issued by the 30 OSS to determine if they need to limit activities or protect property such as a launch vehicle. For example, winds ≥ 30 kt can affect Delta II vehicle transport to the launch pad, Delta IV stage II attitude control system tank load, and other critical operations. The 30 OSS forecasters at VAFB use the mean sea level pressure from seven regional observing stations to determine the magnitude of the pressure difference (dP) as a guide to forecast surface wind speed at VAFB. Their current method uses an Excel-based tool that is manually intensive and does not contain an objective relationship between peak wind and dP. They require a more objective and automated capability to help forecast the onset and duration of warning category winds to enhance the safety of their customers' operations. They also agreed to analyze the pressure gradient (PG) as opposed to dP as it is a more accurate indicator of local wind speed. The 30 OSS has requested that the AMU develop an automated Excel GUI that includes PG thresholds between specific observing stations under different synoptic regimes to aid forecasters when issuing wind warnings. Development of such a tool requires that solid relationships exist between maximum peak wind (MPW) speed and the PG of one or more station pairs.

Climatology Database

Although not part of the original task, the AMU and 30 OSS discussed developing a GUI that would calculate and display climatology statistics based on the VAFB tower data provided for the VAFB Wind Study. This would allow the 30 OSS a way to easily communicate this information to their operational customers in real-time when requested.

Ms. Shafer completed processing all the VAFB tower data and received assistance from Mr. Chris Jessen, a Staff Engineer in ENSCO, Inc.'s Aerospace Sciences and Engineering division, to streamline the functionality of the Microsoft Access GUI to efficiently process the large amount of tower data and finalize the tool. Ms. Shafer delivered the GUI to Mr. Tyler Brock of the 30 OSS on 5 November. The database includes temperature (F), dew-point (F), relative humidity (%), average 1-minute sustained wind speed (kt) and direction (degrees), and peak wind speed (kt) and

direction (degrees) at the 6-, 12-, and 54-ft (2-, 4-, and 16-m) sensor levels from each of the 26 VAFB towers during October 2007 to November 2012. Figure 1 shows an example of the main page of the Access GUI, which includes user input forms, a query table, and a report option.

At the top of the GUI are two tabs; "Single Date" and "Multi Date". These are forms for the user to select specific query information depending on the date(s) of interest. For the "Single Date" option (Figure 2), the user would select up to 26 towers in

The screenshot displays the main page of the 30 OSS tower climatology GUI. At the top, it reads "NASA Launch Services Program Vandenberg Air Force Base Climatology Database" for the period "October 2007 - November 2012". Logos for AMU (Applied Meteorology Unit) and ENSCO are present. The interface has two tabs: "Single Date" (selected) and "Multi Date". Under "Single Date", there is a "Select All Towers" checkbox and a list of Tower IDs (005, 051, 054) with a scroll bar. To the right are dropdown menus for Month (1), Day (1), and Year (ALL). Below these is a "Height" dropdown. A label indicates the data includes "Temperatures (F), Wind Speeds (kt), Wind Directions (deg), Relative Humidity (%)". Three buttons are visible: "Run Query" (green), "Clear Query" (red), and "Open Report" (blue). At the bottom, a table header shows columns for "Hour", "Parameter", "Average", "Min", and "Max". A status bar at the very bottom shows "Records: 14" and a search box.

Figure 1. Main page of 30 OSS tower climatology GUI.

NASA Launch Services Program Vandenberg Air Force Base Climatology Database

October 2007 - November 2012

Single Date Multi Date

Select All Towers

Tower ID: 005, 051, 054
Month: 1, Day: 1, Height: , Year: ALL

Temperatures (F), Wind Speeds (kt), Wind Directions (deg), Relative Humidity (%)

Figure 2. The top portion of the 30 OSS GUI "Single Date" tab (see Figure 1). Users input specific query information in this form to generate desired climatology statistics.

NASA Launch Services Program Vandenberg Air Force Base Climatology Database

October 2007 - November 2012

Single Date Multi Date

Select All Towers

Tower ID: 005, 051, 054
Start Month: 1, Start Day: 1, End Month: 3, End Day: 31
Height: , Years: 2007, 2008

Temperatures (F), Wind Speeds (kt), Wind Directions (deg), Relative Humidity (%)

Figure 3. Same as Figure 2 but for the "Multi Date" tab.

Run Query Clear Query Open Report

Hour	Parameter	Average	Min	Max
0	dwptF	42	3	57
0	gustdir	272	0	360
0	gustspd	15	1	65
0	relh	64	13	99
0	tempF	54	36	78
0	winddir	271	0	360
0	windspd	11	1	55
1	dwptF	42	2	57
1	gustdir	255	0	360
1	gustspd	14	1	64
1	relh	69	9	99
1	tempF	53	34	76
1	winddir	254	0	360
1	windspd	10	1	53
2	dwptF	41	1	58
2	gustdir	233	0	360
2	gustspd	13	1	63
2	relh	71	12	99
2	tempF	52	33	77
2	winddir	231	0	360
2	windspd	10	0	53
3	dwptF	41	1	58
3	gustdir	214	0	360
3	gustspd	12	1	67
3	relh	72	11	99

Record: 168 of 168 No Filter Search

Figure 4. The lower, or query, portion of the GUI with the functional buttons and table of climatology statistics (see Figure 1).

the Tower ID list, one sensor Height, the Month, and the Day before running the query. Data in all years from 2007 to 2012 are automatically included in the query. For a period that is more than a single day, the user would select the "Multi Date" tab (Figure 3). Similar to the "Single Date" tab, the user would select up to 26 towers and one sensor height. They would also select the start and end dates of their period of interest and one or more years to include in the query.

Below the form tabs are three buttons and the query display table (Figure 4). Once the user has completed the form they would then click the green "Run Query" button to populate the query table below. The query table lists the hourly average, minimum and maximum value of each variable within the database that meets the criteria selected in the top portion of the GUI.

Once the user is finished with their query they may clear it by clicking the red "Clear Query" button, or they

NASA Launch Services Program Vandenberg Air Force Base Climatology Database

October 2007 - November 2012

Tower(s): 005, 051, 054, 057, 058, 059, 060, 061, 064, 065, 066, 070, 071, 072, 073, 074, 075, 076, 077, 078, 079, 080, 081, 102, 300, 301

Height: 16m Dates: 1/1 to 3/31 Year(s): 2007, 2008, 2009, 2010, 2011, 2012

Temperatures (F), Wind Speed (kt), Wind Direction (deg), Relative Humidity (%)

Hour	Parameter	Average	Min	Max
0	dwptF	42	3	57
0	gustdir	272	0	360
0	gustspd	15	1	65
0	relh	64	13	99
0	tempF	54	36	78
0	winddir	271	0	360
0	windspd	11	1	55
1	dwptF	42	2	57
1	gustdir	255	0	360
1	gustspd	14	1	64
1	relh	69	9	99
1	tempF	53	34	76
1	winddir	254	0	360
1	windspd	10	1	53

Figure 5. The first page of an example report with the selected query criteria information at the top.

may view and print a query report. Clicking the blue "Open Report" button will re-run the current query and open a report display. The user may then right-click in the window of the report and select the print preview option to print the report. The report displays the query criteria from the form at the top of the first page and the results shown in the query table. Figure 5 is an example of the first page of the multi-page report that shows statistics for every hour in the day.

Final Report

Ms. Shafer completed writing the final report. It was reviewed internally by the AMU and externally by cus-

tomers before distribution. She is waiting for NASA Export Control approval before posting the report on the AMU website.

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

First Cloud-to-Ground Lightning Timing Study (Dr. Huddleston)

NASA's LSP, GSDO, future SLS, and other KSC/CCAFS organizations use the lightning probability forecasts issued by the 45 WS when planning potentially hazardous outdoor activities, such as working with fuels or rolling a vehicle to a launch pad. The probability of CG lightning occurrence is included in the 45 WS daily and weekly lightning probability forecasts. These forecasts are important during May-October, when the area is most affected by lightning. These KSC organizations would benefit

greatly if the 45 WS could provide more accurate timing of the first CG lightning of the day in addition to the probability of lightning occurrence. The AMU has made significant improvements in forecasting the probability of lightning for the day. However, forecasting the time of the first CG lightning with confidence has remained a challenge. The ultimate goal of this task was to develop a tool that provides the distribution of first CG lightning times in the KSC/CCAFS lightning warning circles to assist the 45 WS customers to plan for activities prone to disruption due to lightning activity. Due to small data sample sizes, the AMU could not determine if there is a statistical relationship between speed-stratified

flow regimes and the time of the first CG strike. However, the AMU developed a tool with input from the 45 WS that allows forecasters to visualize the climatological frequencies of the timing of the first lightning strike.

Final Report

Dr. Huddleston completed writing the final report. It was reviewed internally by the AMU and externally by customers before distribution. She is waiting for NASA Export Control approval before posting the report on the AMU website.

For more information contact Dr. Lisa Huddleston at 321-853-8217 or lisa.l.huddleston@nasa.gov.

Assessing Upper-level Winds on Day-of-Launch at Vandenberg Air Force Base and Wallops Flight Facility (Dr. Bauman)

The AMU developed a day-of-launch capability to monitor upper-level wind observations and forecasts for NASA's LSP at KSC and CCAFS, and for future use by NASA's SLS program when it begins operating at KSC. The 45 WS LWOs use this tool to monitor the upper-level winds and to keep their launch customers at KSC/CCAFS informed about observed and forecast changes in upper-level winds (Bauman and Wheeler 2012). Because LSP conducts space launch operations at VAFB in California and WFF in Virginia, the AMU modified the upper-level winds tool for use at both locations. The tool consists of a Excel-based GUI that allows the LWOs at VAFB and WFF to create charts of upper-level wind speed and direction observations and then overlay point

forecast profiles from available numerical weather prediction models on the charts. This tool provides the LWOs with the capability to quickly retrieve and display the upper-level observations, compare them to the numerical weather prediction model point forecasts and provide upper-level wind information to the payload/launch team during the countdown. The observations are from the VAFB Real Time Automated Meteorological Profiling System rawinsondes and WFF rawinsondes. The model data includes the National Centers for Environmental Prediction (NCEP) North American Mesoscale (NAM), Rapid Refresh (RAP) and Global Forecast System (GFS) models. Comparing the model output to the observations allows the LWOs to objectively assess the performance of these models and communicate that information to the launch team.

WFF Implementation

This task was completed with the implementation of the GUI and associated software at WFF. Last quarter, on 27 September, Dr. Bauman received a sample rawinsonde file from

WFF and modified the Visual Basic for Applications code to import, process, and display the rawinsonde observation. On 7 October, he provided the Excel GUI file plus training instructions to WFF for testing, but due to the federal government shutdown the WFF personnel were on furlough and could not test the tool until they returned on 22 October.

Once the WFF meteorologists began testing the GUI, they corresponded with Dr. Bauman as part of the training. Based on a request from the WFF meteorologists after testing, Dr. Bauman updated the GUI code to change the rawinsonde release times from UTC to local time and provided an updated version of the Excel file. WFF meteorologists used the tool operationally for the first time on 19 November to support the Minotaur 1 launch, which set a record of 29 satellites launched from a single vehicle. The launch also was part of the Federal Aviation Administration's (FAA) certification for the Minotaur vehicle.

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

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 the 45 SW WSR, NWS MLB WSR-88D, and the FAA Terminal Doppler Weather Radar at Orlando International Airport as input to available free software that can create the 3-D wind field over the KSC/CCAFS area to support the safety of ground and launch operations.

NWS MLB WSR-88D Data

With the NWS MLB WSR-88D data processed and displaying correctly in WDSS-II, Ms. Crawford ran WDSS-II algorithms to QC the reflectivity and velocity data to prepare for further analysis. It is particularly important that the velocity data used in the dual-Doppler analysis be accurate in order to have confidence in the resulting wind fields.

Doppler radars have limits on the velocity magnitudes they can resolve unambiguously. These limits are determined by specific radar parameter settings (Rinehart 2004). The maximum unambiguous velocity, or Nyquist velocity,

of the WSR-88D data for this case is 55.7 kt. If the actual velocity magnitude exceeds this value, the resulting radar data are said to be aliased. As a simple example of an aliased velocity, if the actual wind speed away from the radar is 1 kt higher than the 55.7 kt Nyquist velocity (i.e. 56.7 kt) it will be displayed as -54.7 kt toward the radar.

Examples of aliased and de-aliased velocity data are shown in Figure 6a and b, respectively. In the color legend at the top of each image the cool colors to the left of the center gray block (0 kt) represent negative velocity values toward the radar and the warm colors to the right represent positive velocities away from the radar. The Nyquist velocity of -55.7 kt towards the radar occurs in the light purple region just left of the green, and 55.7 kt

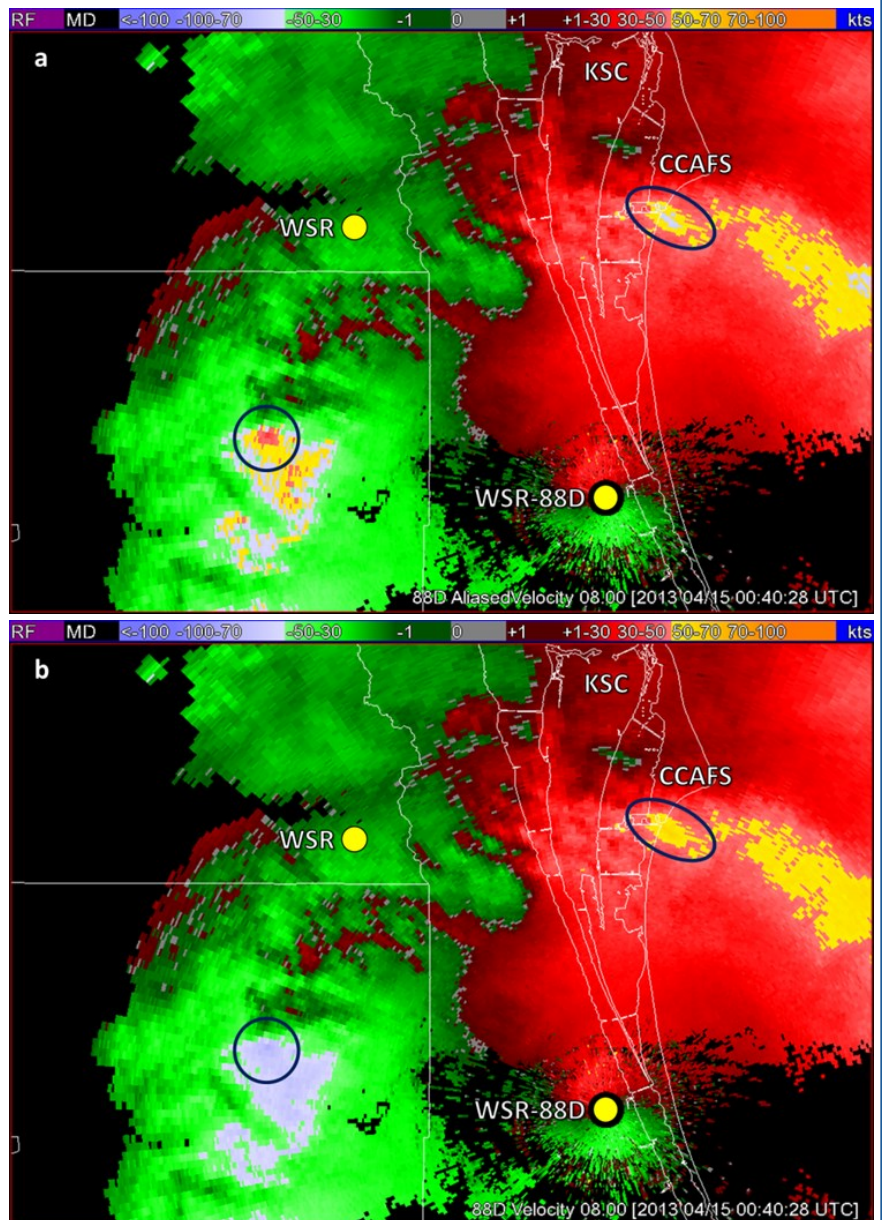


Figure 6. NWS MLB WSR-88D 8.0° velocity at 0040 UTC on 15 April 2013, a) aliased velocity and b) de-aliased velocity. The locations of the WSR-88D and 45 SW WSR radars are shown by the yellow circles, and the circle and ellipse highlight locations of aliased velocities.

away from the radar occurs in the yellow area just right of the red.

In the lower left of Figure 6a, aliased velocities are represented by the yellow and red values in the center of the area surrounded by the circle. Going from the left of this circle toward the right, velocities were toward the radar and increasing in magnitude from -50 to -55 kt represented by the colors changing from green to light purple. Continuing to move toward the right in the center of the circle, the values abruptly changed to 53 kt away from the radar in the yellow and 40 kt away from the radar in the red. If real, this would be an area of very strong convergence, but it is more likely indicative of a level with winds stronger than -55.7 kt toward the radar. Similar aliasing is in the area surrounded by the ellipse in the upper right, except the actual velocities in this case were away from the radar. The speeds increased to 55.7 kt going from the red to yellow, but changed to -53 kt toward the radar where the color changed to light purple in the center of the yellow area. Velocity aliasing is evident in other areas of the display as well. These two areas were chosen for demonstration.

The results of the de-aliasing algorithm are seen in Figure 6b. In the circle, the velocities of 53 to 40 kt away from the radar in yellow and red became velocities toward the radar of -58 to -71 kt represented by light to medium purple. The aliased velocities in the ellipse changed from around -53 kt toward the radar to 57-58 kt away from the radar. The new de-aliased values were more consistent with the surrounding velocities in both speed and direction.

45 SW WSR Data

Ms. Crawford experienced several issues when preparing the WSR data, which is in Interactive Radar Information System (IRIS) format.

She processed the data using two WDSS-II tools: one processed the IRIS data after it had been converted to WSR-88D Level II format, and the other processed the raw IRIS data directly from the WSR. Both algorithms created the Network Common Data Form (netCDF) files needed for display in WDSS-II.

Level II

Mr. McNamara, an LWO with the 45 WS, provided instructions on the use of a utility in the WSR system to convert the 45 SW IRIS data to Level II format. Ms. Shafer wrote a script using the utility to automatically convert the 2,000+ files from IRIS to Level II, and Ms. Crawford processed the Level II files using the WDSS-II Level II tool.

The first issue in displaying the data was that the radar location was not correct. The data displayed at 0° lat/0° long, the intersection of the equator and prime meridian in the Atlantic Ocean. Through assistance from the WDSS-II forum, Ms. Crawford learned that the radar location must be defined in a parameter file before processing. The radar latitude, longitude, and height above sea level were needed in this file. After she made this correction, the data displayed in the correct location, but the elevation angle values were not consistent with those of the WSR. In WDSS-II, the elevation angles are defined in volume coverage pattern (VCP) files. Each VCP has a number designation. The WDSS-II tool finds this number in the Level II files and accesses the corresponding VCP file for elevation angle definitions. At some point during the conversion or processing, the VCP was defined as 11, which is one of the WSR-88D VCPs. The elevation angle values displayed were consistent with VCP 11, but were incorrect for the WSR. There was not a way to define the elevation angles in the VCP with the Level II tool.

IRIS

Ms. Crawford also had limited success using the WDSS-II tool that processes raw IRIS data. The benefit of this tool is that it allows the VCP to be defined in the command line, but a parameter file containing the elevation angle values must exist for it to work. She created a VCP file containing the WSR's 13 elevation angles and processed the data with the IRIS tool. The resulting netCDF files only contained data for two elevation angles, neither of which were defined in the VCP file.

To address the issue of incorrect elevation angles being displayed for the WSR data, Ms. Crawford conducted a detailed analysis of each scan created by the Level II and IRIS tools and discussed the results in the WDSS-II forum. At his request, she sent a subset of all the data files to Mr. Jeff Brogden, one of the WDSS-II developers. After analyzing the data, he discovered that

- the elevation angles in the WSR data were not the same as in the defined VCP and
- there was a bug in the IRIS tool that required a rebuild of WDSS-II.

Table 1 shows the elevation angles in the 45 SW-defined VCP and the actual elevation angles in this dataset. The 45 SW VCP is based on recommendations from the AMU (Short 2008) and meets a 45 SW requirement for minimizing the vertical gaps between beams. As a result of an ongoing software upgrade project, the VCP sometimes changes to a default setting when the system is changed to a baseline configuration. The forecasters and LWOs are sometimes unaware of this change unless they notice something different about the display. Once noticed, they make the change back to the 45 SW VCP. Maintenance and a baseline change had recently been done

Table 1. Elevation angles of the 45 SW and default VCPs for the WSR. The default VCP was being used on 15 April 2013.

45 SW	0.2	2.2	5.7	8.9	12.5	17.6	28.3	22.0	14.5	10.6	7.3	4.0	1.2
Default	0.2	0.4	3.2	6.6	10.9	16.1	22.4	26.0	19.1	13.4	8.6	4.8	1.8

on the WSR in April 2013, causing the system default VCP to be used for this case. This will not be an issue once the software upgrade project is complete.

The WDSS-II developers modified the code in the IRIS tool, rebuilt WDSS-II, and notified Ms. Crawford when the new build was ready. They also recommended using the IRIS tool on the dataset instead of the Level II tool. She downloaded and installed the new version of WDSS-II, then processed the data with the IRIS tool. The new code output the correct elevations angles for the VCP used.

Before the data were QC-d, Ms. Crawford noticed more aliasing in the velocity data than for the WSR-88D. The Nyquist velocity for the WSR is 21.3 m/s, or 41.4 kt. This can be seen clearly in Figure 7a. The legend at the top of the image has the same colors and values in kt as in Figure 6. The Nyquist velocity of -41.4 kt towards the radar occurs in the bright green region on the left, and 41.4 kt away from the radar occurs in the bright red area on the right. These three areas were chosen for demonstration. The circle to the left of the WSR radar in Figure 7a is in an area of velocities toward the radar, and the two to the right of the WSR are in an area of velocities away from the radar. Velocity aliasing is evident in these three circles as well as other areas in the display. In all three circles, velocities between the red/green boundary change abruptly from 40 kt toward the radar in the red to -41 kt away from the radar in the green.

The de-aliased velocities are shown in Figure 7b. The aliased velocities toward the radar in the circle to the right of WSR were changed from ~40 kt away from the radar to -84 kt toward the radar. The correct values should be in the range of -40 to -50 kt toward the radar. The velocities in the upper right circle experienced the same issue. Where the velocities toward the radar (green) should have been changed to 40 to 45 kt away from the radar, they were actually changed to 84 to 87 kt away from the radar. In the lower right circle, the velocities toward the radar that should have been de-aliased were not. Ms. Crawford noted that the WDSS-II display stated the Nyquist velocity was 62.2 kt. She looked further into the netCDF files and found the Nyquist velocity was de-

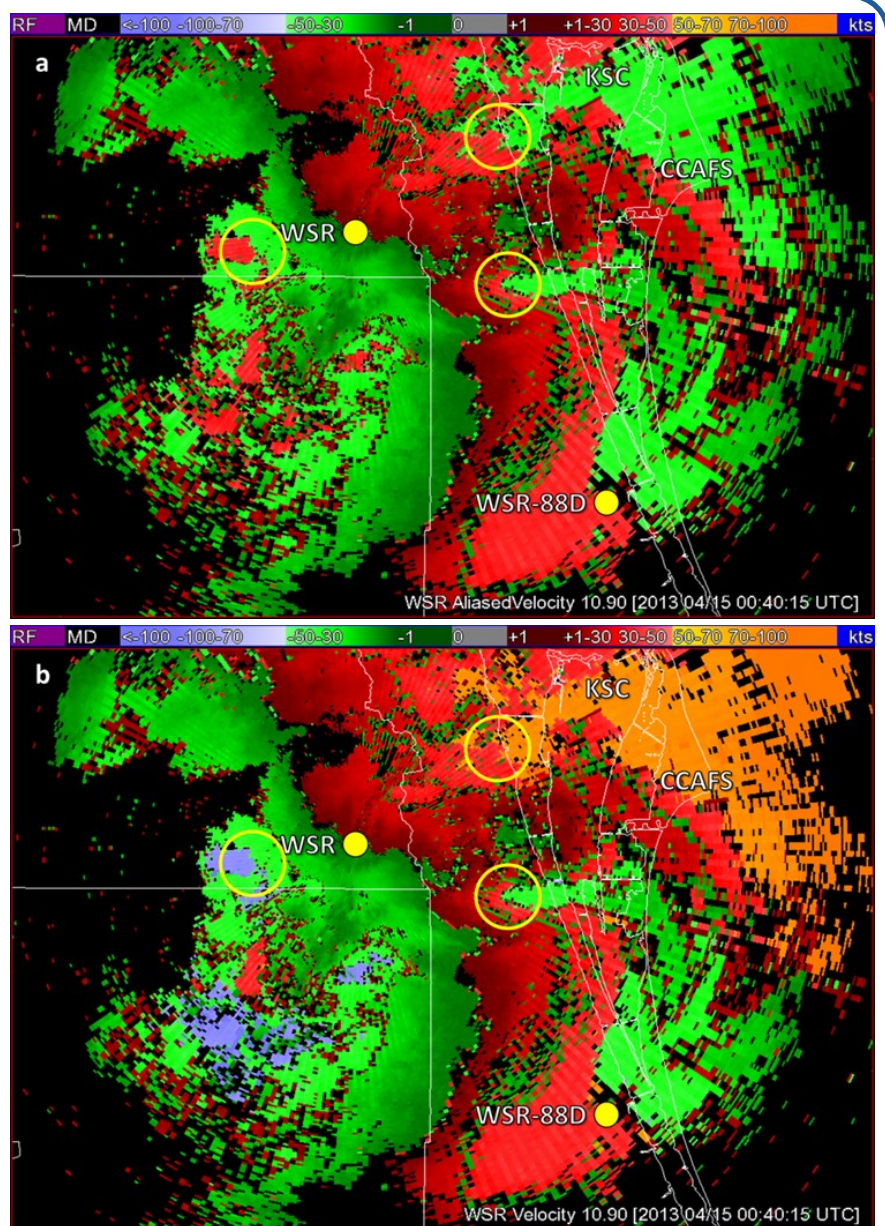


Figure 7. 45 SW WSR 10.9° velocity at 0040 UTC on 15 April 2013, a) aliased velocity and b) de-aliased velocity. The locations of the WSR-88D and 45 SW WSR radars are shown by the yellow circles, and the circles highlight locations of aliased velocities.

defined as 31.98 m/s, or 62.2 kt. It is clear when looking at the aliased velocities in Figure 7a that the Nyquist velocity should be 41.4 kt. It is not clear how it came to be defined as 62.2 kt. Ms. Crawford began researching how to change the Nyquist velocity to the correct value so the WDSS-II de-aliasing algorithm will work correctly on the WSR data.

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

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 Lightning Mapping Array (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 started the market research by conducting a keyword Internet search for software that could potentially ingest and display the data types. He used the keywords

“weather+visualization+software”

to obtain the results. So far, he has found software in four categories from multiple sources as shown in Table 2. Based on the keyword search, the software found can display meteorological data but Dr. Bauman has not yet determined if they can display any of the data sets requested in this task. He will continue searching for potential software using the current and additional keywords.

Data Formats

The format of each data type must be known in order to determine if the software will be able to visualize the data. Dr. Bauman asked the KSC Weather Office for assistance acquiring the data format for the KSC LMA. They provided a contact, Mr. Bill Rison at the New Mexico Institute of Mining and Technology (New Mexico Tech), who provided a sample output file from an LMA similar to the

one being installed at KSC along with an explanation of the data format. The data are output as a compressed and zipped American Standard Code for Information Interchange (ASCII) text file. The ASCII file contains rows of LMA source data including time, latitude, longitude, altitude, goodness of fit, source power, and a mask indicating which of the LMA stations detected the source. Mr. Rison also provided a uniform resource locator (URL) for a New Mexico Tech server (<http://lightning.nmt.edu/sitetestlma/>) showing real-time and archived plots of LMA data as shown in Figure 8.

Knowing the LMA format and that the 45 WS and AMU already have GR2Analyst software, Dr. Bauman contacted Mr. Mike Gibson of Gibson Ridge Software to inquire whether GR2Analyst could ingest and display the LMA data into the software’s 3-D Volume Explorer. Mr. Gibson indicated that GR2Analyst uses slices of volumetric radar data instead of 3-D objects. He stated it would be difficult, but not impossible, to display 3-D objects such as LMA points and the vehicle track with the radar data, but there would be issues where the lightning and track data intersect with the radar reflectivity causing them to

Table 2. Summary of candidate software discovered from the Internet keyword search.

Category	Source	Software name	3-D Capable
Commercial	Baron Services	Omni	Yes
		OmniWxTrac	No
	Gibson Ridge Software, LLC	GR2Analyst	Yes
		OpenViz	Yes
	AVS	AVS Express	Yes
Impressum	Ninjo Workstation	No	
	Ultra Electronics	ProLogic	Yes
Government	NCAR	NCAR Graphics/Vislab	Yes
		AWIPS	Yes
	USAF	FalconView Weather	In development
Open Source	Kitware	ParaView	Yes
University	Georgia Tech	VGIS	Yes

appear in front of or behind the reflectivity when they are really coincident with it. Figure 9 shows a 3-D depiction of anvil cloud from a thunderstorm west of KSC from the Melbourne WSR-88D radar generated by the AMU GR2Analyst software.

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

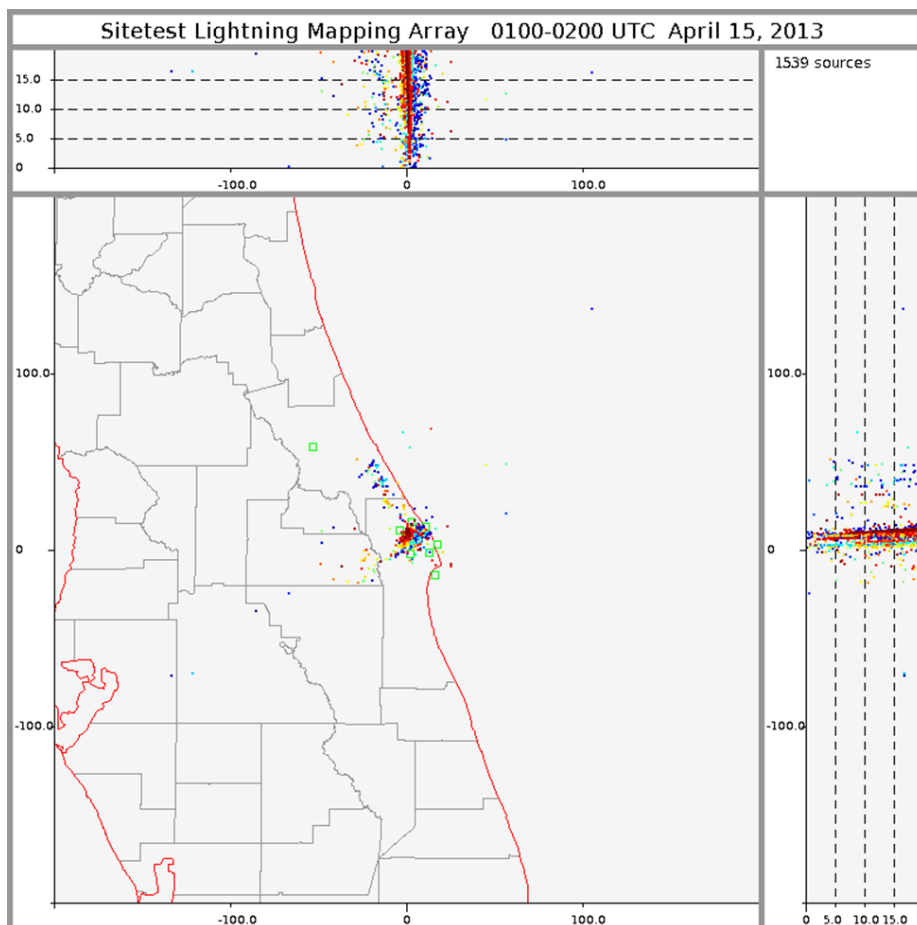


Figure 8. Plot of LMA points from 15 April 2013 in the KSC test network that was operating from fall 2012 to spring 2013.

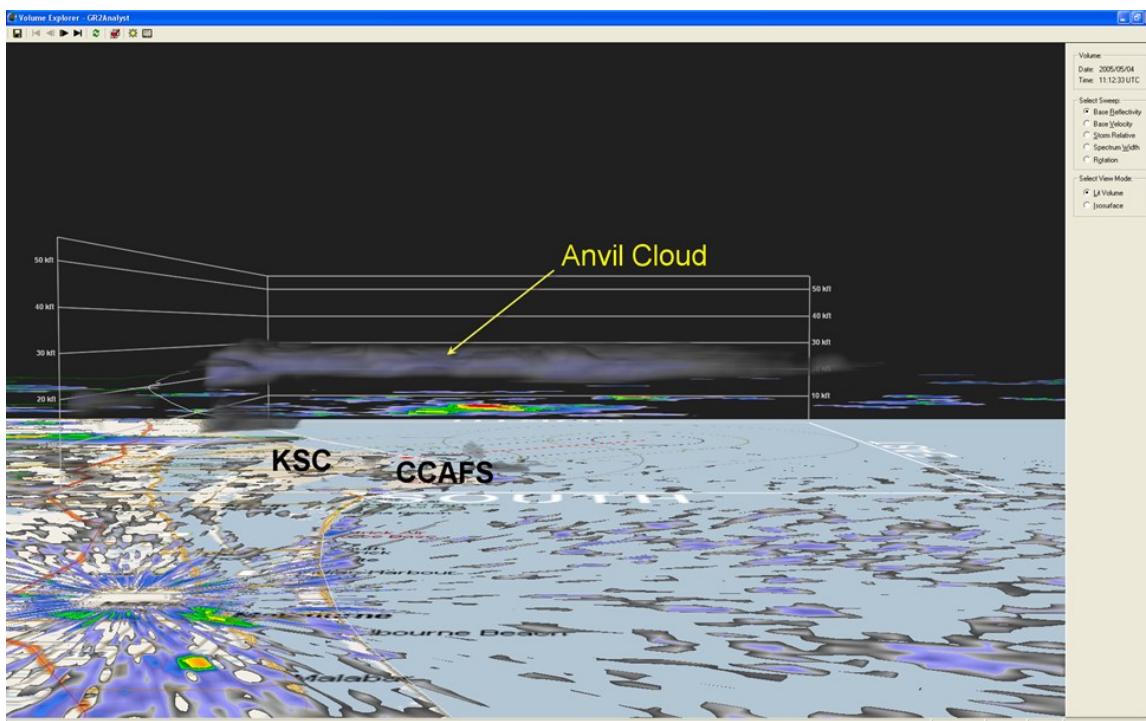


Figure 9. Depiction of anvil cloud from a thunderstorm west of KSC on 4 May 2006 in the GR2Analyst Volume Explorer.

Wind Pairs Database for Persistence Modeling (Mr. Decker)

NASA LSP space launch teams include an upper-level wind assessment in their vehicle commit-to-launch decisions. Their assessments are based on wind measurements obtained earlier in the launch count, which may not represent the environment the vehicle will ascend through. Uncertainty in the upper-level winds over the time period between the assessment and launch can be mitigated by a statistical analysis of wind change over time periods of interest using historical data from the launch range. Without historical data, the launch teams must use theoretical

wind models, which can result in inaccurate wind placards that misrepresent launch availability. This can result in over conservatism in vehicle wind placards and may reduce launch availability. Conversely, if the model is under-conservative it could result in launching into winds that might damage or destroy the vehicle. LSP tasked the AMU to calculate wind change statistics over specific time periods, also known as wind pairs, for each month from historical upper-level wind observations at the ER, WR and WFF. The time intervals of interest are 45 and 90 minutes, and 2, 3 and 4 hours. These databases will help LSP improve the accuracy of launch commit decisions based on upper-level wind assessments. Because of their experience

in working with wind pair databases and statistical analysis of upper-level wind change, the Natural Environments group at Marshall Space Flight Center (MSFC) is working on this task under the AMU's direction.

Status

Mr. Decker completed writing the final report. It was reviewed internally by the AMU and externally by customers before distribution. He is waiting for NASA Export Control approval before posting the report on the AMU website.

For more information contact Mr. Decker at 256-544-3068 or ryan.k.decker@nasa.gov

MESOSCALE MODELING

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. 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.

Configure SPoRT Perl Scripts

Last quarter Dr. Watson received a set of Perl scripts to run GSI/WRF in real-time from Mr. Brad Zavodsky of SPoRT. She made several modifications to the scripts in order for them to run on the local modeling cluster (AMU Quarterly Report Q4 FY13). This quarter she continued to modify the scripts to

- add an option to use the RAP 13-km data as the background model first-guess field and the boundary conditions;

- use the NAM model 12-km land surface data for the boundary conditions;
- ingest real-time Land Information System data from NASA/SPoRT; and
- ingest sea surface temperature (SST) data using both the NCEP Real-time Global SSTs and the NASA/SPoRT 2-km SST composites.

GSI/WRF Cycling and Running Archive Cases

The GSI/WRF scripts use a cycled GSI system similar to the operational NAM. The scripts run a 12-hour pre-cycle in which data are assimilated from 12 hours prior up to the model initialization time. This is done due to the time latency of the satellite data. Satellite data are not available instantaneously as it takes time to receive and process. If the pre-cycling did not occur, there would be very little influence on model output from the satellite observations, which have been shown to have the largest positive impact on most forecast systems. Once the pre-cycling is complete, a 12-hour forecast is run.

Dr. Watson finished running the cycled GSI/WRF for archive cases from 27 Aug 2013 through 10 Nov 2013 for the ER using a 2-km outer and 0.67-km inner domain (Figure 10). The data assimilation was run on the outer domain with the inner domain used to create the high-resolution forecast. The GSI/WRF scripts were run four times per day, with each run producing a 12-hour forecast. Dr. Watson finished post-processing the data and will begin validating the forecasts. In addition, Dr. Watson is continuing to run archive cases while varying the horizontal resolution on which the data assimilation is done. This is to determine the optimal configuration on which to run GSI/WRF.

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

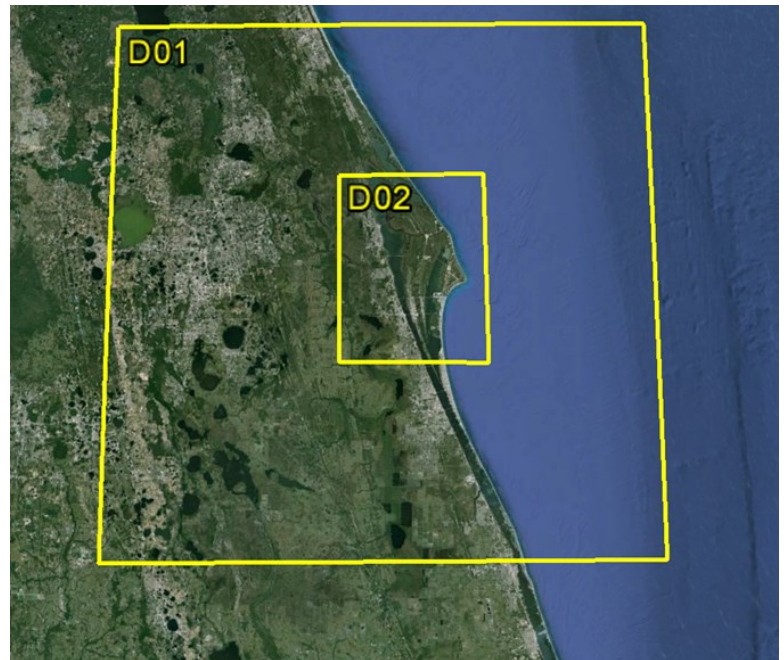


Figure 10. Map of the ER showing 2-km outer (D01) and 0.67-km inner (D02) model domain boundaries.

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.

Install and Configure WRF-EMS

At the start of this task, Mr. Erik Magnuson, a system and software engineer with ENSCO, Inc., set up and configured the second AMU modeling cluster for AMU use. Ms. Shafer and Dr. Watson then installed and configured WRF-EMS and completed a few test runs. Once they confirmed WRF-EMS was running properly, Ms. Shafer and Dr. Watson configured and optimized a triple-nested grid configuration over KSC/CCAFS based on Dr. Watson's previous AMU task (Watson 2013). The results showed the best configuration for the ER was to use the Advanced Research WRF core (ARW) with the Lin microphysical scheme and the Yonsei University planetary boundary layer scheme. Figure 11 shows the boundaries of the three domains included in this task. D01 is the outer domain with 12-km grid spacing, D02 is the middle domain with 4-km grid spacing, and D03 is the inner domain with 1.33-km grid spacing. The boundaries for D01 that include much of the eastern United States were selected should this work grow to include WFF in the future. D03 is centered over the ER and is the domain for which verification statistics will be calculated. Once the triple-nested model setup was configured and tested, Ms. Shafer set up WRF-EMS to automatically run a 12-hour forecast every hour on the cluster. The D03 domain output is available every 15 minutes during the 12 hour forecast period.

Installing MET software

As part of this task, the AMU will verify the performance of the WRF-EMS D03 using the MET verification package. This software will provide standard verification scores comparing gridded model data to point-based observations and object-based verification of precipitation forecasts. Ms. Shafer and Dr. Watson were able to install and compile the MET software on the second AMU cluster, and Ms. Shafer has started working with MET to verify test runs of WRF-EMS D03.

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

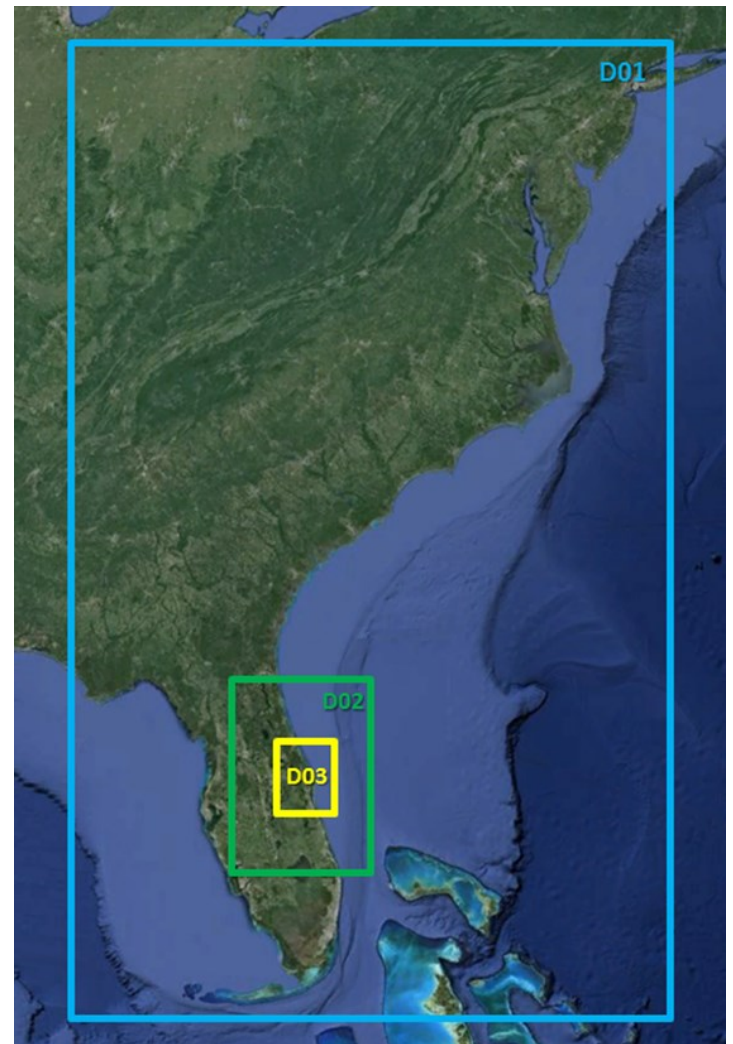


Figure 11. Map of the eastern United States showing the boundaries of each domain. The outer domain (blue rectangle, D01) has 12-km grid spacing, the middle domain (green rectangle, D02) has 4-km grid spacing, and the inner domain (yellow rectangle, D03) has 1.33-km grid spacing. The AMU will calculate verification statistics for the inner-most domain, D03.

AMU OPERATIONS

Assistance to Range Weather Operations and KSC Weather Office

AMU personnel assisted the forecasters in the 45 WS Range Weather Operations (RWO) several times during the quarter:

- During the 45 WS morning weather briefing on 15 October, the forecasters asked Dr. Bauman to clarify the use of the Northern Hemisphere long wave pattern as it related to the “forecast funnel” that is typically used to kick-off a weather shift-change briefing. Dr. Bauman provided verbal and written explanations and offered to present a training briefing to the 45 WS staff.
- During the 45 WS daily weather briefing on 4 November, the forecaster had questions about interpreting the long wave pattern. Ms. Shafer assisted the forecaster and followed-up by discussing how the number of long waves relates to retrograde, stationary and progressive patterns. The more long waves present, the faster weather systems move. The 45 WS stated they would follow-up with forecaster training.
- During the 18 November Atlas V MAVEN launch, Dr. Bauman assisted the LWOs with the LSP Upper Winds Tool, who said that the tool was not plotting the wind speed and direction charts. Dr.

Bauman discovered that the KSC 50 MHz profiler data was missing from the KSC Weather Archive site for the times they were trying to plot. Dr. Bauman updated the tool with brief instructions on the main page for the LWOs and discussed with the KSC Weather Office the possibility of including a manual override of the automated fetching of data for times when the data are not available.

- The AMU staff assisted a 45 WS Staff Meteorologist (Staffmet) with a question regarding display of dual-polarization radar data in the GR2Analyst software. The Staffmet was asking if the software could display data values when the mouse pointer hovered over the output. The AMU staff showed the Staffmet how the reflectivity values, radar elevation, altitude and other parameters were displayed in the software.

Articles and Presentations

Dr. Bauman submitted a journal article titled “A Tool to Predict the Probability of Summer Severe Weather in East Central Florida” to the National Weather Association Journal of Operational Meteorology (JOM). Mr. Roeder from the 45 WS is co-author with Dr. Bauman and received 45 WS approval to submit the article to the JOM.

Dr. Bauman prepared a poster describing the Severe Weather Tool

for presentation in the Fourth Aviation, Range, and Aerospace Meteorology Special Symposium during the 94th American Meteorological Society Annual Meeting.

Training

Dr. Huddleston, Dr. Watson, Ms. Crawford, and Ms. Shafer attended KSC-provided training to learn how to fill out the new electronic NASA Scientific and Technical Information Document Availability Authorization (DAA) form. They will use this form for approval to make AMU reports and presentations available to the general public.

IT

Ms. Shafer and Dr. Bauman assisted Dr. Huddleston with the inventory of AMU equipment by escorting her into the KSC Data Center in the CIF to verify the location and property tags for the AMU modeling clusters.

Dr. Bauman requested Mr. Madison of CSR modify the list of AMU tools on the Meteorological Interactive Data Display System (MIDDS) menu system to make them simpler for the operational forecasters to understand, remove items on the list no longer in use, and to add items previously accessible only by entering string commands from the keyboard. Mr. Madison completed the modification and testing with Dr. Bauman and Ms. Winters of the 45 WS on 25 October.

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Watson, L., 2013: Range-specific High-resolution Mesoscale Model Setup. NASA Contractor Report CR-2013-217911, Kennedy Space Center, FL, 41 pp. [Available from ENSCO, Inc., 1980 N. Atlantic Ave., Suite 830, Cocoa Beach, FL, 32931 and online at <http://science.ksc.nasa.gov/amu/final-reports/range-specific-hi-res-model-setup.pdf>.]

LIST OF ACRONYMS

14 WS	14th Weather Squadron	MET	Model Evaluation Tools
30 SW	30th Space Wing	MIDDS	Meteorological Interactive Data Display System
30 OSS	30th Operational Support Squadron	MSFC	Marshall Space Flight Center
45 RMS	45th Range Management Squadron	NAM	North American Mesoscale model
45 OG	45th Operations Group	NCAR	National Center for Atmospheric Research
45 SW	45th Space Wing	NCEP	National Centers for Environmental Prediction
45 SW/SE	45th Space Wing/Range Safety	netCDF	Network Common Data Form
45 WS	45th Weather Squadron	NOAA	National Oceanic and Atmospheric Administration
AFSPC	Air Force Space Command	NSSL	National Severe Storms Laboratory
AFWA	Air Force Weather Agency	NWS MLB	National Weather Service in Melbourne, Florida
AMU	Applied Meteorology Unit	PG	Pressure Gradient
AWIPS	Advanced Weather Information Processing System	QC	Quality Control
CCAFS	Cape Canaveral Air Force Station	RAP	Rapid Refresh model
CI	Convection Initiation	SLS	Space Launch System
CG	Cloud-to-Ground Lightning	SMC	Space and Missile Center
CSR	Computer Sciences Raytheon	SPoRT	Short-term Prediction Research and Transition Center
dP	Pressure Difference	UL	Upper-Level
DRWP	Doppler Radar Wind Profiler	URL	Uniform Resource Locator
ER	Eastern Range	USAF	United States Air Force
ESRL	Earth System Research Laboratory	VAFB	Vandenberg Air Force Base
FAA	Federal Aviation Administration	WDSS-II	Warning Decision Support System Integrated Information
FSU	Florida State University	WFF	Wallops Flight Facility
GSDO	Ground Systems Development and Operations program	WR	Western Range
GSI	Gridpoint Statistical Interpolation	WRF	Weather Research and Forecasting Model
GUI	Graphical User Interface	WRF-EMS	WRF Environmental Modeling System
IRIS	Interactive Radar Information System	WSR	45 SW Weather Surveillance Radar
JSC	Johnson Space Center	WSR-88D	Weather Surveillance Radar 1988-Doppler
KSC	Kennedy Space Center		
LLCC	Lightning Launch Commit Criteria		
LMA	Lightning Mapping Array		
LSP	Launch Services Program		
LWO	Launch Weather Officer		

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NASA KSC/LX-S1/R. Franco	45 WS/SYA/J. Saul	NWS Melbourne/S. Spratt	ENSCO, Inc./R. Gillen
NASA KSC/SA/R. Romanella	45 WS/SYR/W. Roeder	NWS Melbourne/P. Blottman	ENSCO, Inc./E. Lambert
NASA KSC/SA/B. Braden	45 WS/DOU/K. Schubeck	NWS Melbourne/M. Volkmer	ENSCO, Inc./A. Yersavich
NASA KSC/VA/A. Mitskevich	45 RMS/CC/M. Shoemaker	NWS Southern Region HQ/"W/ SR"/S. Cooper	ENSCO, Inc./S. Masters
NASA KSC/VA-H/M. Carney	45 RMS/RMRA/R. Avvampato	NWS/SR/SSD/STB/B. Meisner	
NASA KSC/VA-H1/B. Beaver	45 SW/CD/G. Kraver	NWS/"W/OST1"/B. Saffle	
NASA KSC/VA-H3/ P. Schallhorn	45 SW/SELR/K. Womble	NWS/"W/OST12"/D. Melendez	
NASA KSC/VA-H3/D. Trout	45 SW/XPR/R. Hillyer	NWS/OST/PPD/SPB/P. Roohr	
NASA KSC/VA-2/C. Dovale	45 SW/XPR/R. Hillyer	NSSL/D. Forsyth	
NASA KSC/VA-2/O. Baez	45 OG/CC/D. Schiess	30 OSS/OSWS/DO/B. Lisko	
NASA KSC/VA-2/T. Dunn	45 OG/TD/C. Terry	30 OSS/OSWS/M. Schmeiser	
Analex Corp/Analex-20/ M. Hametz	CSC/M. Maier	30 OSS/OSWS/T. Brock	
NASA JSC/WS8/F. Brody	CSR 1000/S. Griffin		
NASA MSFC/EV44/B. Roberts	CSR 3410/C. Adams		
NASA MSFC/EV44/R. Decker	CSR 3410/R. Crawford		
NASA MSFC/EV44/H. Justh	CSR 3410/D. Pinter		
	CSR 3410/M. Wilson		
	CSR 4500/J. Osier		
	CSR 4500/T. Long		



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