Applied Meteorology Unit (AMU) Quarterly Report

31 October 2012 Fourth Quarter FY-12 Contract NNK12MA53C DRL-003 DRD-004

In this issue:

Atlas 5 prepped to launch NASA's twin Radiation Belt Storm Probes on 30 August 2012 (http://www.spaceflightnow.com/atlas/av032/status.html)

Launch Support

Dr. Watson and Dr. Huddleston supported the first Atlas 5 launch attempt on 24 August.

Ms. Crawford and Dr. Huddleston supported the second Atlas V launch attempt on 25 August.

Ms. Shafer and Dr. Huddleston supported the successful launch of the Atlas V on 30 August.

This Quarter's Highlights

The AMU team worked on six tasks for their customers:

- Dr. Bauman delivered the final report describing his work on the objective lightning forecast task for the Kennedy Space Center/Cape Canaveral Air Force Station area.
- Ms. Crawford continued working on the objective lightning forecast task for airports in east-central Florida.
- Ms. Shafer began work on a new task for Vandenberg Air Force Base to create an objective and automated tool that will help forecasters relate pressure gradients to peak wind values.
- Dr. Bauman created a graphical user interface for the NASA Launch Services Program and 45th Weather Squadron to assess model forecasts of upper-level winds.
- Dr. Huddleston completed research to determine whether Global Position System precipitable water data could improve the lightning forecast.
- Dr. Watson returned from maternity leave and resumed testing high-resolution model configurations for Wallops Flight Facility to provide forecasters with more accurate depictions of the future state of the atmosphere.

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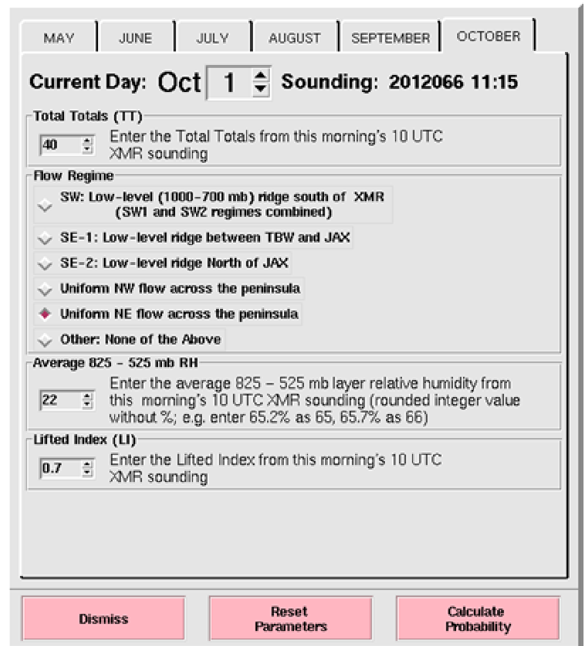
Quarterly Task Summaries

This section contains summaries of the AMU activities for the fourth quarter of Fiscal Year 2012 (July-September 2012). 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.

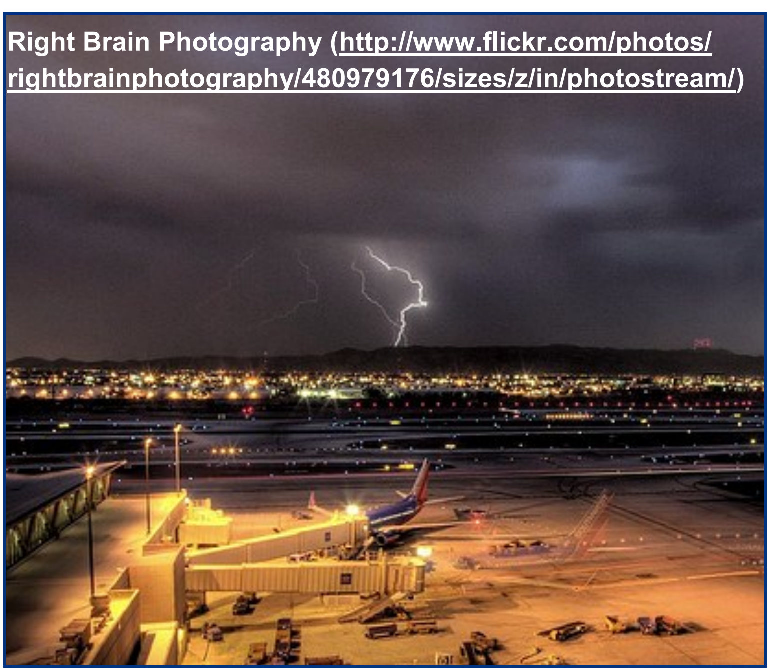
Objective Lightning Probability Forecast, Phase IV (Page 5)



Purpose: Develop updated equations with six more years of data and use the National Lightning Detection Network (NLDN) daily lightning flash count across central Florida to determine if the data can be stratified by lightning sub-season instead of calendar month. If the data cannot be stratified by lightning sub-season, the monthly equations will be updated with the new data. The 45th Weather Squadron (45 WS) uses the AMU-developed Objective Lightning Probability tool as one input to their daily lightning forecasts. Updating the logistic regression equations with additional data and different stratifications could improve the lightning probability forecast and make the tool more useful to operations.

Accomplished: Completed and delivered the final report to the AMU customers and posted the report on the AMU website.

Objective Lightning Probability Forecasts for East-Central Florida Airports (Page 5)

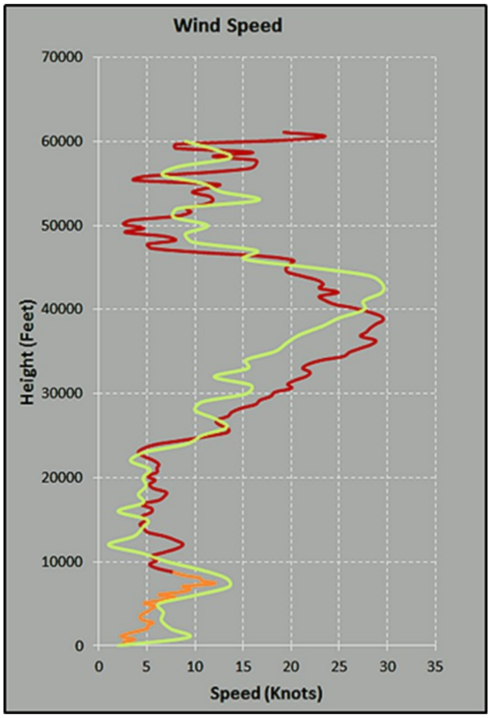

Right Brain Photography (http://www.flickr.com/photos/rightbrainphotography/480979176/sizes/z/in/photostream/)

Purpose: Develop an objective lightning probability forecast tool for commercial airports in east-central Florida to help improve the lightning forecasts during the day in the warm season. The forecasters at the National Weather Service in Melbourne, Fla. (NWS MLB) are responsible for issuing forecasts for airfields in central Florida, and need to make more accurate lightning forecasts to help alleviate delays due to thunderstorms in the vicinity of an airport. The AMU will develop a forecast tool similar to that developed for the 45 WS in previous AMU tasks. The probabilities will be valid for the areas around the airports and time periods needed for the NWS MLB forecast.

Accomplished: Created and tested July lightning probability forecast equations for Orlando (MCO) and Melbourne (MLB) International Airports and determined their performance was not adequate. Met with NWS MLB forecasters to determine next steps and began developing the graphical user interface (GUI).

Quarterly Task Summaries (continued)

Assessing Upper-level Winds on Day-of-Launch (Page 7)



Purpose: Develop a Meteorological Interactive Data Display System (MIDDS) or Excel capability to rapidly assess the model forecast of upper-level winds by calculating the differences between model data and the current upper-level wind speed and direction observations from the 50 MHz Doppler Radar Wind Profiler and Automated Meteorological Profiling System (AMPS). This capability will provide an objective method for the launch weather officers (LWO) to compare the forecast upper-level winds to the observed data and assess the model potential to accurately forecast changes in the upper-level profile through the count.

Accomplished: Completed Excel GUI based on 45 WS LWOs feedback. Addressed two Information Technology challenges: software compatibility and data access. The 45 WS installed the required software on one of their computers, and several solutions were proposed that will allow 45 WS access to the model data needed for the tool. Completed the final report.

Vandenberg AFB Pressure Gradient Wind Study (Page 9)

Purpose: Provide a wind forecasting capability that will improve wind warning forecasts and enhance the safety of the 30th Operational Support Squadron (30 OSS) customers' operations. This capability will be an Excel GUI that ingests surface pressure data automatically and determine the likelihood of reaching warning-level winds based on the pressure gradient across Vandenberg Air Force Base (VAFB). This will allow 30 OSS forecasters to evaluate pressure gradient thresholds between specific pairs of regional observing stations under different synoptic regimes to help determine the onset and duration of warning category winds.

Accomplished: Began working with the 30 OSS to acquire observations from 26 VAFB wind towers. Started writing Perl scripts to develop a database containing the maximum hourly peak winds for each day from 2007-2012.

Quarterly Task Summaries
(continued)

Using Global Positioning System Integrated Precipitable Water Vapor to Forecast Lightning on KSC/CCAFS (Page 10)

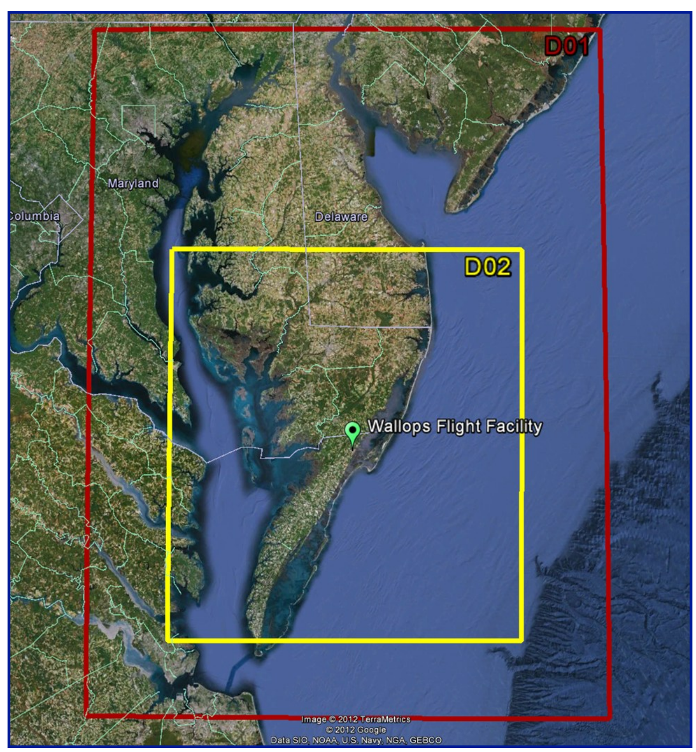
Purpose: Use output from the 45 WS Objective Lightning Probability tool, the current Global Positioning System (GPS) integrated precipitable water vapor (IPW) value, and the change in the GPS-IPW value over the last 0.5 to 24 hours (in 30-minute increments) to determine the time period for the GPS-IPW change that produces the best probability forecast. The output from the combined Objective Lightning Probability/IPW tool will be compared to the output of the Objective Lightning Probability tool alone to determine the value added, if any, to lightning prediction capability. If the value added is sufficient, the AMU will develop a forecast tool using the Objective Lightning Probability tool output and the IPW data as input.

Accomplished: Completed the data analysis and found that GPS-IPW provided no added value to the lightning probability forecasts. Drafted the final report.

Range-Specific High-Resolution Mesoscale Model Setup (Page 14)

Purpose: Establish a high-resolution model for the Eastern Range (ER) and Wallops Flight Facility (WFF) to better forecast a variety of unique weather phenomena. 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: Completed all model test cases for WFF using several Weather Research and Forecasting (WRF) model domain configurations, and validated and compared all output against local observations. The results were mixed, the configurations performed similarly.



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

Objective Lightning Probability Forecast – Phase IV (Dr. Bauman and Ms. Crawford)

The 45 WS includes the probability of lightning occurrence in their daily morning briefings. This forecast is important in the warm season months, May-October, when the area is most affected by lightning. The forecasters use this information when evaluating launch commit criteria and planning for daily ground operations on Kennedy Space Center (KSC) and Cape Canaveral Air Force Station (CCAFS). The daily lightning probability forecast is based on the output from an objective lightning forecast tool developed in two phases by the AMU that the forecasters supplement with subjective analyses of model and observational data. The tool developed in Phase II consists of a set of equations, one for each warm season month, that calculates the probability of lightning occurrence for the day more accurately than previous forecast methods (Lambert and Wheeler 2005, Lambert 2007). The equations are accessed through a graphical user interface in the 45 WS primary weather analysis and display system, MIDDS. The goal of Phase III was to create equations based on the progression of the lightning season as seen in the daily climatology instead of an equation for each month in order to capture the physical attributes that contribute to thunderstorm formation. Five sub-seasons were discerned from the daily climatology, and the AMU created and tested an equation for each. The Phase III equations did not outperform Phase II. Therefore, the Phase II equations are still in operational use. For this phase, the 45 WS requested the AMU make another attempt to stratify the data by lightning sub-season. The AMU did this by using lightning observations across central Florida from NLDN. After an extensive analysis, Dr. Bauman determined the NLDN-based lightning sub-seasons were unidentifiable, so he created monthly equations with six more years of data than used in Phase II. The new equations did not outperform those from Phase II and will not be transitioned to operations with the exception of the October equation that does not currently exist in the Phase II operational tool.

Final Report

Dr. Bauman completed the final report. After the KSC Export Control Office completed the Scientific and Technology Information assessment, he distributed the report to the AMU customers and Ms. Crawford posted the final report on the AMU website. at http://science.ksc.nasa.gov/amu/.

For more information contact Dr. Bauman at bauman.bill@ensco.com or 321-853-8202, or Ms. Crawford at crawford.winnie@ensco.com or 321-853-8130.

Objective Lightning Probability Forecasts for East-Central Florida Airports (Ms. Crawford and Dr. Bauman)

The forecasters at NWS MLB are responsible for issuing weather forecasts to several airfields in central Florida. They identified a need to make more accurate lightning forecasts to help alleviate delays due to thunderstorms in the vicinity of an airport. Such forecasts would also provide safer ground operations around terminals, and would be of value to Center Weather Service Units serving air traffic controllers in Florida. To improve the forecast, the AMU was tasked to develop an objective lightning probability forecast tool for the commercial airports in east-central Florida for which NWS MLB has forecast responsibility using data from the NLDN. The resulting forecast tool will be similar to that developed by the AMU for the 45 WS in previous tasks (Lambert and Wheeler 2005, Lambert 2007). The lightning probability forecasts will be valid for the time periods and area around each airport needed for the NWS MLB forecasts in the wet season months, defined as May-September.

MCO and MLB July Equations

After learning that the MCO May and June equations developed from the new period of record (POR) with the new flow regime candidate predictors did not show improved performance over the previous equations (AMU Quarterly Report Q3 FY12), Mr. Volkmer of NWS MLB asked Ms. Crawford to develop and test July equations for MCO and MLB. Both Mr. Volkmer and Ms. Crawford thought the equations for July might perform better because this month had the highest percentage of lightning occurrence in the POR. They expected that more lightning days in the data set was more likely to result in robust relationships between the predictors and lightning occurrence. The results would help them determine whether to continue with MCO equation development.

Ms. Crawford calculated the percent improvement or degradation in skill of the new equations over five forecast benchmarks using the Brier Skill Score (SS) defined in Wilks (2006). Table 1 contains the SS values showing the skill of the July MCO and MLB equations using the development and verification datasets. In general, equations perform better when using the data from which they were developed and not as well using an independent verification dataset. Ms. Crawford used these two datasets as input to determine if this was the case for the July equations.

The positive values in Table 1 indicate the equations had more skill than the corresponding forecast method, and negative values indicate less skill. As in all previous tests, the equations outperformed 1-day persistence. However, the results for the daily climatology and flow regime probabilities were mixed when using either the development or verification dataset. Values with magnitudes within 10% of 0, positive or negative, likely indicate that the equations performed similarly to the corresponding forecast method. The general rule of development data performing better than verification data held in this case. The development data SS values were higher and all positive, but a large percentage of the values were < 10%. A majority of the verification SS values were within 10%, and several of those were negative. That both datasets produced results showing similar performance between the forecast benchmarks and the equations indicated that the equations did not provide added value to the forecast.

Table 1. The percent improvement (positive black font) or degradation (negative red font) in skill of the MCO and MLB July equations over the forecast benchmarks of 1-day persistence, daily climatology and three flow regime probabilities. Scores were calculated using the development and verification data set for each station. Cells shaded in yellow contain values within 10% of 0, not inclusive.

Station	***Dataset***	***Forecast Benchmark***	***15-18***	***18-21***	***21-00***	***00-03***
MCO	Development	1-Day Persistence	52	44	48	56
		Daily Climatology	14	13	13	6
		Flow Regime Probability	11	11	6	3
		Flow Regime 2-Speed	8	11	6	4
		Flow Regime 3-Speed	9	10	4	3
	Verification	1-Day Persistence	48	51	50	48
		Daily Climatology	-6	8	28	4
		Flow Regime Probability	-7	5	23	-3
		Flow Regime 2-Speed	0	5	20	-5
		Flow Regime 3-Speed	-3	4	12	-6
MLB	Development	1-Day Persistence	48	47	49	49
		Daily Climatology	15	21	22	10
		Flow Regime Probability	13	9	6	7
		Flow Regime 2-Speed	12	9	6	4
		Flow Regime 3-Speed	11	9	4	5
	Verification	1-Day Persistence	53	45	54	51
		Daily Climatology	-4	-7	10	1
		Flow Regime Probability	-8	-9	3	-3
		Flow Regime 2-Speed	-1	-4	-7	2
		Flow Regime 3-Speed	-5	-9	-2	-4

Area and Time Stratifications

To help determine why the MLB equations did not perform well, Ms. Crawford compared the area and time stratifications to the 45 WS's Objective Lightning Probability tool developed by the AMU (Lambert 2007). The area in the 45 WS tool is larger than the 10 NM radius around MLB and MCO, and the time period was 17 hours (0700 to midnight local time) as opposed to the four three-hour time periods during 1500 to 0300 UTC, which totals 12 hours (1100 to 2300 local time). If lightning occurred just outside of the 10 NM radius or just before or after a time period, a robust relationship between predictors and the predictand might not be fully realized by the equations.

Ms. Crawford and Dr. Huddleston spoke with with Mr. Sharp and Mr. Volkmer of NWS MLB and suggested increasing the area and/or time period to help improve equation performance. Dr. Huddleston found similar issues with the time stratification in another AMU task to use GPS IPW estimates to forecast lightning (AMU Quarterly Report Q3-FY12). Mr. Sharp and Mr. Volkmer said the area cannot be changed, but they would consider lengthening the time periods. In a later meeting with Ms. Crawford and Dr. Bauman, they requested that the equations be developed for MCO and MLB using the original requested area and time period stratifications, even if they did not perform significantly better than the daily and flow regime climatologies.

Excel GUI

Mr. Sharp and Mr. Volkmer requested that the GUI to be created with the task include the daily and flow regime climatologies as well as the equation output for each month. Ms. Crawford began creating a GUI to display the daily climatology and flow regime probability values and will add input and output for the equations when they are finished. Figure 1 shows the initial form in the GUI to input values needed to output all the climatology values. The month, day, station and time are needed for the daily climatology, these values plus the flow regime are needed for the flow regime probabilities, and all values including the speed are needed for the speed-stratified flow regime probabilities.

Status

Ms. Crawford finished a rough draft of the GUI to output values for the daily and flow regime climatologies. She is preparing and testing it before showing it to Mr. Volkmer for his input on the design and functionality.

For more information contact Ms. Crawford at 321-853-8130 or crawford. winnie@ensco.com, or Dr. Bauman at 321-853-8202 or bauman.bill @ensco.com.

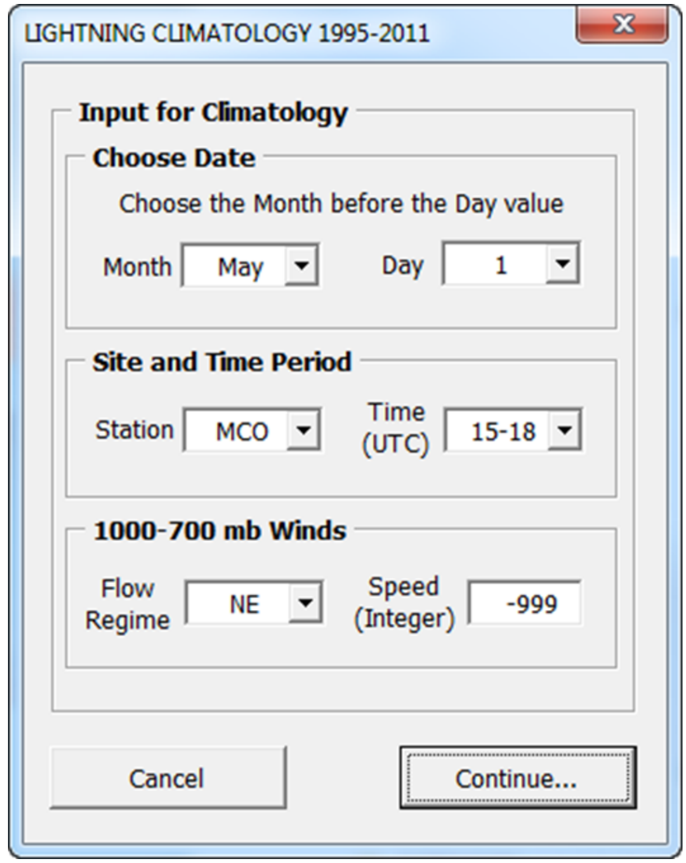


Figure 1. The initial form in the GUI to input the values needed to output the climatology values.

Assessing Upper-Level Winds on Day-of-Launch (Dr. Bauman)

On the day-of-launch, the 45 WS LWOs monitor the upper-level winds for their launch customers to include NASA's Launch Services Program. They currently do not have the capability to display and overlay profiles of upper-level observations and numerical weather prediction model forecasts. The LWOs requested the AMU to develop a capability in the form of a GUI that will allow them to plot upper-level wind speed and direction observations from the KSC 50 MHz wind profiler and CCAFS AMPS radiosondes, and then overlay forecast profiles from the North American Mesoscale (NAM), Rapid Update Cycle (RUC), which is now the Rapid Refresh (RAP) and Global Forecast System (GFS) models to assess the performance of these models.

Excel GUI

Dr. Bauman completed the final version of the GUI after demonstrating it to the 45 WS LWOs. The final version shown in Figure 2 consists of three major changes based on the LWOs feedback. First, the background color of the charts was changed from white to gray so the wind speed and wind direction lines will stand out against the background. Second, the 50 MHz profiler and rawinsonde observations are displayed as solid dark red lines and the 915 MHz profiler as solid orange lines; and the forecasts are displayed as dashed blue lines trending from light blue for the first forecast valid time to dark blue for the last forecast valid time. Finally, the number and interval of each model's forecast displayed are limited to four at three-hour intervals for clarity.

Information Technology

Information Technology (IT) challenges in this task included incompatible versions of commercial off-the-shelf software and changing IT security requirements. These issues impacted the ability of the software to produce the required results and changed data acquisition methods.

Software Compatibility

Dr. Bauman used Excel 2010 to develop the GUI because it was part of the standard AMU software load as part of Microsoft Office 2010 as approved by NASA IT System Administration and Security. After Dr. Bauman first demonstrated the GUI to the LWOs, they suggested that the he conduct tests of the tool on the 45th Space Wing (45 SW) network. Upon doing so, Dr. Bauman realized that most of the charting functionality used in the Excel 2010 version of the tool was not backwards compatible with the Excel 2007 version on the 45 SW network. Only Excel 2010 possessed the capabilities to automatically format the charts to meet the requirements set forth in this task. To solve this issue, Dr. Bauman requested the 45 WS install Excel 2010, which they did after getting permission from 45 SW IT Security.

Data Access

Testing the tool on the 45 SW network also revealed that 45 SW IT Security did not permit 45 SW com-

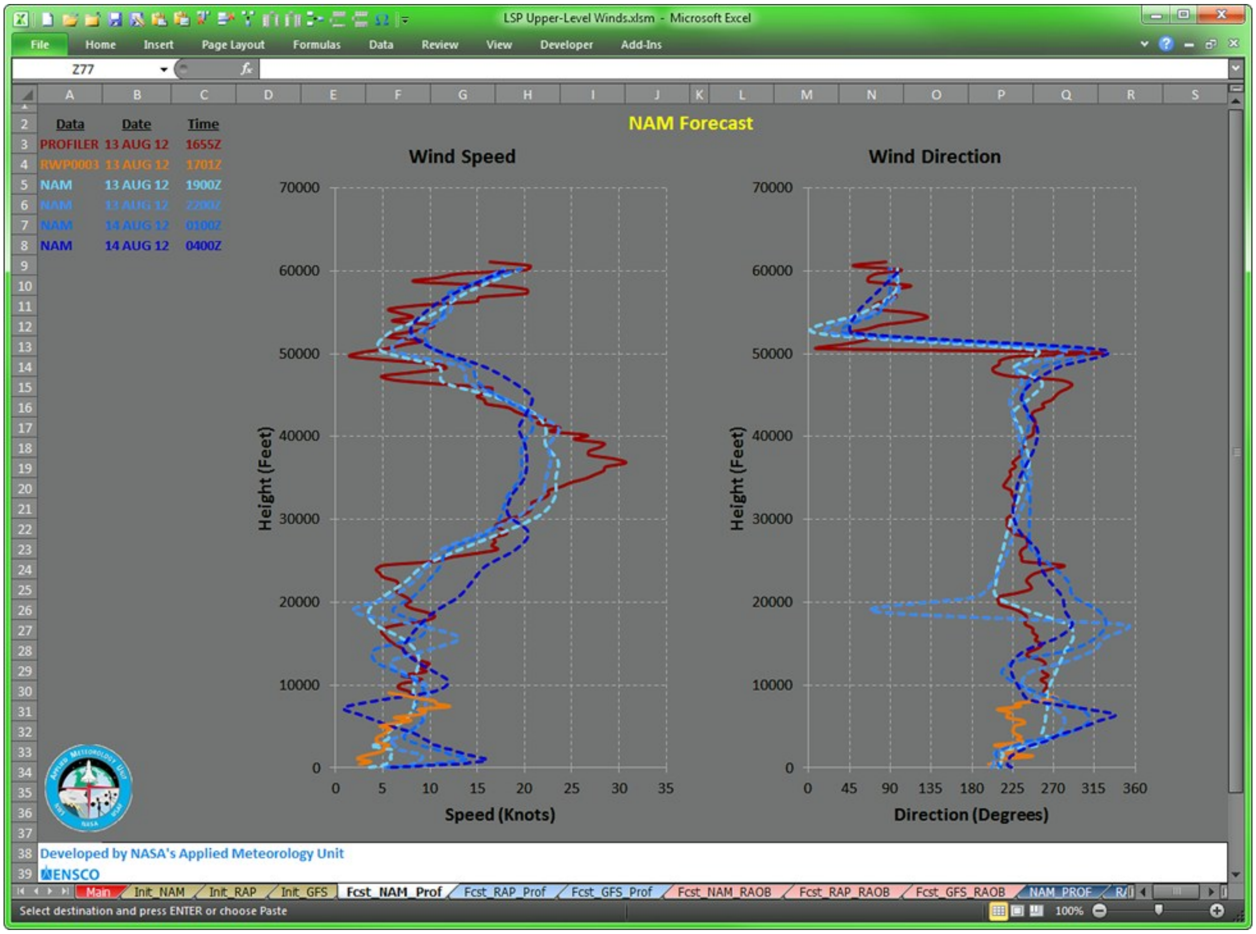


Figure 2. Wind speed (left) and wind direction (right) profiles from the 1655 UTC 13 August 2012 50 MHz profiler observation (dark red lines), 1701 UTC 13 August 2012 915 MHz profiler observation (orange lines) and NAM model forecasts (dashed blue lines) valid every three hours from 1900 UTC 13 August 2012 through 0400 UTC 14 August 2012 plotted in Excel. The legend for data type, date and time are shown in the upper left of the chart. The legend text colors match the line colors in the charts.

puters to access the Iowa State University Weather Archive server where the model forecast data files were located. The 45 WS suspected this would be an issue as access to .edu Universal Resource Locators (URL) is normally blocked by IT Security. Since Dr. Bauman's testing also revealed that access to the Spaceport Weather Data Archive, a .gov URL, was permitted, they asked the KSC Weather Office if the Spaceport Weather Data Archive curator, Mr. Gemmer of Abacus Technology, could routinely retrieve the model files from the Iowa State University Weather Archive server and save them in a directory on the Spaceport Weather Data Archive for access by the 45 WS. Mr. Gemmer notified the KSC Weather Office that they could retrieve and save the model files for 45 WS access.

When this task was about 75% complete, the KSC Weather Office notified Dr. Bauman that the Spaceport Weather Data Archive was being phased out and transitioning to the Spaceport Weather Archive at a new URL: http://wxarchive.ksc.nasa.gov. The AMU tested access to the new site via the File Transfer Protocol (FTP) being used in the Excel Visual basic for Applications (VBA) scripts and found that the directory structure used on the old site was not the same on the new site. Upon manual inspection of the new URL, Dr. Bauman discovered that the new site is built only for human interface to search and acquire data, not for automated retrieval of data by another computer. Dr. Bauman asked Mr. Gemmer for assistance and he indicated that due to NASA IT security regulations the FTP portion of the server would be shut down, but they could setup a directory structure to allow the automated transfer of files via Hypertext Transfer Protocol (HTTP). This was not an issue because Dr. Bauman would only have to modify the VBA code to use HTTP instead of FTP for the correct directory structure on the server.

Based on resolution of the challenges presented in the preceding paragraphs, Dr. Bauman continued to develop the GUI and complete the task. After final testing on the NASA network and prior to transferring the tool to the 45 WS computer for testing, Dr. Bauman checked on the status of the HTTP directory structure on the new Spaceport Weather Archive URL so they could update the VBA code. Mr. Gemmer informed him that since his last communication, NASA IT Security was shutting down HTTP servers thereby disallowing the tool to automatically access any files on the Spaceport Weather Archive. Dr. Bauman and Dr. Huddleston met with Mr. Ebuen and Ms. Burdett of Abacus Technology to determine if there was another solution to allow the tool to automatically access the data on the servers. Four possible solutions were discussed:

- Use HTTP Secure access with password protection,
- Run the Excel GUI on the Spaceport Weather Archive server,

- Implement a Web service, which is a software system designed to support interoperable machine-to-machine interaction over a network, and
- Implement a Server Message Block or Common Internet File System that operates as an application-layer network protocol to provide shared access to files between nodes on a network.

After assessing the four options, Mr. Gemmer, Mr. Ebuen and Ms. Burdett thought implementing a Web service would be the best option. Based on this assessment and working with Mr. Gemmer, Dr. Huddleston submitted an IT Work Request to NASA/KSC IT Security to request support to provide a solution. Once a solution is in-place, Dr. Bauman will work with the 45 WS system administrators to install the GUI on a 45 WS computer with Excel 2010 and test it on the 45 SW network.

Final Report

Dr. Bauman completed the final report. After the KSC Export Control Office completes the Scientific and Technology Information assessment, the AMU will post the final report on the AMU website.

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

Vandenberg AFB Pressure Gradient Wind Study (Ms. Shafer)

Warning category winds can adversely impact day-to-day space lift operations at VAFB. 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 30th Operational Support Squadron (30 OSS) forecasters at VAFB use the mean sea level pressure from seven regional observing stations to determine the magnitude of the pressure gradient 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 pressure gradient. 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. The 30 OSS has requested that the AMU develop an automated Excel GUI that includes pressure gradient thresholds between specific observing stations under different synoptic regimes to aid forecasters when issuing wind warnings.

Current 30 OSS Tool

Mr. Brock of 30 OSS provided Ms. Shafer with an Excel file containing the current 30 OSS tool used by the forecasters to determine pressure gradients between specific regional observing stations. She examined the contents of the file to better understand their needs and identified the 7 observing stations (Figure 3) and the 12 station pairs they use to determine the pressure gradient. The 12 pairs taken from Figure 3 are

- KVBG - KBFL
- KBFL - KLAS
- KVBG - KLAS
- KACV - KSFO
- KSFO - KPRB
- KPRB - KVBG
- KVBG - KLAX
- KACV - KPRB
- KPRB - KLAX
- KACV - KVBG
- KSFO - KVBG
- KACV - KLAX

Figure 3. Locations of the seven observing stations included in the pressure gradient assessment. KVBG is VAFB.

Ms. Shafer and Dr. Bauman noted the current tool requires several manual inputs from the user throughout the day and discussed the ability to automate it. Mr. Brock agreed this would be a great advantage for the forecasters and would like to see this capability in the new pressure gradient tool. Ms. Shafer will use the current 30 OSS tool as a starting point and will upgrade it to include automation and the results of the pressure gradient assessment.

Data Acquisition and Processing

Part of this task is to determine past high wind events and compare the local pressure gradients at the time. Ms. Shafer will collect the historical wind data from the 26 VAFB wind tower network and observations from each of the regional observing stations will be collected from the National Climatic Data Center archive. In order to confirm the wind tower data is in a format the AMU could easily process, Mr. Brock provided Ms. Shafer sample wind data files collected from two of the VAFB wind towers. She began writing Perl scripts to determine the hourly 4 meter peak wind for each tower on a given day, which will be used to develop the peak wind database.

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

Using GPS-IPW to Forecast Lightning on KSC/CCAFS (Dr. Huddleston)

The 45 WS forecasters include a probability of lightning occurrence in their daily 24-hour and weekly planning forecasts. This value is used by personnel involved in determining the possibility of violating launch commit criteria and planning for daily ground operation activities on KSC/CCAFS. To help improve this forecast, the AMU developed the 45 WS's Objective Lightning Probability tool, which is used every day during the warm season to forecast the probability of lightning occurrence for the day. This tool outperformed the 45 WS's previous objective lightning probability technique by 56% (Lambert 2007). The 45 WS and others have also investigated techniques using GPS-IPW observations and changes over specified time periods to predict the probability of lightning, each showing promising results (Mazany et al. 2002; Inoue and Inoue 2007; Kehrer et al. 2008; Suparta et al. 2011a; and Suparta et al. 2011b). In this task, the AMU determined the utility of using GPS-IPW and output from the Objective Lightning Probability tool to predict the probability of lightning at the temporal resolution of the GPS-IPW, which is every 30 minutes.

Logistic Regression

After an exploratory data analysis, Dr. Huddleston determined that a multiple, logistic regression model was the best choice for this study. Logistic regression is the appropriate model to use when the predictand, or element to be forecast, is binary. In this case, the element to be forecast was lightning occurrence: yes, or 1, meant lightning occurred and no, or 0, meant lightning did not occur within the specified time period and area of interest. As in Kehrer et al. (2008), Dr. Huddleston developed 2-hour and 9-hour forecast models. These models were limited to the hours between 0700-0000 EDT to be consistent with the Objective Lightning Probability tool. The output of the logistic regression equation is a lightning index that gives the probability that lightning will occur.

Predictor Selection Methodologies

Because there were 50 candidate predictors for these models, the goal was to determine a subset of predictors that affected the predictand to create a model that fits the data well without the negative effects of overfitting the model. Models that are overfit tend to be too dependent to the development data set and the fitted relationship falls apart when used with independent, verification data (Wilks 2006).

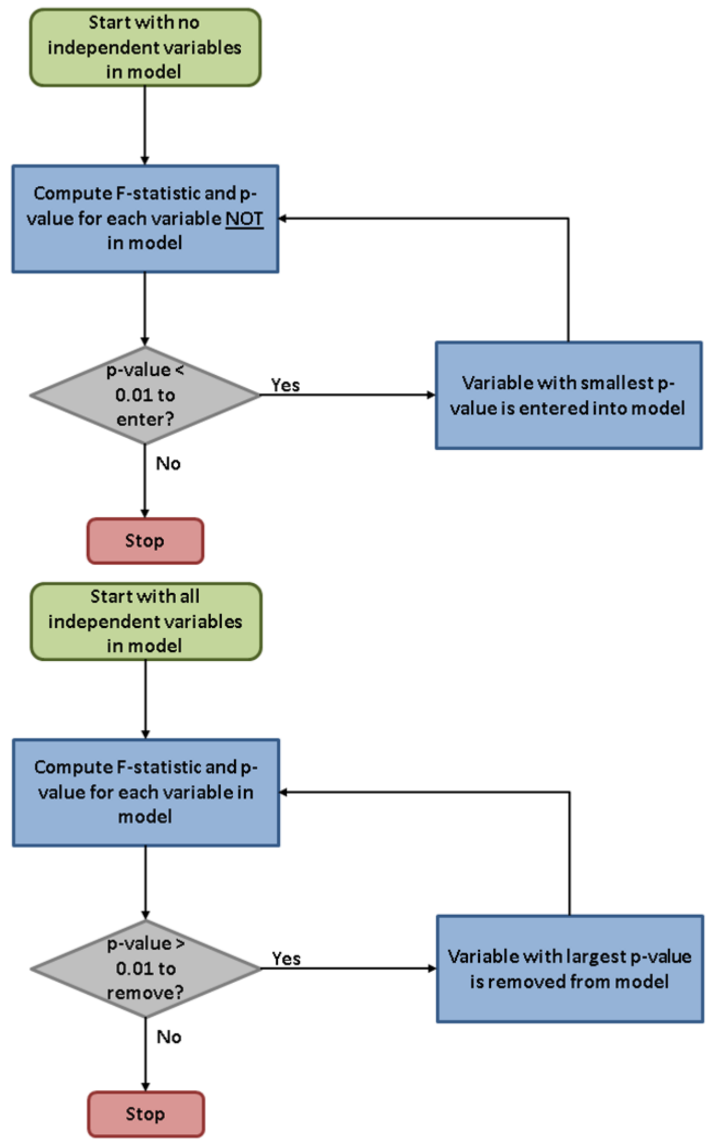


Figure 4. Flowcharts depicting the forward selection (top) and backward elimination (bottom) methods of choosing model predictors (Anderson et al. 2012).

Dr. Huddleston used two methods of predictor selection for this task: forward selection and backward elimination (Figure 4). In many cases, the two selection methods chose different predictors for the final model. Predictors were added or removed based on a p-value of a stringent 0.01 significance level in order to match the level selected by Mazany et al. (2002). The predictors selected for final equations for the 2-hour and 9-hour forecasts using both the forward selection and backward elimination methods ranged from 8 to 19 variables.

Relative Operating Characteristics

Dr. Huddleston developed relative operating characteristics (ROC) curves for each model as a graphical way of showing the model's ability to correctly anticipate the occurrence or non-occurrence of lightning. The ROC curve is useful in helping to identify an optimum warning criterion by indicating the trade-off between misses and false alarms (Mason et al. 1999). Generally, for a skillful forecast system, the ROC curve bends towards the top left, where hit rates are larger than false alarm rates and the area under the curve (AUC) is greater than 0.5. If the curve is close to the 45º diagonal, the AUC is near

0.5 and the forecast system does not provide any useful information. If the curve lies below the 45º diagonal, the AUC is less than 0.5 and the forecast system provides negative skill (Mason and Graham 1999). Mason and Graham (1999) provides a simple transformation, S, such that S = 2 x (AUC - 0.5). The range of S is from 1 for a perfect forecast to -1 for the worst forecast, with 0 indicating no skill.

The ROC curves for the 2-hour forecast logistic regression variables determined by using the backward elimination method are shown in Figure 5 along with the ROC curves for the Objective Lighting Probability tool and the logistic regression equation. The logistic regression equation contains the Objective Lightning Probability as a predictor, along with the seven changes in GPS-IPW values shown in the Figure 5 legend. The backward elimination method for the 2-hour forecast model was one of the best performers in terms of AUC and had fewer predictors in the final model; therefore Dr. Huddleston chose this model for illustration. From this graphic representation it is easily seen that the seven additional GPS-IPW predictors provide little additional information to improve predictability. The specific S values for the ROC curves, each predictor, and the AUC are shown in Table 2. Clearly, the Objective Lightning Probability predictor accounts for most of the variability in the logistic regression equation with the remaining predictors offering not much more predictability than would be expected by random chance.

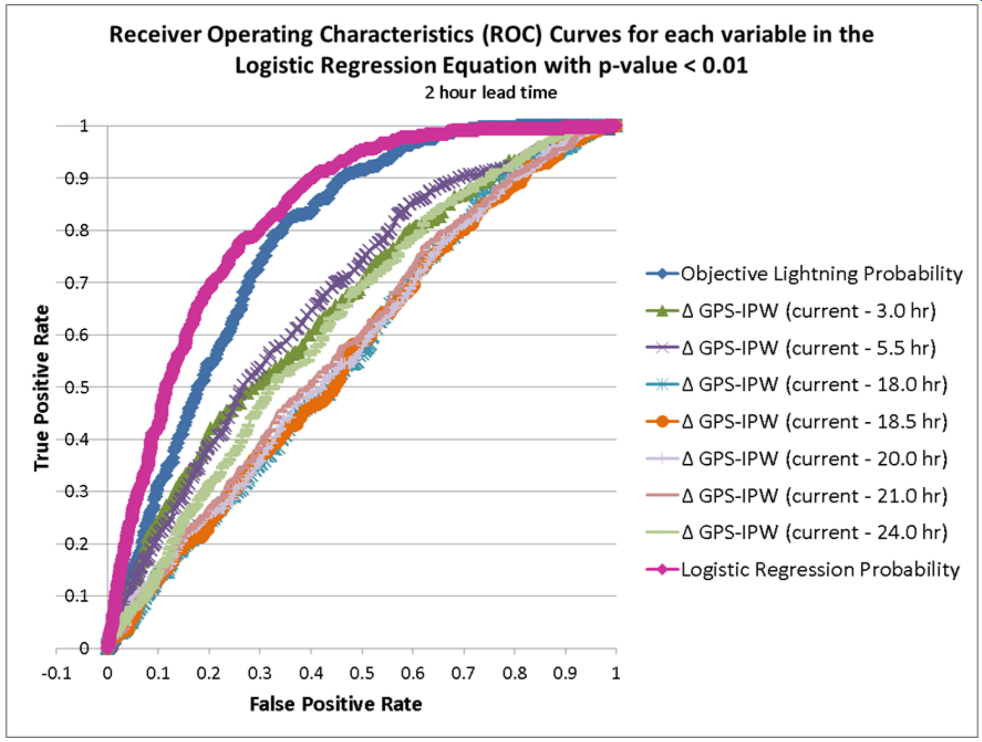


Figure 5. ROC curve for each variable in the 2-hour forecast regression equation using the backward elimination method of variable selection.

Table 2. Area under the ROC curve and forecast skill index, S, for each variable in the 2-hour forecast logistic regression equation using the backward elimination method of variable selection.

Variable	Area Under Curve (AUC)	S
Objective Lightning Probability	0.781	0.56
Δ GPS-IPW (current - 3.0 hr)	0.654	0.31
Δ GPS-IPW (current -5.5 hr)	0.668	0.34
Δ GPS-IPW (current – 18.0 hr)	0.565	0.13
Δ GPS-IPW (current - 18.5 hr)	0.565	0.13
Δ GPS-IPW (current - 20.0 hr)	0.571	0.14
Δ GPS-IPW (current - 21.0 hr)	0.589	0.18
Δ GPS-IPW (current - 24.0 hr)	0.627	0.25
Logistic Regression Probability	0.828	0.66

Reliability Diagram

A reliability diagram for the logistic regression equation for the 2-hour forecast backward elimination method is shown in Figure 6. In the reliability diagram, the dashed diagonal line represents perfect reliability and the red curve represents the reliability of the forecast equation. The histogram in the lower right shows the frequency of the number of observations in each probability range. When the curve is below the dashed line, the equation over-forecasted lightning occurrence. When the curve is above the dashed line, the equation under-forecasted lightning occurrence. At values of 0.2 and below, the logistic regression equation performed well, but above 0.2 the reliability curve of the equation is below the dashed line indicating that it over-forecasted lightning occurrence. Regardless of the selection method used, the logistic regression equations only produced lightning indexes greater than 0.4 only 0.1% of the time. Therefore these values were treated as extreme and not shown in the reliability diagram.

Predictor Collinearity

Multicollinearity occurs when two or more independent variables in the model are approximately determined by a linear combination of other independent variables in the model. Multicollinearity can make the predictor variables redundant in some cases. Of the 50 candidate predictor variables, 48 are a linear combination of the current GPS-IPW value and one of the half hour interval values between 0.5 and 24 hours. Therefore there could be some multicollinearity of the independent variables.

It is common to evaluate a scree plot to determine how many predictors should be included in a model. The scree plot is a graphical repre-

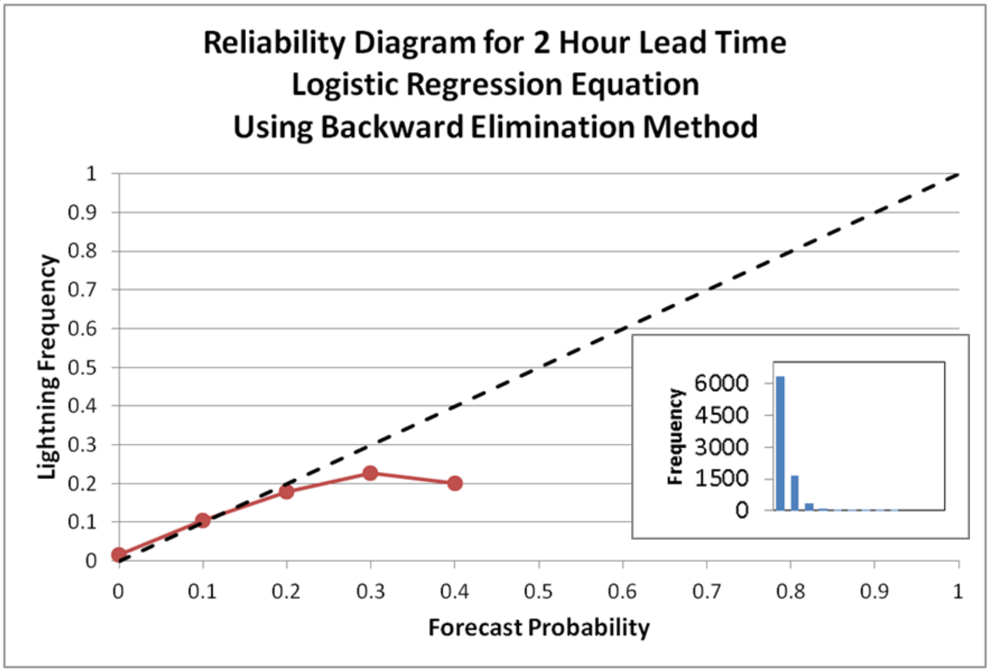


Figure 6. Reliability diagram for the 2-hour forecast equation using the backward elimination method of variable selection. The dashed diagonal line represents perfect reliability and the red curve represents the reliability of the 2-hour forecast equation. The histogram in the lower right shows the frequency of the number of observations in each probability range. The x-axis of the histogram is the same as the forecast probability axis on the reliability diagram.

sentation of the incremental variance accounted for by each predictor in the model. Generally, the number of predictors that should be in the model is limited to those with an eigenvalue > 1*. A predictor with an eigenvalue of < 1 means the variable is not contributing an average amount to explaining the variance in the model (Walker and Maddan 2009). Based on this analysis and the results of the above ROC diagram, Dr. Huddleston developed new equations so she could examine the differences in the performance metrics. A scree plot for the 2-hour forecast equation for the backward elimination method of predictor selection is shown in Figure 7.

Dr. Huddleston examined the eigenvalues for the 2-hour and 9-hour forecast models using both predictor selection methods to further reduce the number of predictors in the equations. The number of predictors was reduced to two in each model. One of the predictors that remained in all models was the Objective Lightning Probability tool output.

*In factor analysis, a component's eigenvalue is the amount of variance the component explains. The major reason for this is the eigenvalue's definition as a weighted sum of squared correlations. However, the actual variance of the component scores also equals the eigenvalue. Thus in factor analysis the "factor variance" and "amount of variance the factor explains" are equal. Therefore the two phrases are often used interchangeably, even though conceptually they stand for very different quantities (Darlington 2012).

Equation Performance

The performance metrics for the equations perform differently depending on the lightning threshold index value chosen. The accuracy measures of probability of detection (POD), hit rate (HR), false alarm rate (FAR), Kuipers skill score (KSS) and Operational Utility Index (OUI) were chosen to match the performance measures used in a previous GPS-IPW study performed at KSC by Kehrer et al. (2008). The OUI is a locally developed performance metric used to emphasize personnel safety (Kehrer et al. 2008). The equation for OUI is [(3 x POD) + (2 x KSS) - (1 x FAR)]/6. Performance metrics for each model included the HR, FAR, POD, KSS, OUI, and bias at various lightning index thresholds. The lightning index threshold is the point at which lightning is predicted when the model probability falls above the threshold and not predicted when model probability falls below the threshold (Kehrer et al. 2008). To maximize the OUI, Dr. Huddleston had to reduce the lightning threshold index to 0.05, but even then the OUI was not as good as the model by Kehrer et al. (2008) for either the 2-hour or 9-hour forecast model. Performance metrics for the 2-hour forecast using the forward, backward, and two-predictor forward and back-

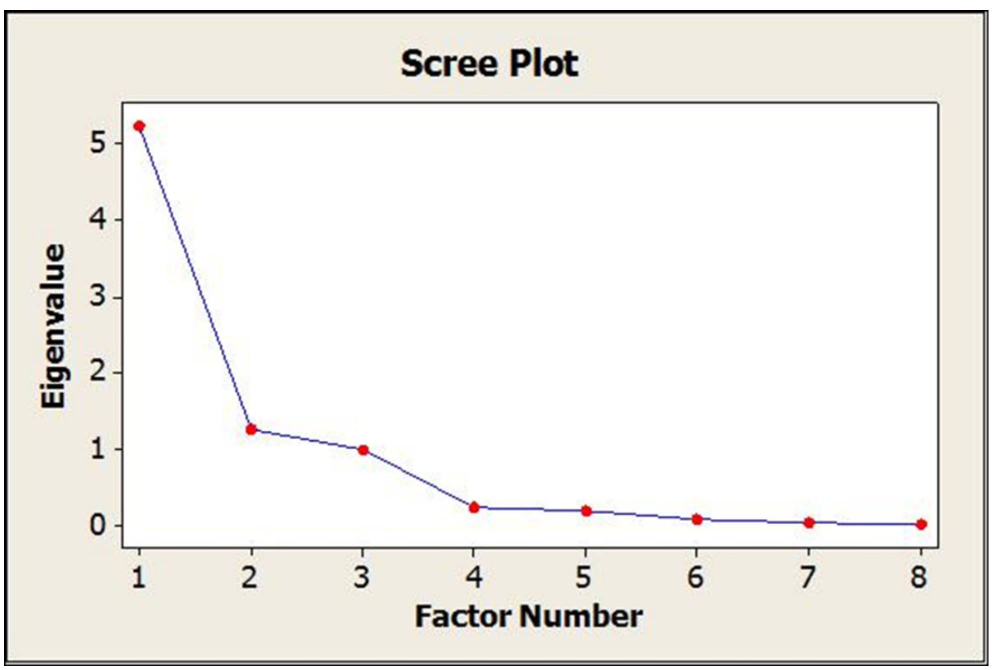


Figure 7. Scree plot for each predictor in the 2-hour forecast regression equation using the backward elimination method of predictor selection.

ward selection methods and lightning index values are shown in Table 3. Performance metrics for the 9-hour forecast were similar and will be shown in the final report.

Conclusions

Dr. Huddleston investigated the utility of using GPS-IPW and output from the AMU Objective Lightning Probability tool to predict the probability of lightning occurrence at the half-hour resolution of the GPS-IPW output. Using the proven methodology of multiple logistic regression to evaluate the binary predictand, she evaluated a total of 50 candidate predictors to determine a subset of predictors that affected the predictand. The forward selection method and the backwards elimination method were used to select the predictor.

Although previous studies showed the GPS-IPW values to be promising in forecasting lightning, the results of this study did not find them to be very useful. This is likely because the level of noise in the Objective Lightning Probability tool, which dominates the regression equations, is greater than the increase in predictive capability offered by the inclusion of the GPS-IPW data. The Objective Lightning Probability tool was designed to predict the probability of lightning for the day between the hours of 0700 to 2400 local time. The equations used in the Objective Lightning Probability tool were not designed for the temporal resolution of one half hour. As a result, this study demonstrated that inclusion of the GPS-IPW data into the AMU objective lightning probability as a predictor in the equations did not improve model performance.

Final Report

Dr. Huddleston began writing the final report.

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

Table 3. Comparison of accuracy measurements, skill scores, and bias for the 2-hour forecast equations, using the backward elimination method, forward selection method, and the truncated forecast equations using the backward elimination method and forward selection method. The scores are shown for a range of lightning index threshold values.

Index	Selection Method	Hit (%)	POD (%)	FAR (%)	KSS (%)	OUI (%)	Bias
0.00	Backward	4.2	100	95.8	0.0	34.0	32.91
	Forward	4.2	100	95.8	0.0	34.0	23.91
	2 predictor back	4.2	100	95.8	0.0	34.0	23.91
	2 predictor fwd	4.2	100	95.8	0.0	34.0	23.91
0.05	Backward	76.9	72.4	87.9	49.5	38.1	5.98
	Forward	76.1	76.7	87.7	52.8	41.3	6.24
	2 predictor back	74.9	74.7	88.5	49.7	39.2	6.49
	2 predictor fwd	73.9	78.4	88.5	52.1	41.8	6.81
0.1	Backward	87.8	42.9	84.5	32.7	18.3	2.77
	Forward	87.2	44.0	85.1	33.1	18.9	2.95
	2 predictor back	87.1	43.2	85.4	32.2	18.1	2.95
	2 predictor fwd	86.6	46.3	85.2	34.7	20.5	3.12
0.2	Backward	94.2	12.8	79.9	10.6	-3.4	0.64
	Forward	94.5	11.1	79.4	9.2	-4.6	0.54
	2 predictor back	94.6	7.7	83.0	6.0	-8.0	0.45
	2 predictor fwd	94.3	11.9	80.0	9.9	-4.1	0.60
0.3	Backward	95.4	3.1	81.7	2.5	-11.2	0.17
	Forward	95.5	3.4	74.5	3.0	-9.7	0.13
	2 predictor back	95.6	1.1	85.7	0.8	-13.4	0.08
	2 predictor fwd	95.5	2.8	76.8	2.4	-10.6	0.12
0.32	Backward	95.4	1.7	86.7	1.2	-13.2	0.13
	Forward	95.6	2.6	76.9	2.2	-10.8	0.11
	2 predictor back	95.6	0.9	85.7	0.6	-13.7	0.06
	2 predictor fwd	95.6	2.6	76.3	2.2	-10.7	0.11
0.4	Backward	95.6	0.3	94.1	0.1	-15.5	0.05
	Forward	95.7	1.1	81.0	0.9	-12.6	0.06
	2 predictor back	95.7	0.6	84.6	0.4	-13.7	0.04
	2 predictor fwd	95.7	0.3	91.7	0.2	-15.1	0.03
0.5	Backward	95.7	0.0	N/A	-0.1	N/A	0.03
	Forward	95.7	0.0	N/A	-0.1	N/A	0.02
	2 predictor back	95.8	0.0	100.0	-0.1	-16.7	0.01
	2 predictor fwd	95.8	0.0	100.0	-0.06	-16.7	0.01

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

The ER and WFF would benefit greatly from high-resolution mesoscale model output to better forecast a variety of unique weather phenomena. Global and national scale models cannot properly resolve important local-scale weather features at each location due to their horizontal resolutions being much too coarse. A properly tuned model at a high resolution would provide that capability. This is the first phase in a multi-phase study in which the WRF model will be tuned individually for each range. The goal of this phase is to tune the WRF model based on the best model resolution and run time while using reasonable computing capabilities. The ER and WFF supported tasking the AMU to perform a number of sensitivity tests in order to determine the best model configuration for operational use at each of the ranges.

Model Test Cases for WFF

While Dr. Watson was on maternity leave, Dr. Bauman continued to run model test cases for WFF using data from 1-30 April 2012 and 1-14 November 2011. The model configurations are:

- Configuration 1: Advanced Research WRF (ARW) core, 2 km outer domain and 0.67 km inner domain, Lin microphysics scheme, Yonsei University PBL scheme (Lin-Yonsei),
- Configuration 2: ARW core, 2 km outer domain and 0.67 inner domain, Ferrier microphysics scheme, Yonsei University PBL scheme (Ferrier-Yonsei), and
- Configuration 3: ARW core, 2 km outer domain and 0.67 inner domain, WDM6 microphysics scheme, Yonsei University PBL scheme (WDM6-Yonsei).
- Configuration 4: Non-hydrostatic Mesoscale Model (NMM) core, 3 km outer domain and 1 km inner domain, Ferrier microphysics scheme, Mellor-Yamada-Janjic (MYJ) planetary boundary layer (PBL) scheme (NMM 3/1).

Ms. Crawford and Ms. Shafer continued to process the model output generated by Dr. Bauman. They calculated verification statistics for the April model runs using hourly surface and sounding observations.

On her return from maternity leave, Dr. Watson finished running four of the NMM forecasts for 6-7 November 2011 and then calculated the verification statistics. When examining the model output from April 2012, Dr. Watson noticed that an inadvertent change had been made to a run-time parameter in some of the completed runs. She reran 30 model forecasts and recomputed the verification statistics. Dr. Watson also noticed erroneous data in the METAR observations for both April and November. At each of the sites, there were many instances in which both the wind direction and wind speed were recorded as 0. The data looked suspect to Dr. Watson, therefore she removed them from the observational dataset.

Test Case Verification

Dr. Watson recomputed the verification statistics for the temperature and wind data at each METAR site once the erroneous data were removed. The recalculated Mean Error (ME) and Root Mean Square Error (RMSE) data were then used to repopulate the color-coded Good-Bad-Neutral (GBN) tables that Ms. Crawford and Ms. Shafer created. The GBN tables show which model configuration performed the best and worst. A 'good' rating indicates that the model configuration had the lowest ME or RMSE values among the different configurations. A 'bad' rating had the highest ME or RMSE values and 'neutral' fell in the middle.

Table 4 contains GBN values for the combined 30-day (April) ME and RMSE of the three ARW configurations at each of the seven METAR and four buoy sites. Table 5 contains the combined seven-day (1-7 April) ME and RMSE GBN values for the three ARW and one NMM configuration at three of the METAR sites. The NMM was only run for 1-7 April and, therefore, not compared to the 30-day results for the three ARW configurations. Results indicate that for 1-30 April, Configuration 1 (Lin-Yonsei) outperformed the other configurations, while Configuration 4 (NMM) performs the best for 1-7 April.

Table 4. GBN totals from the ME and RMSE values for the three ARW configuration forecasts at seven METAR and four buoy sites during 1-30 April 2012 in the WFF vicinity.

1-30 April 2012 Totals			
	Good	Neutral	Bad
Configuration 1	45	13	22
Configuration 2	27	29	23
Configuration 3	9	35	36

Table 5. GBN totals from the ME and RMSE values for the three ARW and one NMM configuration forecasts at three METAR sites from 1-7 April 2012 in the WFF vicinity.

1-7 April 2011 Totals			
	Good	Neutral	Bad
Configuration 1	3	15	6
Configuration 2	6	11	7
Configuration 3	0	18	6
Configuration 4	15	3	5

The same GBN values are shown for 1-14 and 1-7 November in Tables 6 and 7, respectively. Again, the NMM was only run for 1-7 November and, therefore, not compared to the 14-day results for the three ARW configurations. Configuration 2 (Ferrier-Yonsei) performs the best for 1-14 November, while the Configuration 4 (NMM) performs the best for the 1-7 November period. It should be noted that differences in ME and RMSE for all configurations were small. A detailed breakdown of the statistical differences will be provided in the final report.

Dr. Watson compared precipitation forecasts from all model runs. She compared the 24-hour forecast accumulated rainfall to the 24-hour accumulation of observed rain using the National Centers for Environmental Prediction (NCEP) Stage-II analysis data. Results (not shown) indicate that Configuration 2 (Ferrier-Yonsei) produced the best precipitation forecast.

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

Table 6. GBN totals from the ME and RMSE values for the three ARW configuration forecasts at seven METAR and four buoy sites during 1-14 November 2011 in the WFF vicinity.

1-14 November 2011 Totals			
	Good	Neutral	Bad
Configuration 1	18	13	25
Configuration 2	26	15	15
Configuration 3	12	28	16

Table 7. GBN totals from the ME and RMSE values for the three ARW and one NMM configuration forecasts at three METAR sites from 1-7 November 2011 in the WFF vicinity.

1-7 November 2011 Totals			
	Good	Neutral	Bad
Configuration 1	4	14	6
Configuration 2	0	20	4
Configuration 3	6	10	7
Configuration 4	15	1	8

AMU ACTIVITIES

AMU Operations

AMU Tasking

In preparation for the upcoming AMU Tasking meeting, AMU team members contacted and met with customers to determine possible tasks for the next year. The customers and the AMU submitted tasks to Dr. Huddleston. After receiving all proposals, the AMU staff prepared responses including the estimated time to complete each task and the proposed deliverables. Dr. Huddleston scheduled the tasking meeting on 16 November.

Visitors

The AMU team attended a meeting with the KSC Weather Office, the and Dr. Luciana Pires of the Department of Science and Aerospace Technology in Sao Jose dos Campos, Brazil. Dr. Pires was interested in collaborating with NASA for her post-doctoral research at the University of Georgia in the area of atmospheric modeling. The group provided with several ideas for her to pursue.

Mr. Paul O'Brien, the new Lightning Advisory Panel (LAP) member, and Mr. Joe Mazur of Aerospace Corporation visited the AMU to tour the lab and discuss technology transition of weather research results to operations.

The AMU team attended the presentation given by the Plymouth State University summer interns Colt Sholton and Kevin Lupo and their advisor, Dr. Jim Koermer. Their work was a continuation research being done at the AMU over the last few summers to improve 45 WS convective wind forecasts.

Dr. Bauman presented an overview briefing of the AMU to the new AMU co-liaisons from the 45 WS: 1Lt Schubeck and Mr. Craft. They were particularly interested in the AMU tasking process. All AMU team members attended.

Conferences and Training

Dr. Bauman and Ms. Shafer each prepared and submitted an abstract to the 2013 American Meteorological Society Meeting in Austin, Texas. Both were accepted for oral presentation. Dr. Bauman and co-author Mr. Flinn of the 45 WS submitted an abstract titled "Integrating Wind Profiling Radars and Radiosonde Observations with Model Point Data to Develop a Decision Support Tool to Assess Upper-Level Winds for Space Launch". Ms. Shafer and co-author Mr. Brock of the 30 OSS submitted an abstract titled "Determining the Probability of Violating Upper-Level Wind Constraints for the Launch of Minuteman III Ballistic Missiles at Vandenberg Air Force Base". Ms. Shafer is also a co-author with four members of the 45 WS on an abstract titled "Communicating the Threat of a Tropical Cyclone to the Eastern Range". That abstract was submitted by the 45 WS.

Dr. Huddleston and the AMU staff planned, set up and manned the AMU booth at the KSC Innovation Expo on 6 September. They met people from other groups on KSC who indicated the AMU may be able to help them with some of their projects that depend on weather.

All AMU team members attended the Day Of Launch Working Group technical interchange meeting at KSC on 19-20 September.

Security

Dr. Bauman and Ms. Shafer submitted the monthly Asset Import Table spreadsheet to KSC IT Security. This is a new recurring IT Security requirement.

Equipment and Software

Mr. Magnuson from ENSCO's Aerospace Sciences and Engineering Division upgraded the AMU and Range Weather Operations Advanced Weather Information Processing System (AWIPS). The upgrade included the high resolution Rapid Refresh model used to support AMU-developed tools

Dr. Bauman, Dr. Watson and Mr. Magnuson surveyed potential locations for the two new AMU modeling clusters with Mr. Brown and Ms. Wilson of NASA KSC. They selected a server room located in the KSC Emergency Operations Center in the Launch Control Center building.

Dr. Watson and Dr. Bauman had a telecon with Mr. Case and Mr. Zavodsky of the Short-term Prediction Research and Transition Center (SPoRT) to discuss using SPoRT datasets in future AMU modeling work. Mr. Case provided information and articles about several datasets that can be used to initialize the WRF model for better results. Mr. Zavodsky provided information on his work with data assimilation that will assist the AMU in the next phase of the Range Modeling task. Through the course of the telecon, the AMU learned of a NASA-proprietary WRF model (NU-WRF) developed at SPoRT that may be of use in future AMU modeling tasks. With Mr. Case's help, Dr. Watson got in touch with the NASA/NU-WRF representative and obtained permission to use the software.

Dr. Bauman submitted a paper titled "A New Technique to Display and Assess Upper-Level Wind Forecasts on Day-of-Launch using Commercial Off-the-Shelf Software" to the 2012 Research and Technology (R&T) Annual Report for Kennedy Space Center's technology projects. The report, with its wide distribution, provides NASA, academia and industry with a broad overview of KSC's accomplishments in technology development.

Dr. Bauman entered an abstract in the 2012 Best of KSC Software Award competition for the Assessing Upper-level Winds on Day-of-Launch task software. By entering this competition, Dr. Bauman was required to submit a New Technology Report which is titled "Development of a Decision Support Tool to Assess Upper-Level Winds for Space Launch".

AMU Chief's Technical Activities (Dr. Huddleston)

Dr. Huddleston updated VBA code to automatically collect model output statistics in an Excel spreadsheet for Mr. McAleenan of the 45 WS. They use this spreadsheet to calculate skill scores of the GFS model for predicting precipitation and lightning from Day-1 to Day-7 and to compare these skill scores to those from forecasts made by 45 WS operational personnel.

Dr. Huddleston attended the Lightning Advisory Panel meeting on July 25-26.

Dr. Huddleston conducted some calibration runs for the Infrared Thermometer (IRT) IPW project with Dr. Merceret. This project uses inexpensive commercially available IRTs to measure total column water vapor in the KSC/CCAFS area as outlined in Mims et al. (2011).

Dr. Huddleston reviewed two proposals for the NASA Experimental Program to Stimulate Competitive Research (EPSCoR) program titled "Understanding the Atmospheres of Hot Earths and the Impact on Solar System Formation," and "Research Portfolio for Inaugural Aerospace Science Doctoral Program."

Dr. Huddleston completed and submitted a review of a NASA EPSCoR project at University Of Alaska Fairbanks to improve the accuracy of wildfire weather models by combining meteorological measurements, imaging spectrometers, and synthetic aperture radar with observations of burn activity and intensity.

Dr. Huddleston completed a Princeton University online statistics course available through Coursera to learn the R statistical software package for possible use in future AMU tasks.

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LIST OF ACRONYMS

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
AMPS	Automated Meteorological Profiling System
AMU	Applied Meteorology Unit
ARW	Advanced Research WRF
AUC	Area Under the Curve
AWIPS	Advanced Weather Information Processing System
CCAFS	Cape Canaveral Air Force Station
CSR	Computer Sciences Raytheon
EDT	Eastern Daylight Time
ER	Eastern Range
ESRL	Earth System Research Laboratory
FAR	False Alarm Rate
FSU	Florida State University
FTP	File Transfer Protocol
GBN	Good Bad Neutral
GFS	Global Forecast System
GPS	Global Positioning System
GUI	Graphical User Interface
HR	Hit Rate
HTTP	Hypertext Transfer Protocol
IPW	Integrated Precipitable Water
IRT	Infrared Thermometer
IT	Information Technology
JSC	Johnson Space Center
KSC	Kennedy Space Center
KSS	Kuiper Skill Score
LAP	Lightning Advisory Panel
LWO	Launch Weather Officer
MCO	Orlando International Airport
ME	Mean Error
MIDDS	Meteorological Interactive Data Display System
MLB	Melbourne International Airport
MSFC	Marshall Space Flight Center
NAM	North American Mesoscale model
NCEP	National Centers for Environmental Prediction
NLDN	National Lightning Detection Network
NMM	Non-hydrostatic Mesoscale Model (WRF)
NOAA	National Oceanic and Atmospheric Administration
NWS MLB	National Weather Service in Melbourne, Fla.
OUI	Operational Utility Index
POD	Probability of Detection
POR	Period of Record
RAP	Rapid Refresh model
RMSE	Root Mean Square Error
ROC	Relative Operating Characteristics
RUC	Rapid Update Cycle model
SMC	Space and Missile Center
SPoRT	Short-term Prediction Research and Transition Center
SS	Brier Skill Score
URL	Uniform Resource Locator
USAF	United States Air Force
VAFB	Vandenberg Air Force Base
VBA	Visual Basic for Applications
WFF	Wallops Flight Facility
WRF	Weather Research and Forecasting Model
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 KSC/GP-B/F. Merceret
NASA KSC/GP-B/
L. Huddleston
NASA KSC/GP-B/J. Wilson
NASA KSC/GP-B/K. Cummings
NASA KSC/GP-G4/R. Brown
NASA KSC/LX-D1/M. Galeano
NASA KSC/LX-S1/P. Nicoli
NASA KSC/SA/R. Romanella
NASA KSC/SA/B. Braden
NASA KSC/VA/A. Mitskevich
NASA KSC/VA-H/M. Carney
NASA KSC/VA-H1/B. Beaver
NASA KSC/VA-H3/
P. Schallhorn
NASA KSC/VA-2/C. Dovale
NASA KSC/VA-2/O. Baez
NASA KSC/VA-2/T. Dunn
NASA KSC/OP-MS/K. Boos
Analex Corp/Analex-20/
M. Hametz
NASA JSC/WS8/F. Brody
NASA MSFC/EV44/B. Roberts
NASA MSFC/EV44/R. Decker
NASA MSFC/EV44/H. Justh
NASA MSFC/ZP11/
G. Jedlovec
NASA MSFC/VP61/J. Case
NASA MFSC/VP61/G. Stano
NASA WFF/840.0/A. Thomas
NASA WFF/840.0/T. Wilz
NASA WFF/840.0/N. Kyper
NASA WFF/840.0/E. Thomas
NASA DFRC/RA/E. Teets
NASA LaRC/M. Kavaya
45 WS/CC/S. Cahanin
45 WS/DO/B. Belson
45 WS/DOR/M. McAleenan
45 WS/DOR/J. Smith
45 WS/DOR/M. Howard
45 WS/DOR/F. Flinn
45 WS/DOR/ T. McNamara
45 WS/DOR/J. Tumbiolo
45 WS/DOR/K. Winters
45 WS/DOR/D. Craft
45 WS/DOU/W. Whisel
45 WS/SY/M. Lewis
45 WS/SYA/J. Saul
45 WS/SYR/W. Roeder
45 RMS/CC/V. Beard
45 RMS/RMRA/R. Avvampato
45 SW/CD/G. Kraver
45 SW/SELR/K. Womble
45 SW/XPR/R. Hillyer
45 OG/CC/D. Schiess
45 OG/TD/C. Terry
CSC/M. Maier
CSR 1000/S. Griffin
CSR 3410/C. Adams
CSR 3410/R. Crawford
CSR 3410/D. Pinter
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
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M. Babcock
NWS Melbourne/B. Hagemeyer
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 Southern Region HQ/"W/SR3"/D. Billingsley
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
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ENSCO, Inc./J. Clift
ENSCO, Inc./E. Lambert
ENSCO, Inc./A. Yersavich
ENSCO, Inc./S. Masters