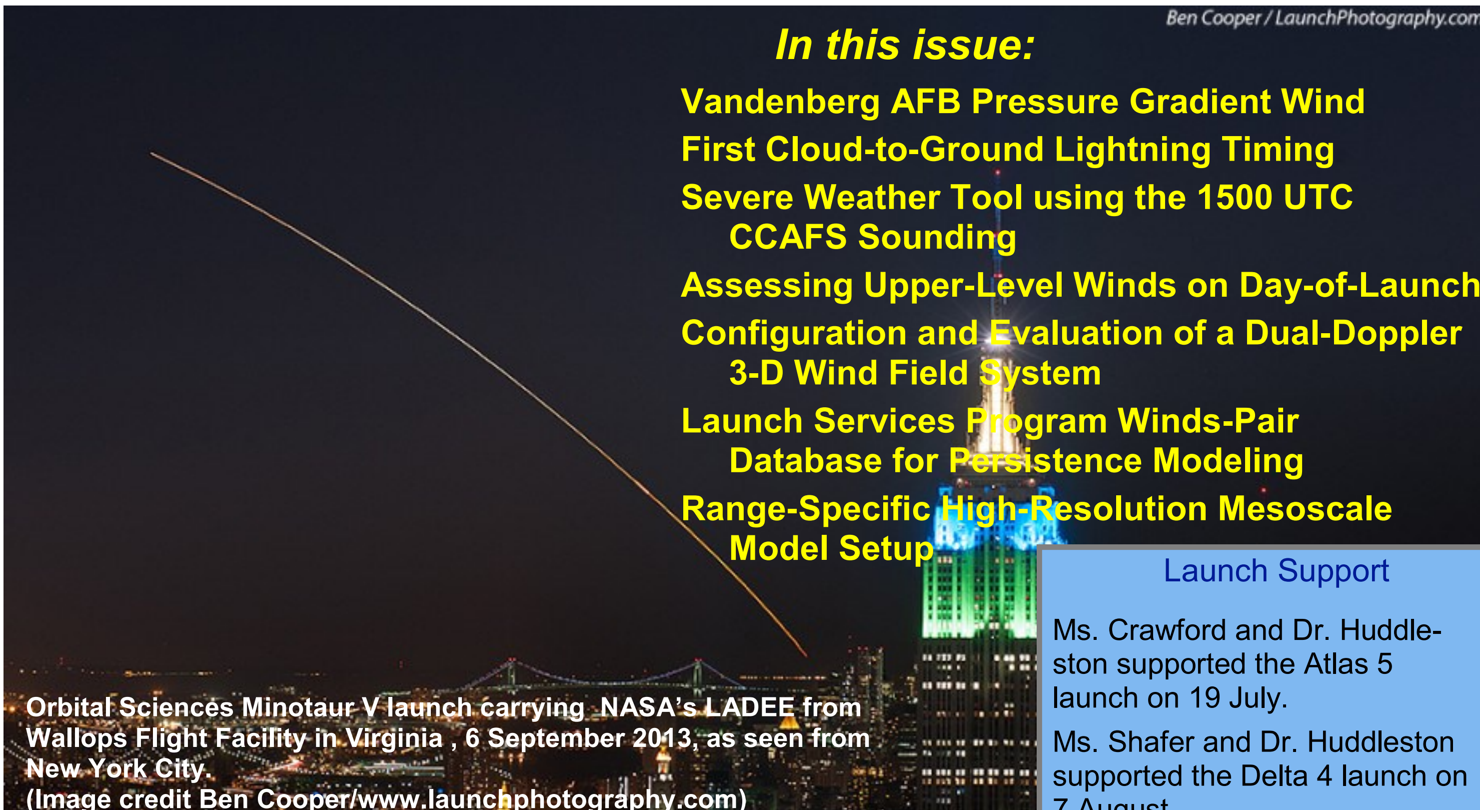
AMU Applied Meteorology Unit

Infusing Weather Technology Into Aerospace Operations

Quarterly Report
Fourth Quarter FY-13
31 October 2013

Contract NNK12MA53C/DRL-003 DRD-004



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Orbital Sciences Minotaur V launch carrying NASA's LADEE from Wallops Flight Facility in Virginia , 6 September 2013, as seen from New York City.
(Image credit Ben Cooper/www.launchphotography.com)

Launch Support

Ms. Crawford and Dr. Huddleston supported the Atlas 5 launch on 19 July.

Ms. Shafer and Dr. Huddleston supported the Delta 4 launch on 7 August.

Dr. Watson and Dr. Huddleston supported the Atlas 5 launch on 18 September.

This Quarter's Highlights

The AMU team worked on seven tasks for their customers:

- Ms. Shafer completed the task to determine relationships between pressure gradients and peak winds at Vandenberg Air Force Base (VAFB), and began developing a climatology for the VAFB wind towers.
- Dr. Huddleston completed the task to develop a tool to help forecast the time of the first lightning strike of the day in the Kennedy Space Center (KSC)/Cape Canaveral Air Force Station (CCAFS) area.
- Dr. Bauman completed work on a severe weather forecast tool focused on the Eastern Range (ER), and also developed upper-winds analysis tools for VAFB and Wallops Flight Facility (WFF).
- Ms. Crawford processed and displayed radar data in the software she will use to create a dual-Doppler analysis over the east-central Florida and KSC/CCAFS areas.
- Mr. Decker completed developing a wind pairs database for the Launch Services Program to use when evaluating upper-level winds for launch vehicles.
- Dr. Watson continued work to assimilate observational data into the high-resolution model configurations she created for WFF and the ER.

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Quarterly Task Summaries

This section contains summaries of the AMU activities for the fourth quarter of Fiscal Year 2013 (July-September 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 VAFB in California 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. The 30 OSS requested the AMU to provide a wind forecasting capability that will improve wind warning forecasts and enhance the safety of their customers' operations. This will allow 30 OSS forecasters to evaluate pressure gradient (PG) thresholds between specific pairs of regional observing stations under different synoptic regimes 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 PG 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 writing the final report. Continued working with Microsoft Access to deliver the climatology database and statistics.

First Cloud-to-Ground Lightning Timing Study (Page 7)

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. The AMU will determine if there is a relationship between speed-stratified flow regimes and the time of the first CG strike. This relationship, if it exists, would be used in a final tool to assist forecasters in determining when the first CG lightning will occur on KSC/CCAFS.

Accomplished: Continued writing the final report, which is delayed due to other KSC Weather Office (WO) priorities.

Quarterly Task Summaries
(continued)

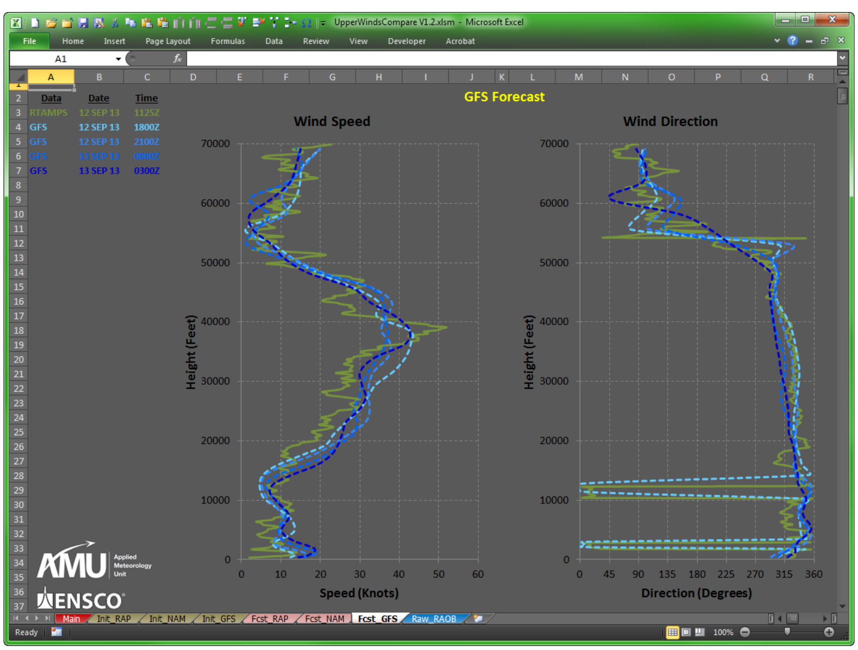
Severe Weather Tool using 1500 UTC CCAFS Sounding (Page 7)

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

Purpose: The severe weather elements of strong winds, hail, and tornadoes can injure individuals and cause costly damage to structures if not properly protected. NASA's LSP, GSDO, and the future SLS programs along with other organizations at KSC and CCAFS use the daily and weekly severe weather forecasts issued by the 45 WS to determine if they need to limit an activity such as working on gantries, or protect property such as a vehicle on a pad. To help mitigate the severe weather risk, the AMU will develop a capability to assess the daily severe weather threat during the warm season months of May-September at KSC/CCAFS based on the late morning, 1500 UTC, CCAFS sounding. Using the late morning sounding for this capability instead of the early morning, 1000 UTC, sounding will provide the 45 WS forecasters with a more accurate assessment of the atmospheric instability each day leading to a better assessment of the severe weather threat.

Accomplished: Completed testing and delivered the 1500 UTC real-time severe weather tool. Based on the new 1500 UTC tool, modified and delivered an updated 1000 UTC real-time severe weather tool.

Assessing Upper-level Winds on Day-of-Launch at Vandenberg Air Force Base and Wallops Flight Facility (Page 9)



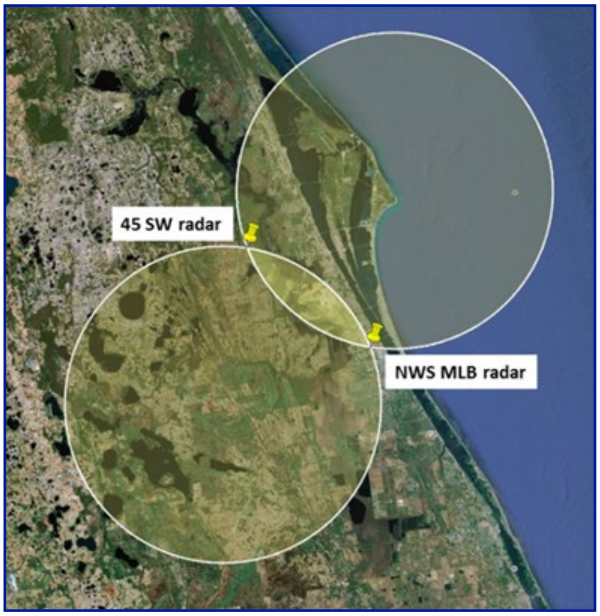
Customers: NASA's LSP and SLS program

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 VAFB and began modification of the tool for the WFF launch weather team.

Quarterly Task Summaries

Configuration and Evaluation of a Dual-Doppler 3-D Wind Field System (Page 11)



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: Installed the Weather Decision Support System – Integrated Information (WDSS-II) software. Processed the NWS MLB Weather Surveillance Radar 1988-Doppler (WSR-88D) and displayed the data in WDSS-II. Researched ways to process the 45th Space Wing (45 SW) Weather Surveillance Radar (WSR) and Orlando International Airport (MCO) Terminal Doppler Weather Radar (TDWR) data so they can also be displayed in WDSS-II and used in the dual-Doppler analysis

Wind Pairs Database for Persistence Modeling (Page 13)

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.

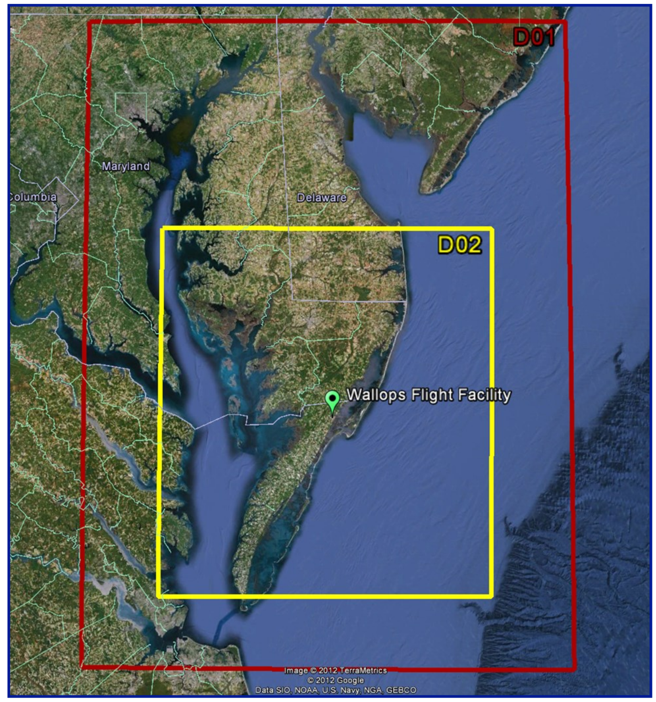
Accomplished: Analyzed the ER and WR wind pair databases to determine how well the sample populations characterize wind change extremes for use in vehicle performance assessments. Briefed LSP on the limitations of the WFF wind pair database and recommended using the 4-hour extreme wind change for all time change intervals. Began writing the final report.

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: Finished installing and configuring needed software on the new NASA AMU modeling cluster. Received and configured 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). Began archiving real-time observational and model data.



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 them 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.

Final Report

Based on the subjective PG review and the objective Pearson Correlation Coefficient values performed last quarter, the AMU determined there was no relationship between PG and MPW and therefore did not develop an automated GUI for the 30 OSS. Ms. Shafer completed the final report after internal AMU and external customer reviews. NASA approved the report for public distribution and it is now on the AMU website at science.ksc.nasa.gov/amu/final-reports/30oss-pgrad.pdf.

Climatology Database

Ms. Shafer discovered that Microsoft Excel is not capable of containing the entire VAFB tower network database and, after discussing this with the 30 OSS weather personnel, decided to use Microsoft Access, which can contain a much larger amount of data than Excel. The database includes temperature (F), dewpoint (F), relative humidity (%), average 1-minute sustained wind speed (kt) and direction (degrees), and peak wind speed (kt) and direction (degrees) at the 2-, 4-, and 16-m (6-, 12-, and 54-ft) sensor levels from each of the 26 VAFB towers during October 2007 to November 2012. Ms. Shafer completed processing all VAFB tower data for the climatology database work that was tasked to the AMU if time permitted upon completion of the VAFB Pressure Gradient Wind Study task. Because of the size of the database and complexities of using Access to manipulate the data, Ms. Shafer requested assistance from Mr. Chris Jessen, a Staff Engineer in ENSCO, Inc.'s Aerospace Sciences and Engineering division. She is working with Mr. Jessen to streamline the functionality of the database so Access can efficiently process the large amount of tower data. After this is complete, she will finalize the Access GUI and deliver it to the 30 OSS.

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.

Status

Dr. Huddleston continued writing the final report for this task. Completion of the task has been delayed due to her other KSC WO priorities. She is unable to determine a completion date for the report due to the government shutdown.

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

Severe Weather Tool Using 1500 UTC CCAFS Soundings (Dr. Bauman)

People and property at KSC and CCAFS are at risk when severe weather occurs. Strong winds, hail and tornadoes can injure individuals and cause costly damage to structures if not properly protected. NASA's LSP, GSDO, and future SLS programs along with other organizations at KSC and CCAFS use the daily and weekly severe weather forecasts issued by the 45 WS to determine if they need to limit an activity such as working on gantries, or protect property such as a vehicle on a pad. Missed lead-times and false alarm rates have shown that severe weather in east-central Florida is difficult to forecast during the warm season (May-September). Due to the threat severe weather poses to life and property at the ER and the difficulty in making the forecast, the 45 WS tasked the AMU to develop a warm season severe weather tool based on the late morning, 1500 UTC (1100 local time), CCAFS (XMR) sounding. The 45 WS frequently makes decisions to issue a severe weather watch and other severe weather warning support products to NASA and the 45 SW in the late morning, after the 1500 UTC sounding, which is more representative of the atmospheric instability than the early morning, 1000 UTC, sounding. A tool using the 1500 UTC sounding should provide improved accuracy for severe weather notifications and better allow decision makers to implement appropriate mitigation efforts. Because the 1500 UTC tool was a significant improvement over the original 1000 UTC tool, the KSC WO approved modifying the 1000 UTC tool to incorporate the same statistical formulation and GUI design as the 1500 UTC tool.

MIDDS Tool Testing

Dr. Bauman completed testing the 1500 UTC and 1000 UTC versions of the Severe Weather Tool by running them on the AMU Meteorological Interactive Data Display System (MIDDS) each day a sounding was available to ensure MIDDS was calculating the correct threat score for each parameter and Total Threat Score (TTS) for each sounding. He did so by writing each sounding's MIDDS parameters to a file, importing the file into Excel and recalculating the threat scores and TTSs in Excel. He tested 88 soundings using the 1500 UTC tool and 66 soundings using the 1000 UTC tool with no discrepancies noted in the threat score calculations between MIDDS and Excel. He also retrieved a sample of the tool's 1500 UTC and 1000 UTC output from the 45 WS operational MIDDS and compared that to the AMU MIDDS and the Excel calculations with no discrepancies noted.

Delivery and Modifications

After Dr. Bauman delivered beta versions of both tools to the 45 WS for testing, he made two modifications based on forecaster feedback. The first modification was to change some of the information displayed to the forecasters in MIDDS. Initially, when the forecasters ran the tool in MIDDS, it displayed a summary window and a detailed window to the screen showing the TTS and other parameters for each sounding. Both windows included a look-up table with seven TTS categories and associated reported severe weather occurrences. An example of the original summary window is shown in Figure 1. The forecasters requested that the reported occurrence of severe weather be added to the display windows instead of a categorical look-up table. An example of the resulting modified summary window is shown in Figure 2. It no longer has a look-up table but instead displays both the TTS and the reported occurrence of severe weather based on the TTS derived from the sounding.

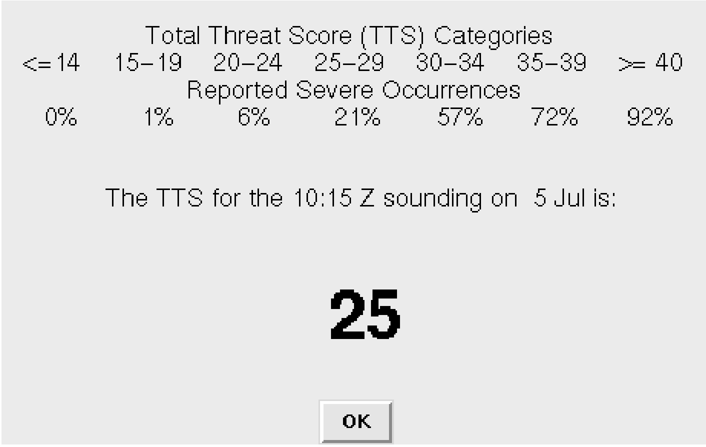


Figure 1. Original TTS summary window displayed in MIDDS shows the TTS categories and associated reported severe occurrences in the top four rows. The time, date and TTS for the sounding are displayed below the first four rows.

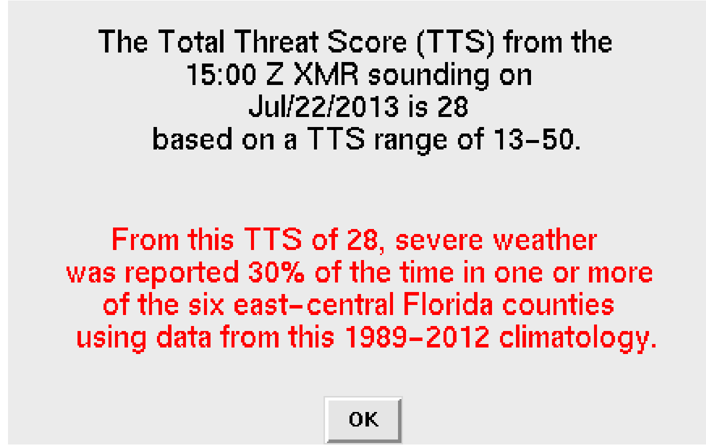


Figure 2. Modified TTS summary window displayed in MIDDS shows the time, date and TTS for the sounding plus the climatological TTS range (black text) and the occurrence of reported severe weather based on the sounding's TTS (red text).

The second modification Dr. Bauman implemented was to use individual TTS values instead of categories to provide higher fidelity output of reported severe weather frequency because the forecasters believed seven categories were too broad to provide quality guidance when considering the probability of severe weather for the day. Figure 3 shows a line chart of each TTS value. While this methodology provides higher fidelity, it also has more noise than the categorical data—especially at higher TTS values with a smaller sample size. To help minimize the noisy data and create a more useful tool for the forecasters, Dr. Bauman fit several types of curves to the data including logarithmic and polynomial. A second order polynomial is shown in Figure 4. However, the polynomial curve reached a maximum of 59% at a TTS of 37 and fell below 0% at a TTS of 18. Further examination of the distribution in Figure 3 suggests a best-fit logistic curve would maintain the increased fidelity while reducing the noise.

Mr. Roeder of the 45 WS offered to do a best-fit logistic curve since the logistic curve is constrained within 0% to 100% and is often used in probabilistic regression. Fitting a logistic curve cannot be solved analytically and must be done iteratively, in this case manually due to lack of statistical software. Each of the three coefficients was step-wise iterated until the root mean square error of the differences between the logistic curve and the observed values was minimized. The iteration was cycled until the coefficients changed by less than 0.0005 (optimized to three decimal places). He also tested quadratic, exponential, and power law best-fit curves for completeness in case they performed better. These three curves exceeded 100% at the higher TTS values, similar to the second order polynomial curve. The best-fit logistic regression curve is specified by the following formula and is shown in Figure 5.

$$y = 100 * \left(\frac{1}{1 + exp\left(-\left(0.764 + 0.270 * (x - 34.013)\right)\right)} \right)$$

The logistic curve is a better fit to the data than the other methods and offers the desired behavior of not exceeding 100% at large TTS values or falling below 0% at low TTS values.

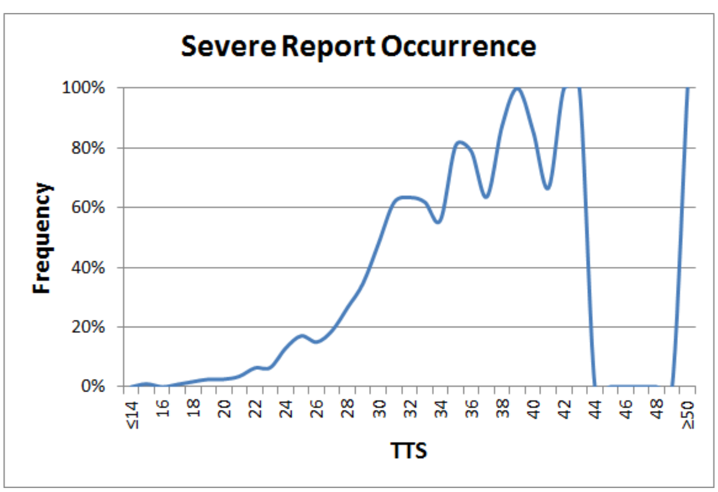


Figure 3. The distribution of reported severe weather frequency based on individual TTS values.

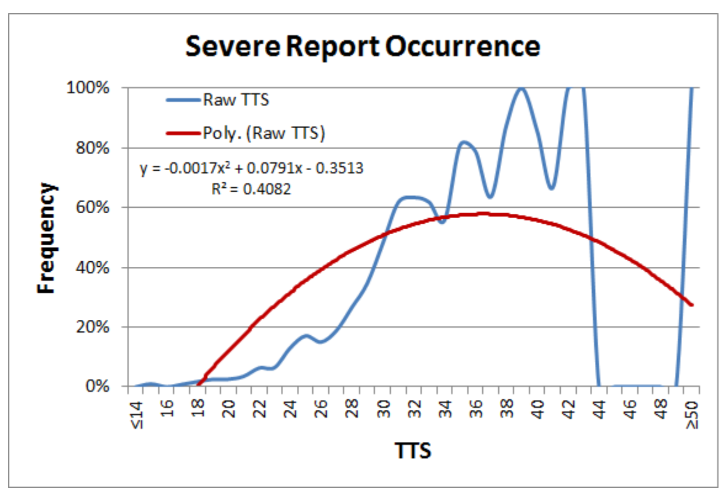


Figure 4. As in Figure 3 with a second order polynomial curve (red line) fit to the TTS values (blue line).

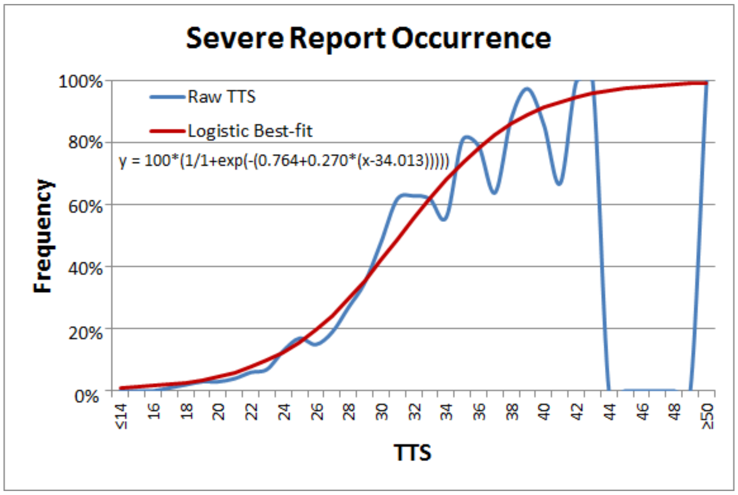


Figure 5. As in Figure 3 with a best-fit logistic regression curve (red line) fit to the TTS values (blue line). A correlation coefficient is not available because best-fit logistic curves must be done iteratively and manually.

The mean difference between the actual data and the logistic curve is -0.66, indicating the logistic curve is slightly more conservative overall. The best-fit logistic curve offers just over a 19% improvement over the original categorical approach and that improvement is a higher probability of severe weather, which is conservatively safer.

Table 1 shows the final TTS values and corresponding occurrences of reported severe weather based on the logistic regression curve shown in Figure 5 that were implemented in the MIDDS GUI and used to populate the output windows.

Final Report

Dr. Bauman completed the final report after internal AMU and external customer reviews. NASA approved the report for public distribution and it is now on the AMU website at science.ksc.nasa.gov/amu/final-reports/severe-tool-15z.pdf.

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

Table 1. The final TTS values (green shading) and corresponding occurrences of reported severe weather (red shading) based on the logistic regression curve fit.

TTS	≤14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Severe Freq (%)	1	1	2	2	3	4	5	6	8	10	13	16	20	24	30	36	42	49
TTS	32	33	34	35	36	37	28	39	40	41	42	44	45	46	47	48	29	≥50
Severe Freq (%)	56	62	68	74	79	83	86	89	92	93	95	97	98	98	99	99	99	99

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.

GUI Modification

The goal of this task was to provide a GUI with the same design for VAFB and WFF as is used at KSC/CCAFS. This provides the users with a familiar interface, makes modifying the existing tool easier resulting in a

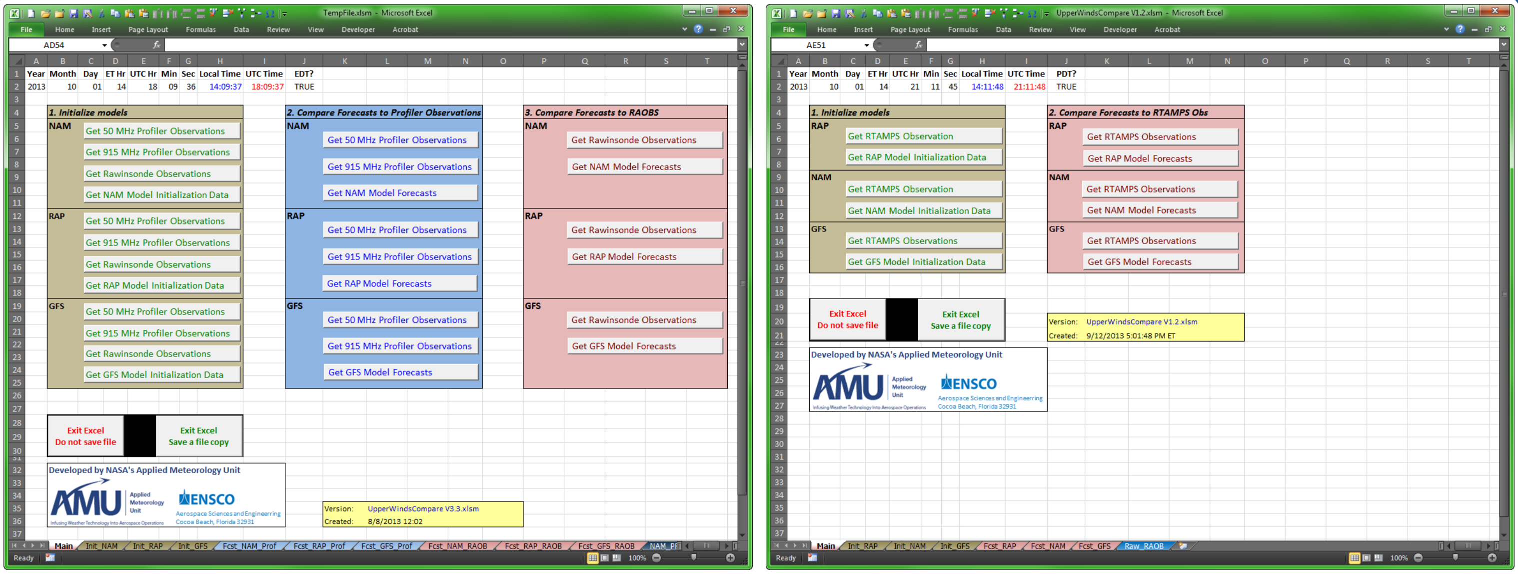


Figure 6. Main interface of the KSC/CCAFS GUI (left) and of the VAFB GUI (right). There are fewer selections in the VAFB GUI because there are no operating upper-tropospheric DRWP sensors at VAFB.

fast delivery of the VAFB and WFF versions, and also allows easier maintenance of the software in the future. Figure 6 shows the main interface of the KSC/CCAFS GUI on the left and of the VAFB GUI on the right. The interface is not identical because the KSC/CCAFS tool uses the 50- and 915-MHz Doppler Radar Wind Profiler (DRWP) sensors in addition to the balloon-borne rawinsonde sensors to measure the upper-level winds, but neither VAFB nor WFF have operating upper-tropospheric DRWP sensors. To account for this difference, Dr. Bauman modified the Excel Visual Basic for Applications (VBA) scripts in the existing GUI to remove all code used to access, import, process, and display the DRWP data. Therefore, the DRWP selection buttons in the VAFB and WFF main interface were removed.

The design of the rawinsonde and model plots presented to the launch directors at the different launch sites is nearly identical as shown in Figure 7. In this example of rawinsonde observations overlaid with GFS model forecasts, the KSC/CCAFS GUI is shown on the left and the VAFB GUI on the right. The only difference is that the data are from two different locations.

Another modification was required because the rawinsonde data at VAFB and WFF are accessed differently than at KSC/CCAFS. The rawinsonde data files are manually retrieved by the LWO and saved on a local computer. At KSC/CCAFS, the rawinsonde files are routinely retrieved by the KSC Weather Archive server (kscwxarchive.ksc.nasa.gov) from the 45 WS MIDDS. The GUI VBA code automatically determines what rawinsonde file to import from the KSC Weather Archive server and then process. Working with meteorologists at VAFB and WFF, Dr. Bauman modified the VBA code to ask the user to choose a rawinsonde file to process from a pre-selected directory path on their computer. Once the user chooses the file, the rawinsonde data are imported, processed, and

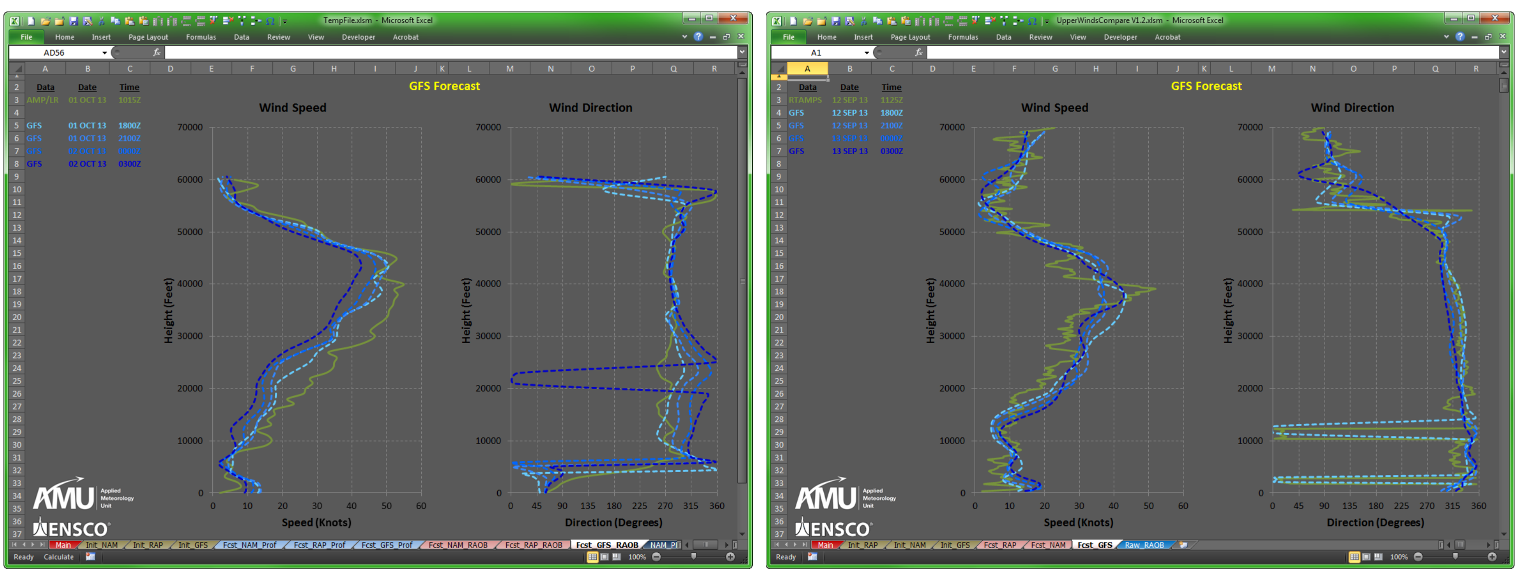


Figure 7. Rawinsonde observations with GFS model point forecast overlaid in the KSC/CCAFS GUI (left) and VAFB GUI (right). The rawinsonde plots are green solid lines and the GFS model data are dashed lines in different shades of blue denoting forecast time.

displayed in Excel. The formats of the rawinsonde files at VAFB and WFF are also different from each other as well as from KSC/CCAFS, which required Dr. Bauman to modify the VBA code further to import the files into Excel.

The model point forecast data files for the NAM, RAP, and GFS models are located at the Iowa State University Archive Data Server (mtarchive.geol.iastate.edu) for all three launch sites. The 45 SW network does not permit direct access of the model files from Iowa State, so the files are downloaded by the KSC Weather Archive server and the GUI accesses the files from there. Conversely, the VAFB 30th Space Wing and NASA WFF networks permit direct access of the model point data files from Iowa State. Therefore, Dr. Bauman modified the VBA code for VAFB and WFF to automatically download, import, process, and display the model point data files when the user requests them. The only other change required in the VBA code to access the model point data was to change the three-letter site identifier from XMR (model point at the CCAFS Skid Strip) to VBG for VAFB and WAL for WFF.

Status

Dr. Bauman delivered the GUI to VAFB on 10 September and provided training to 30 OSS staff via e-mail and telephone. The launch weather team tested the tool and used it to support a Minuteman missile launch and a SpaceX Falcon 9 launch. They stated the tool provided valuable upper winds information to the launch team allowing them to proceed safely with the launch in a situation where the upper winds were an issue.

Dr. Bauman received a sample rawinsonde file from WFF on 27 September and modified the VBA code to import, process, and display the rawinsonde observation.

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

INSTRUMENTATION AND MEASURMENT

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 Federal Aviation Administration (FAA) MCO TDWR as input, and available free 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.

WDSS-II

Ms. Crawford continued efforts to install the libraries and other components needed to run WDSS-II. With assistance from the knowledge base on the WDSS-II forum, Dr. Watson's knowledge of the Linux environment, and ENSCO system and software engineer Mr. Magnuson's assistance in finding the correct libraries and graphics software, she was able to run the WDSS-II GUI.

It is clear from this experience that installing and running the WDSS-II software requires a working knowledge of the Linux operating system. Anyone who wants to use this software package should get Linux training if not already knowledgeable.

Data

Ms. Crawford now has data from all three local Doppler radars (Figure 8) for the test case, a local tornadic event that occurred during the evening of 14 April 2013. The data must be in NWS WSR-88D Level II format (www.roc.noaa.gov/wsr88d/level_ii/level2info.aspx) in order to create the dual-Doppler analysis in WDSS-II. While WDSS-II does not ingest Level II data directly, it has utilities to convert the Level II data to Network Common Data Form (netCDF) or Extensible Markup Language (XML) that can be manipulated by WDSS-II algorithms. The WSR-88D data are in Level II format, but data from the other two radars are not and must be converted to Level II format.

NWS MLB WSR-88D

Ms. Crawford downloaded the NWS MLB WSR-88D Level II data for the test case from the National Climatic Data Center website. She used

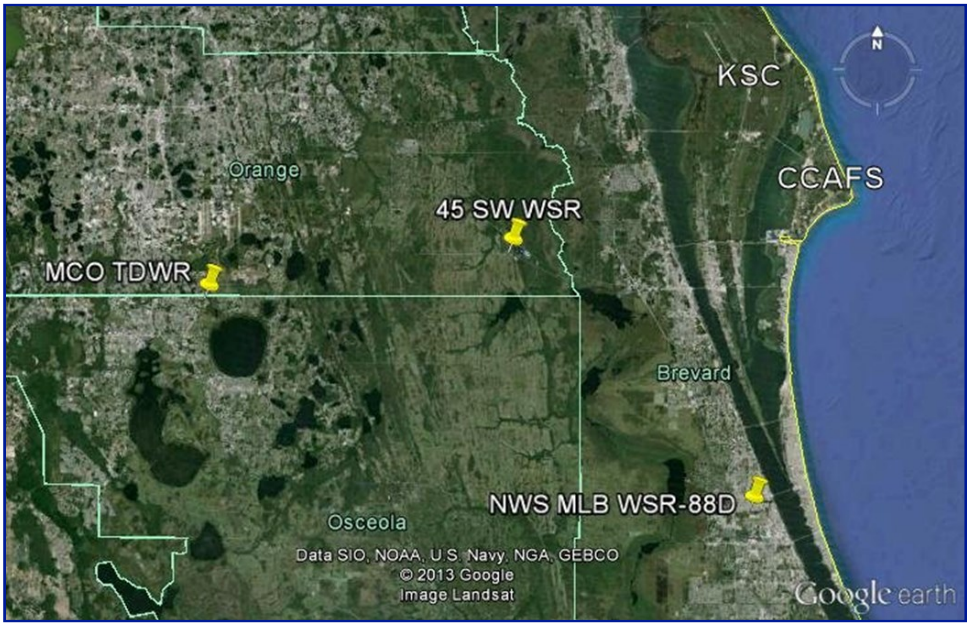


Figure 8. Google Earth image showing the locations of the MCO TDWR, 45 SW WSR, and NWS MLB WSR-88D, whose data are used in the task.

the WDSS-II utility that converts Level II format to netCDF on all the files and was able to display the data in WDSS-II. Figure 9 shows the WDSS-II display of the reflectivity and velocity fields for the first tornadic event on 14 April 2013 over Cocoa, Florida (www.srh.noaa.gov/media/mlb/pdfs/Damage_041413_Survey.pdf). The tornado location is surrounded by a yellow circle.

45 SW WSR

Mr. Todd McNamara, a 45 WS LWO, provided the 45 SW WSR data for the test case. These data were in Interactive Radar Information System (IRIS) format and had to be converted to Level II. Ms. Crawford contacted Dr. Lawrence Carey of the University of Alabama Huntsville, who has worked with the 45 SW WSR data in previous projects. He provided Ms. Crawford with a link to a National Center for Atmospheric Research (NCAR) program that converts IRIS data to Level II format.

Dr. Bauman assisted Ms. Crawford in installing the NCAR software on the Linux PC. After converting a few files, they used GR2Analyst, a Level II weather radar data display program, to make sure the program converted the data to the proper format. The data would not display, so she sent a converted file to Mr. Mike Gibson, the GR2Analyst developer, for analysis. He stated that the file format created by the NCAR program could not be read by the GR2Analyst data input algorithm because of technical formatting issues. Mr. Fritz O'Hora, a consultant for Vaisala, showed Mr. McNamara and Ms. Crawford how to use a utility in the IRIS software package to convert the data to Level II. They were able to display these converted files in GR2Analyst. The IRIS files will be converted to Level II using the IRIS utility.

MCO TDWR

Ms. Crawford requested the MCO TDWR data in Level II format from Mr. Paul Biron of the FAA, which he delivered on a DVD. However, the WDSS-II utility she used to convert the data to netCDF produced an error stating that the data files were not Level II. She consulted with Dr. Lakshmanan of the University of Oklahoma (OU), the WDSS-II developer, who confirmed the data files were not in Level II format.

Ms. Crawford presented this finding to Mr. Biron, who confirmed with

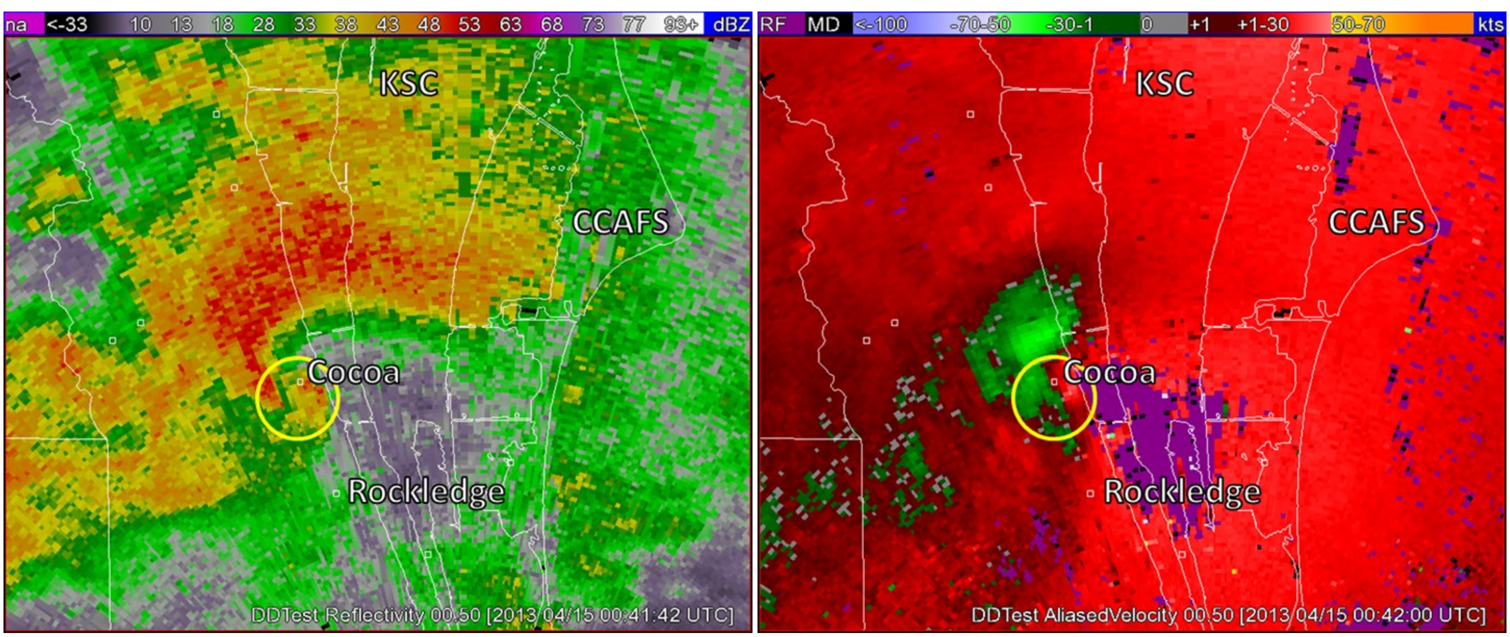


Figure 9. The 0.5° reflectivity (left) and Doppler velocity (right) at 0042 UTC 15 April 2013 (2042 EDT 14 April) products from the NWS MLB WSR-88D of the tornadic event in Cocoa, Florida. The tornado location is surrounded by a yellow circle in both images.

a colleague that the data files were indeed not Level II format. He suggested that software in the TDWR Supplemental Product Generator at NWS MLB may be needed to process the data, and also suggested another contact at OU, Dr. Mike Biggerstaff, who may be able to help in converting the TDWR data to Level II format. Ms. Crawford contacted Drs. Biggerstaff and Lakshmanan via email asking what can be done to use the TDWR data, and included Mr. Pete Blottman of NWS MLB in the communication. A reference on the WDSS-II website (www.cimms.ou.edu/~lakshman/Papers/w2merger.pdf) shows that dual-Doppler analysis has been done using TDWR and WSR-88D data. Ms. Crawford will continue to pursue a solution that will allow use of these data in WDSS-II to create the dual-Doppler analysis with the WSR-88D.

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

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.

Wind Change Statistics

Mr. Decker analyzed the distributions of maximum wind change for each time interval in the ER and WR wind pair databases developed previously (AMU Quarterly Reports Q2 and Q3 FY13). The numbers of pairs in each time interval at each range are shown in Table 2. His analysis of the WFF wind pairs (AMU Quarterly Report Q3 FY13) indicated that there are too few samples in each time period to characterize wind change extremes for use in LSP activities. Mr. Decker recommended an alternative solution to apply the 4-hour extreme wind change for all time change intervals at WFF. This approach makes use of the historical data and produces more conservative results for shorter time periods, but less conservative results occur as the time change interval approaches 4 hours.

The WR database includes wind profiles from the Jimsphere system (AMU Quarterly Report Q2 FY13) as well as rawinsondes. Jimsphere wind profiles were generated during launch vehicle operations and manually quality controlled (QC) by technicians prior to distribution to launch vehicle operators. These manual QC checks are performed to remove suspect data for use in flight vehicle assessments (Divers et al. 2000). Mr. Decker performed additional automated QC checks on the data for this task:

- A profile was removed if its lowest altitude was higher than 400 ft or if the profile contained any decreasing altitude values with increasing height,
- All variables (altitude, wind speed, and wind direction) were removed if at least one of the variables was missing,
- All data were removed above the first altitude containing missing data, and
- Any linear wind component interpolations at the top of the profile were removed.

After the automatic QC, Mr. Decker combined the remaining Jimsphere profiles with the WR rawinsonde data to create the wind pairs.

The individual wind pairs for the WR can be made up of two Jimspheres, two rawinsondes, or a Jimsphere and a rawinsonde. The issue with the Jimsphere/rawinsonde combination is that a difference exists in the smallest resolvable wavelengths between these two wind profiles due to their sampling intervals.

Table 2. Sample size of wind pairs at each location.

Time Interval	*ER*	*WR*	*WFF*
45 minutes	273,265	435	78
90 minutes	260,878	401	54
2 hours	297,491	548	75
3 hours	273,189	508	127
4 hours	276,108	366	74
TOTAL	1,380,931	2,258	408

Mr. Decker removed the small-scale wavelengths from the JImsphere profiles through a filtering algorithm in order to maintain an equivalent effective vertical resolution between the rawinsonde and Jimsphere profiles (Wilfong et al. 1997). Filtering the Jimsphere data was necessary in order to use wind profiles from either system interchangeably in assessing wind affects on vehicle performance (Wilfong et al. 1997).

Mr. Decker conducted analyses to quantify the distribution and the confidence interval in the observed maximum wind change from the various sample sizes of each pair set. Extreme wind change population distributions are usually non-Gaussian (Merceret 1997), so he used an extreme theoretical probability function to fit the data. The generalized extreme value (GEV) distribution function (Coles, 2001) provides a good fit of the extreme u- and v-component wind changes in each pair up to roughly the 99th percentile level. Using the results from the GEV, Mr. Decker calculated 95% confidence intervals at various percentile levels using the Asymptotic Distribution of Percentiles (ADP) method (DasGupta 2008). The ADP equation is a function of the confidence interval, sample size, and percentile level of interest. Mr. Decker used the 95% confidence interval as a conservative approach to assess the range of extreme wind change for selected percentile levels.

For the WFF and WR samples the 95% confidence interval range of uncertainty increased as the sample size decreased. The WR 95% confidence interval range of uncertainty was approximately 30 kt for both wind components in all but the 4-hour pairs where the range of uncertainty was ~80 kt. Because of the large uncertainty at the extreme empirical percentile in the 4-hour pairs, Mr. Decker applied another approach to quantify the confidence of the observed wind change data. This approach uses a function from Smith and Adelfang (1998) that approximates the probability level of a sample population with a specified sample size to a probability level of the universal population. The function is independent of the probability distribution function of the wind change and is defined as:

$$P_u = 1 + \left[(n-1) - \frac{n}{P_s}\right] P_s^n$$

where P_u is the probability that the sample contains the universal population at the sample probability, P_s, and the sample size, n. Stated another way, a certain sample size is required to be P_u percent confident that the sample contains the P_s value of the universal population. Table 3 presents the confidence levels of the universal population for various sample probability levels based on the sample size in each WR wind pair interval. For the 366 4-hour wind pairs, there is 88.1% confidence that the pairs contain the 99th percentile of wind change during this time interval. The confidence level exceeds 90% for the other four time periods. These results indicate the WR samples are large enough to apply the wind change statistics in most vehicle performance applications; however, a low confidence exists that these samples capture the wind changes at extreme (e.g., > 99th percentile) levels.

Mr. Decker conducted a similar analysis for the ER wind pairs database. Due to the large sample sizes (Table 2), the wind change statistics are robust, and there is high confidence that the ER database captures wind changes at extreme levels. Mr. Decker will present details of the ER analysis in the final report.

Status

Mr. Decker began writing the final report. It will be finalized and distributed in the first quarter of fiscal year 2014.

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

Table 3. Confidence levels of the universal population for arbitrarily selected sample probability levels and the WR sample size for each wind pair time interval (Smith and Adelfang 1998).

Sample Probability	Time Interval (Sample Size)				
	45 minutes (435)	90 minutes (401)	2 hours (548)	3 hours (508)	4 hours (366)
0.500	1	1	1	1	1
0.750	1	1	1	1	1
0.900	1	1	1	1	1
0.950	0.9999999951	0.9999999742	1	0.9999999999	0.9999998576
0.990	0.9318892422	0.9102472336	0.9734932962	0.9628265943	0.8813414653
0.995	0.6400217131	0.5960258712	0.7592780050	0.7215858165	0.5466402874
0.999	0.0710955543	0.0617397316	0.1050219721	0.0925644635	0.0525946042

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.

Configuring New Modeling Clusters

Dr. Watson finished installing and configuring software needed to conduct this task on one of the new NASA AMU modeling clusters. After installation was complete, she began troubleshooting various minor issues on the new cluster with the help of Mr. Erik Magnuson, a system and software engineer with ENSCO, Inc.

Installing SPoRT Perl Scripts

Dr. Watson received a set of Perl scripts to run WRF/GSI in real-time from Mr. Brad Zavodsky of SPoRT. She installed the scripts and began configuring them to run on the new cluster. A WRF/GSI tutorial case was included with the scripts. Dr. Watson used the tutorial as a test case to troubleshoot runtime issues on the modeling cluster. She had to make several modifications to the scripts in order for them to run.

Acquiring Real-time Data

The GSI can analyze many types of observational data including satellite, radar and conventional data. The data must be in PrepBUFR (Binary Universal Form for the Representation of meteorological data) format, which are special quality-controlled BUFR files containing the entire set of data. This data set is available through NCEP. Dr. Watson began acquiring the real-time observational data from NCEP and archiving it. In addition, Dr. Watson began archiving RAP 13-km data to use as the background model first-guess field.

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

AMU OPERATIONS

Assistance to Range Weather Operations and KSC WO

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

- Dr. Bauman presented two introductory training sessions on the new AMU severe weather forecasting tools.
- AMU staff provided Advanced Weather Information Processing System (AWIPS) training to RWO personnel on several occasions in support of forecast preparation for daily operations.
- RWO forecasters asked the AMU for help to assess the Storm Relative Velocity (SRV) product in their GRLevel3 software. SRV is an important parameter in the AMU-developed Waterspout Tool in MIDDS, which they were using to determine the threat of waterspout development on 18 July that could affect daily operations and Atlas V launch preparations.
- At the request of the KSC WO, Dr. Bauman verified that the XMR precipitable water (PW) values in the AMU 24-year historical sounding database used to develop the AMU lightning and severe weather forecast tools matched the XMR PW values calculated in MIDDS. This confirmed the AMU tools were developed using the same MIDDS values and can continue to be used to support daily and launch operations at KSC/CCAFS. The concern arose when 45 WS forecasters noticed that PW values in MIDDS were lower than those from the Global Positioning System sensor at CCAFS.
- During the 45 WS training day, the AMU was invited to sit in on the discussion about interpreting the Skew-T log-P (Skew-T) sounding diagram. One of the 45 WS members incorrectly described how to determine convective temperature. Ms. Shafer corrected the information by describing how to correctly determine this value on a Skew-T.
- While attending a 45 WS morning weather discussion, Dr. Bauman and Ms. Shafer noted a discrepancy in the lightning probability value derived from the Objective Lightning Tool between the RWO and AMU MIDDS. They discovered a file conflict in MIDDS between the Objective Lightning Tool and the Severe Weather Tool. They resolved the conflict and, after testing, Mr. Madison of Computer Sciences Raytheon populated all of the MIDDS workstations with the updated Objective Lightning Tool code.

- During the 7 August Delta IV launch countdown, Ms. Winters, the 45 WS LWO, discovered the AMU-developed LSP Upper Level Winds Tool was not retrieving current data from the KSC 50 MHz wind profiler. Ms. Shafer discovered the KSC weather archive had no new data since 6 August. She informed Dr. Huddleston who notified Mr. Gober from Kegman, Inc. and Mr. Gemmer from Abacus Technology about the missing data. The issues were fixed within two hours and the data began updating correctly, allowing the LWO to use the tool to support the launch.
- Dr. Merceret requested assistance from the AMU to provide an image file of the KSC 50-MHz DRWP from MIDDS for a presentation he was creating. Dr. Watson and Dr. Bauman generated several images from real-time 50-MHz DRWP data in MIDDS and from the LSP Upper Winds Tool and provided them to Dr. Merceret.

Meetings and Briefings

The AMU staff presented an overview briefing of the AMU to the KSC GP Director, Dr. Pat Simpkins. The AMU also participated in the 2nd Annual KSC Innovation Expo with an exhibit booth in the KSC Operations and Checkout building lobby to support the KSC Showcase. Dr. Watson, Ms. Crawford and Dr. Bauman highlighted the AMU's capabilities with poster presentations and demonstrations of AMU computer-based tools to include the new Severe Weather Tool and LSP Upper Winds Tool.

Training

Ms. Crawford, Ms. Shafer and Dr. Bauman attended KSC-provided SharePoint 101 training to learn how to setup and develop the AMU SharePoint Server site for the AMU Standard Operating Procedures repository. Dr. Bauman completed Sensitive But Unclassified SATERN training on 8 August.

IT

Mr. Magnuson and ENSCO IT staff completed wiping the old AMU cluster hard drives as required for equipment turn-in to KSC. The cluster was removed from ENSCO's facility and returned to KSC for disposal.

Dr. Bauman completed dismantling the AMU's inactive modeling cluster located in the Morrell Operations Center (MOC) and wiping all information from the hard drives so the cluster can be turned-in to KSC for disposition. This action will result in one less system in the AMU IT System Security Plan. Dr. Huddleston submitted the request to have the system removed from the MOC and properly disposed of by KSC.

The AMU staff participated in 45 SW testing of the Range External Interface Network (REIN) system that will deliver KSC/CCAFS weather data to users via a secure ftp server. Access to REIN is important for AMU modeling tasks and other work that requires real time access to the KSC/CCAFS weather data. They discovered that the Uniform Resource Locator (URL) for REIN was not accessible from the NASA network. The AMU notified NASA IT, who subsequently unblocked the URL after determining it was being blocked at KSC.

AMU Tasking Meeting

The AMU Tasking Meeting was held on 24 September at KSC. It was attended by personnel from the 45 WS, 30 OSS, LSP, MSFC NE, Spaceflight Meteorology Group at Johnson Space Center, NWS MLB, KSC WO, and the AMU team. Four proposals were presented and discussed by the AMU customers. However, due to reduced AMU funding, the AMU customers recommended and approved working on the two current tasks in parallel by multiple staff members as much as possible to shorten the projected delivery time. The current tasks will be delayed from their original projected delivery date due to the significant loss of funding for the AMU contract in FY14 unless partial or full funding can be restored.

The AMU was assigned two new tasks in addition to the current workload that were modified from those originally proposed so they can be accomplished in a shorter time period. The KSC WO proposal, "The Three Dimensional Lightning Criteria Visualization Tool", will be divided into phases, with the first phase being a market research of commercially available software that might be able to ingest the lightning mapping array, weather radar reflectivity, vehicle flight path, and other data so that all can be visualized together. The tasking team also decided to postpone the evaluation of the Air Force Weather Agency (AFWA) 1.67 km WRF numerical model, proposed by the 45 WS, because it was unlikely a sufficient amount of the model's gridded data during the 2013 warm season had been archived at AFWA. The 45 WS will work with AFWA to provide the gridded model output to the AMU beginning 1 May 2014 so the AMU can archive the data. In lieu of verifying the AFWA model, the AMU proposed to begin running the local WRF model, configured in a current AMU task, in real-time on the second NASA AMU cluster. The model output will be sent to the AMU AWIPS and used to conduct a verification of the real-time model.

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LIST OF ACRONYMS

14 WS	14th Weather Squadron
30 SW	30th Space Wing
30 OSS	30th Operational Support Squadron
45 RMS	45th Range Management Squadron
45 OG	45th Operations Group
45 SW	45th Space Wing
45 SW/SE	45th Space Wing/Range Safety
45 WS	45th Weather Squadron
AFSPC	Air Force Space Command
AFWA	Air Force Weather Agency
AMU	Applied Meteorology Unit
AWIPS	Advanced Weather Information Processing System
BUFR	Binary Universal Form for the Representation of meteorological data
CCAFS	Cape Canaveral Air Force Station
CI	Convection Initiation
CG	Cloud-to-Ground Lightning
CSR	Computer Sciences Raytheon
dP	Pressure Difference
DRWP	Doppler Radar Wind Profiler
ER	Eastern Range
ESRL	Earth System Research Laboratory
FAA	Federal Aviation Administration
FSU	Florida State University
GFS	Global Forecast System model
GSDO	Ground Systems Development and Operations program
GSI	Gridpoint Statistical Interpolation
GUI	Graphical User Interface
IRIS	Interactive Radar Information System
JSC	Johnson Space Center
KSC	Kennedy Space Center
KSC WO	KSC Weather Office
LSP	Launch Services Program
LWO	Launch Weather Officer
MCO	Orlando International Airport 3-letter identifier
MIDDS	Meteorological Interactive Data Display System
MOC	Morrell Operations Center
MPW	Maximum Peak Wind
MSFC	Marshall Space Flight Center
NAM	North American Mesoscale model
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NE	MSFC Natural Environments
netCDF	Network Common Data Form
NOAA	National Oceanic and Atmospheric Administration
NSSL	National Severe Storms Laboratory
NWS MLB	National Weather Service in Melbourne, Florida
OU	University of Oklahoma
PG	Pressure Gradient
QC	Quality Control
RAP	Rapid Refresh model
REIN	Range External Interface Network
SLS	Space Launch System
SMC	Space and Missile Center
SPoRT	Short-term Prediction Research and Transition Center
SRV	Storm Relative Velocity
TDWR	Terminal Doppler Weather Radar
TTS	Total Threat Score
URL	Uniform Resource Locator
USAF	United States Air Force
VAFB	Vandenberg Air Force Base
VBA	Excel Visual Basic for Applications
WDSS-II	Warning Decision Support System Integrated Information
WFF	Wallops Flight Facility
WR	Western Range
WRF	Weather Research and Forecasting model
WSR	45 SW Weather Surveillance Radar
WSR-88D	Weather Surveillance Radar 1988-Doppler
XMR	CCAFS 3-letter identifier

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

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NASA LaRC/M. Kavaya
45 WS/CC/S. Klug
45 WS/DO/K. Doser
45 WS/ADO/J. Smith
45 WS/DOR/M. McAleenan
45 WS/DOR/P. Sweat
45 WS/DOR/J. Britt
45 WS/DOR/F. Flinn
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45 SW/SELR/K. Womble
45 SW/XPR/R. Hillyer
45 OG/CC/D. Schiess
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CSR 3410/M Wilson
CSR 4500/J. Osier
CSR 4500/T. Long
SLRSC/ITT/L. Grier
SMC/OL-U/M. Erdmann
SMC/OL-U/T. Nguyen
SMC/OL-U/R. Bailey
SMC/CON/J. Gertsch
HQ AFSPC/A3FW/J. Carson
HQ AFWA/A3/M. Surmeier
HQ AFWA/A3T/S. Augustyn
HQ AFWA/A3T/D. Harper
HQ AFWA/16 WS/WXE/ J. Cetola
HQ AFWA/16 WS/WXE/ G. Brooks
HQ AFWA/16 WS/WXP/ D. Keller
HQ USAF/A30-W/R. Stoffler
HQ USAF/A30-WX/T. Moore
HQ USAF/Integration, Plans, and Requirements Div/ Directorate of Weather/ A30-WX
NOAA "W/NP"/L. Uccellini
NOAA/OAR/SSMC-I/J. Golden
NOAA/NWS/OST12/SSMC2/ J. McQueen
NOAA Office of Military Affairs/ M. Babcock
NWS Melbourne/D. Sharp
NWS Melbourne/S. Spratt
NWS Melbourne/P. Blottman
NWS Melbourne/M. Volkmer
NWS Southern Region HQ/"W/ SR"/S. Cooper
NWS/SR/SSD/STB/B. Meisner
NWS/"W/OST1"/B. Saffle
NWS/"W/OST12"/D. Melendez
NWS/OST/PPD/SPB/P. Roohr
NSSL/D. Forsyth
30 OSS/OSWS/DO/B. Lisko
30 OSS/OSWS/M. Schmeiser
30 OSS/OSWS/T. Brock
30 SW/XPE/R. Ruecker
Det 3 AFWA/WXL/K. Lehneis
NASIC/FCTT/G. Marx
46 WS//DO/J. Mackey
46 WS/WST/E. Harris
412 OSS/OSW/P. Harvey
412 OSS/OSWM/G. Davis
UAH/NSSTC/W. Vaughan
FAA/K. Shelton-Mur
FSU Department of Meteorology/H. Fuelberg
ERAU/Applied Aviation Sciences/C. Herbster
ERAU/J. Lanicci
NCAR/J. Wilson
NCAR/Y. H. Kuo
NOAA/ESRL/GSD/S. Benjamin
Office of the Federal Coordinator for Meteorological Services and Supporting Research/ R. Dumont
Aerospace Corp/T. Adang
ITT/G. Kennedy
Timothy Wilfong & Associates/ T. Wilfong
ENSCO, Inc./J. Stobie
ENSCO, Inc./R. Gillen
ENSCO, Inc./E. Lambert
ENSCO, Inc./A. Yersavich
ENSCO, Inc./S. Masters