Applied Meteorology Unit (AMU) Quarterly Report

31 July 2012 Third Quarter FY-12 Contract NNK06MA70C DRL-003 DRD-004

In this issue:

Atlas 5 launching a payload for the National Reconnaissance Office 20 June 2012 (http://www.spaceflightnow.com/atlas/av023/remotes/index2.html)

Launch Support

Dr. Watson, Ms. Shafer and Dr. Huddleston supported the Atlas 5 launch on 5 May.

Ms. Crawford, Ms. Shafer and Dr. Huddleston supported the Falcon 9 launch on 22 May.

Ms. Shafer and Dr. Huddleston supported the Atlas 5 launch on 20 June.

Dr. Bauman and Ms. Wilson supported the Delta 4 launch on 29 June

This Quarter's Highlights

The AMU team worked on six tasks for their customers:

- Dr. Bauman completed working 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 created and delivered a tool to help Vandenberg Air Force Base launch weather officers determine the probability of violating upper-level wind thresholds during launches.
- Dr. Bauman continued developing a capability for the NASA Launch Services Program and 45th Weather Squadron to assess model forecasts of upper-level winds .
- Dr. Huddleston began research to determine whether Global Position System precipitable water data could improve the lightning forecast when used with the AMU Objective Lightning Probability tool.
- With Dr. Watson on maternity leave, Dr. Bauman, Ms. Crawford and Ms. Shafer began testing high-resolution model configurations for Wallops Flight Facility to provide forecasters with more accurate depictions of the future state of the atmosphere.

ENSCO

1980 N. Atlantic Ave., Suite 830
Cocoa Beach, FL 32931
(321) 783-9735, (321) 853-8203 (AMU)

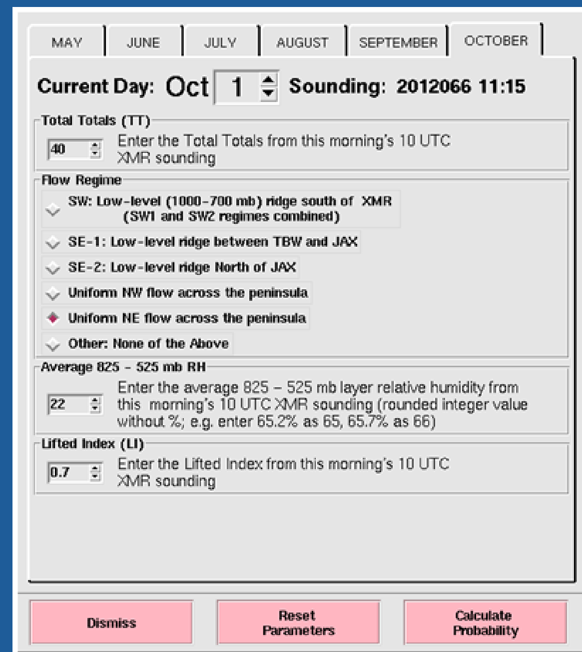
Quarterly Task Summaries

This section contains summaries of the AMU activities for the third quarter of Fiscal Year 2012 (April-June 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.

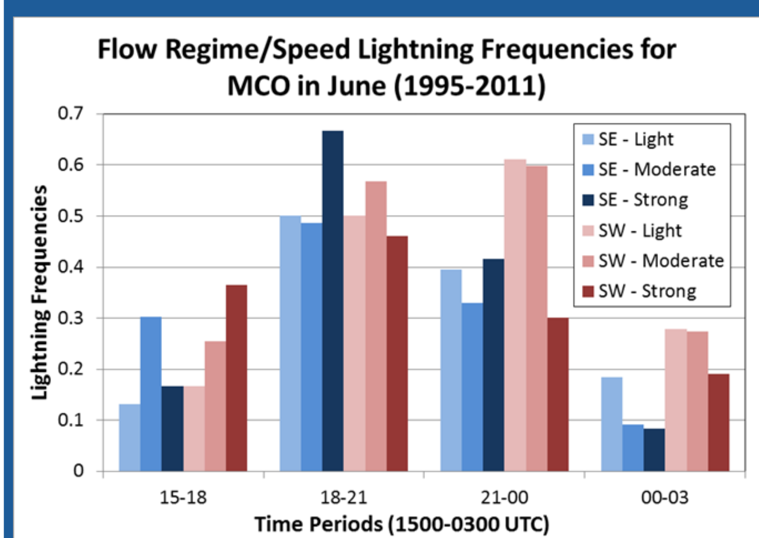
Objective Lightning Probability Forecast, Phase IV (Page 5)

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: Fixed several bugs in the Meteorological Interactive Data Display System (MIDDS) code that was incorrectly calculating stability parameters used in the tool. Started writing the final report, but was interrupted due to IT Security requirements.



Objective Lightning Probability Forecasts for East-Central Florida Airports (Page 6)



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.

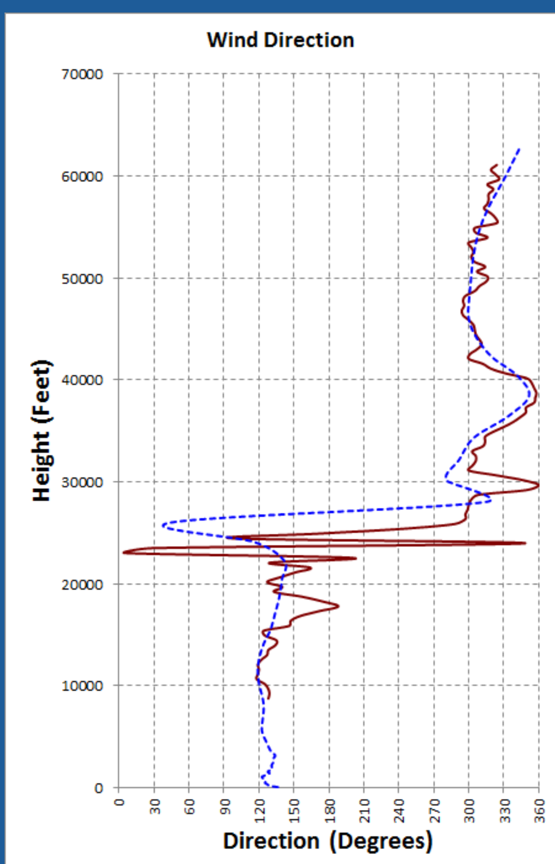
Accomplished: Reduced the period of record (POR) by six years to eliminate NLDN data collected before a system upgrade in 1994. Updated the variables created by NLDN data, and created new flow regimes stratified by wind speed. The equations developed after these modifications did not outperform those developed last quarter.

Quarterly Task Summaries
(continued)

Vandenberg AFB Upper-Level Wind Launch Weather Constraints (Page 8)

Purpose: Develop a tool to determine the probability of violating upper-level wind constraints to improve overall forecasts on the day of launch. This tool will allow the launch weather officers (LWOs) to evaluate upper-level thresholds for wind speed and wind shear constraints specific to Minuteman III ballistic missile operations at Vandenberg Air Force Base (VAFB).

Accomplished: Completed development of the Excel graphical user interface (GUI) to display current sounding data and calculate the probability of violation (PoV) for each launch constraint. Added Rapid Refresh (RAP) model forecast sounding data to provide wind forecast information for the LWOs on launch day. Began writing the final report.



Assessing Upper-level Winds on Day-of-Launch (Page 10)

Purpose: Develop a MIDDS-based or Excel-based 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 LWOs 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: Demonstrated the Excel GUI to the 45 WS LWOs. Obtained permission from the Kennedy Space Center (KSC) Weather Office to host the model point data on the NASA/KSC Spaceport Weather Data Archive website. Developed code in Excel to ingest and display 915 MHz profiler observations, radiosonde observations and model forecast data.

Quarterly Task Summaries
(continued)

Using Global Positioning System Integrated Precipitable Water Vapor to Forecast Lightning on KSC/Cape Canaveral Air Force Station (Page 14)

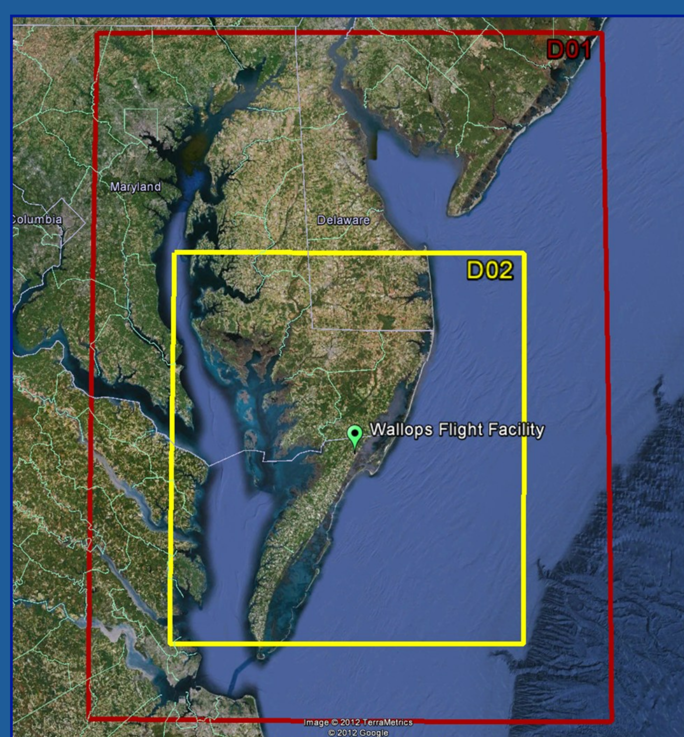
Purpose: Use output from the 45 WS Objective Lightning Probability tool, the current Global Positioning System (GPS) integrated precipitable water vapor (IPW) value, and the change in the GPS IPW value over the last 0.5 to 24 hours (in 30-minute increments) to determine the time period for the GPS IPW 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: Collected and processed all the data needed for the task and began exploratory data analysis.

Range-Specific High-Resolution Mesoscale Model Setup (Page 17)

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: Ran warm season test cases for WFF using several Weather Research and Forecasting (WRF) model domain configurations, and prepared the warm season output for verification using observations.



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 (LCC) and planning for daily ground operations on 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.

GUI Testing

At the beginning of the 2012 warm season, the AMU staff began running the AMU-developed Objective Lightning (Lambert and Wheeler 2005) and Severe Weather Forecast (Watson 2011) tools daily and discovered several errors in the Tool Command Language (Tcl)/Toolkit (Tk) code for the GUI in both tools.

Vertical Totals

The normal range of the vertical total (VT) stability parameter is 20-35 but the Objective Lightning tool was intermittently displaying a value of 0. Dr. Bauman, Ms. Shafer and Mr. Madison of Computer Sciences Raytheon (CSR) began troubleshooting the Objective Lightning tool Tcl/tk GUI code and tracked down the error to a file that was common between this and the Severe Weather Forecast tool. Both tools were creating a file with the same name to read in the date and time. However, the output format of the file being created was not the same. Once the file was created on any given day, it would not be overwritten. Therefore, if the Severe Weather Forecast tool was run first, the Objective Lightning Tool would input the date and time incorrectly causing the VT to be 0. To solve this dilemma, Mr. Madison updated the code in both tools such that each one created a different filename for the date and time. He then moved the updated Tcl/Tk GUI code from the AMU MIDDS to the operational MIDDS.

Lifted Index

The only month that directly outputs Lifted Index (LI) in the Objective Lightning tool is October, although other months use LI to calculate Thompson Index (TI). TI is calculated by subtracting LI from the K Index (KI). While running the Objective Lightning tool, Ms. Shafer noticed the TI value was always 0 while the TI value in the sounding was not 0. Ms. Shafer and Dr. Bauman discovered an error in the Objective Lightning tool Tcl/tk code that called the KI instead of LI to compute TI. Therefore, TI was being calculated by the difference of KI and KI, resulting in a value of 0. Ms. Shafer updated the code by changing KI to LI, which solved the problem. Mr. Madison again moved the updated Objective Lightning tool code to the operational MIDDS.

Relative Humidity

Dr. Bauman and Ms. Shafer noticed that the relative humidity (RH) value was the same in the Objective Lightning tool and the Severe Weather Forecast tool. This is unlikely because the Objective Lightning tool calculates the layer-averaged RH in the vertical layer from 825-525 mb and the Severe Weather Forecast Tool calculates layer-averaged RH in the vertical layer surface-700 mb. Upon review of the Tcl/Tk code, they found that both tools retrieved their respective layer-averaged RH values from the sounding and then wrote out a file containing the RH to be used later in each program. The error in the code was that both tools called the same file containing the layer-averaged RH but the file was only generated once on any given day. Therefore, the tool that was run first created the file that both tools then used for their RH values. Dr. Bauman changed the name of the output file in the Objective Lightning tool code, which solved the problem. After further testing, Mr. Madison moved the updated Objective Lightning tool code to the operational MIDDS.

Final Report

Dr. Bauman began writing the final report, but his progress was interrupted due to IT Security requirements. He will complete the final report in the next quarter. Once complete and approved by NASA, it will be posted 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 warm season months, defined as May-October.

New Period of Record

With approval from Mr. Volkmer and Mr. Sharp of NWS MLB, Ms. Crawford deleted warm season data from the six years 1989-1994, resulting in new 17-year period of record, 1995-2011. This was a result of information she learned from one of the presentations (Hodanish 2012) at Vaisala's International Lightning Meteorology Conference during the first week of April. The NLDN system underwent a major upgrade in 1994 (Cummins et al. 1998), causing researchers to not use data from before 1994. Dr. Ken Cummins provided her with 2°x2° grids containing NLDN detection efficiency (DE) correction values over the U.S. during 1994-1998 relative to 1999 DE, shown in Figure 1. The DE correction values are proportional to the DE in each grid cell. To normalize the flash

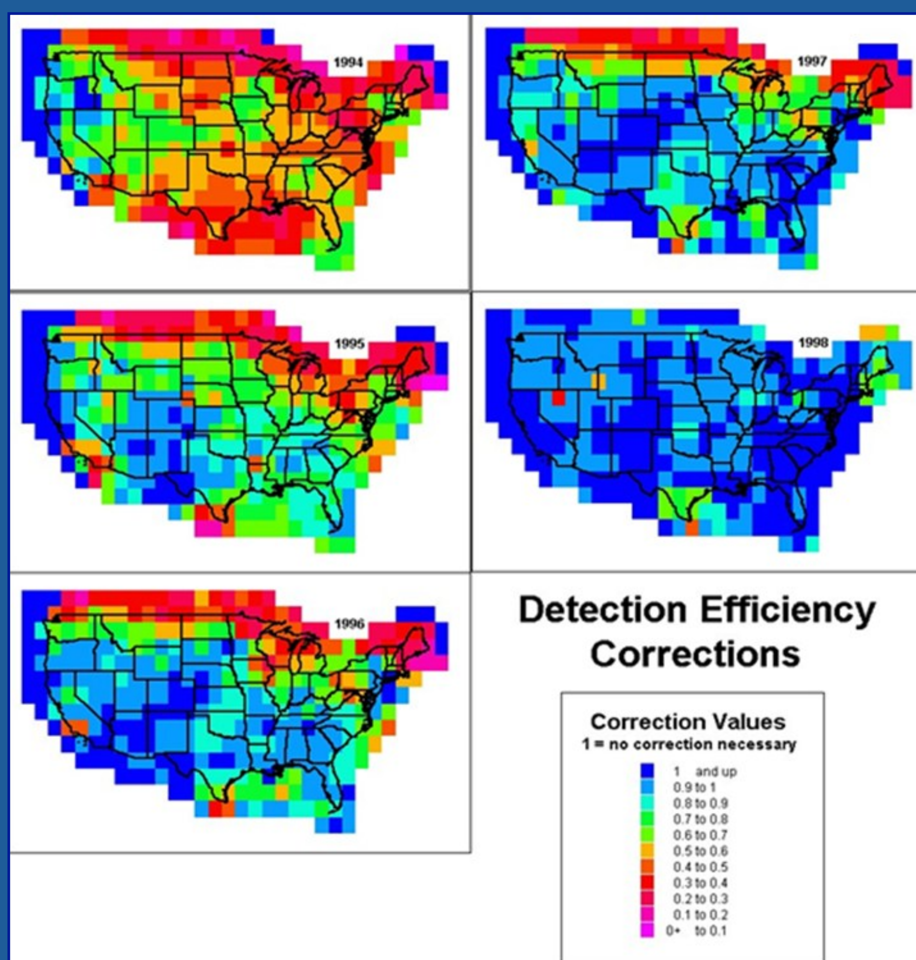


Figure 1. 1994-1998 NLDN DE corrections relative to 1999 values. The grid cell size is 2°x2° latitude/longitude (image created by Vaisala).

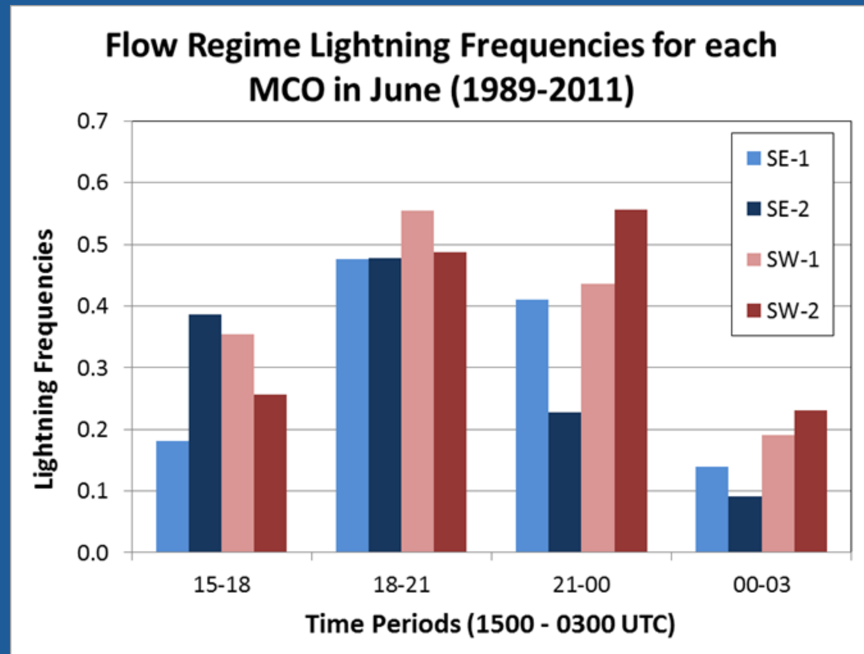
counts and make them consistent with 1999 performance, the number of strikes actually detected is divided by the DE correction for that year. For a DE correction < 1, this results in a larger number of strikes.

Since the forecast depends on whether lightning occurred and not the number of strikes, the DE corrections values in Figure 1 will not be used in this task. However, the low DE of 0.5-0.6 over Florida in 1994 could indicate strikes were missed by NLDN. This information led to the decision to use data from 1995 onward, when the DE correction values increased to ≥ 0.7 over Florida.

Updated Values

The change to the POR required Ms. Crawford to create new daily climatology values, flow regime probabilities, and development and verification data sets before creating new equations for Orlando International Airport (MCO). The new daily climatology and flow regime values are very similar to those for the previous POR, which were shown in previous AMU Quarterly Reports (Q1 and Q2 FY12).

Mr. Volkmer and Mr. Sharp suggested combining the low-level mean wind speed with the flow regimes may help improve the MCO forecast equation performance. Ms. Crawford created this new candidate predictor by stratifying each flow regime into speed ranges defined by Mr. Volkmer. She used the mean speed in the 1000-700 mb layer from the CCAFS 1000 UTC sounding to create two- and three-category speed ranges for each flow regime. For the two-category ranges, speeds < 10 kt were considered low and speeds ≥ 10 kt were considered high. For the three-category ranges, speeds < 6 kt were considered light, speeds ≥ 6 and ≤ 14 kt were considered moderate, and speeds > 14 kt were considered strong.



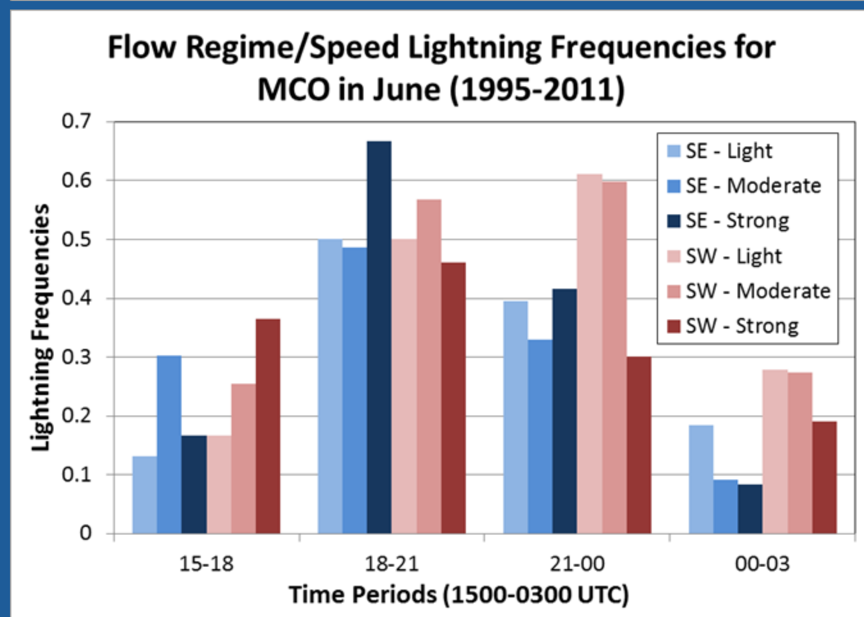


Figure 2. The frequencies of lightning occurrence for the southeast (SE) and southwest (SW) flow regimes for (top) the values of the previous POR and (bottom) the three-category ranges of light, moderate and strong flow.

Stratifying the data by flow regime and speed ranges reduced the number of observations in each category. In order to increase the observations in each stratification, Ms. Crawford combined the two southeast (SE-1 and SE-2) and two southwest (SW-1 and SW-2) regimes into one regime each (SE and SW) before stratifying the flow regime data by speed category. The lightning frequencies for these two flow regimes and the three-speed category are shown in Figure 2. As an example, lightning occurred 67% of the time in the 1800-2100 UTC period when the flow regime was SE and the mean 1000-700 mb wind speed was in the strong range, or > 14 kt.

Equation Development and Testing

Ms. Crawford created and tested the May and June equations for MCO. The development data she used included the new flow regime and flow regime/speed candidate predictors. The predictors chosen for each equation in rank order are given in Table 1 (next page). Of the eight equations, TI was the most important predictor in six, and KI the most important predictor in the other two. Some form of the flow regime probabilities (FR Prob) was the second predictor in seven of the equations, Total Totals (TT) in one. All the predictors after the second was a mix of the mean RH in the 800-600 mb layer (800-600 MRH), the daily climatology (Daily Climo), VT and 1-day persistence.

Table 1. The final predictors for the May and June MCO equations, in rank order of their reduction in residual deviance.

Time Period	***May***	***June***
1500-1800	TI, FR Prob 3-Spd	TI, FR Prob 2-Spd, 1-Day Persistence, Daily Climo
1800-2100	TI, TT, 800-600 MRH, Daily Climo	TI, FR Prob 2-Spd, 1-Day Persistence
2100-0000	KI, FR Prob 3-Spd, Daily Climo, VT, 1-day Persistence	TI, FR Prob 3-Spd, VT
0000-0300	TI, FR Prob 3-Spd	KI, FR Prob, VT

Table 2 contains the Brier Skill Score (SS) values showing the skill of the new May and June MCO equations relative to the other forecast methods for the equations. For comparison, Table 2 also contains the SS values of the equations developed from the original POR and shown in the last AMU Quarterly Report (Q2 FY12). Positive values indicate the equations had more skill than the corresponding forecast method, and negative values indicate less skill. All equations outperformed 1-day persistence, but results for the daily climatology and flow regime probability were still mixed. Values with magnitudes within 10% of 0, positive or negative, could indicate that the equations performed similarly to the corresponding forecast method.

In the previous set of May equations, four values met this criterion for the later time periods. The new equations had the same overall result for the same forecast benchmarks, but for the first and last time periods. The previous June equations also had four low values for the first and last periods. The new June equations had five low values: one in the second time period for the daily climatology and all four time periods for the flow regime probability. Although the values were slightly different, the overall result is that the equations developed from the new POR with the new flow regime candidate predictors did not show improved performance over the previous equations.

Table 2. The percent improvement (positive) or degradation (negative red font) in skill of the MCO equations over the forecast benchmarks of persistence, daily climatology and flow regime probabilities. These scores were calculated using the verification data set for each month. Cells shaded in yellow contain values within 10% of 0.

Month	***POR***	***Forecast Benchmark***	***15-18***	***18-21***	***21-00***	***00-03***
May	1989-2011	1-Day Persistence	43	12	34	41
		Daily Climatology	13	25	7	1
		Flow Regime Probability	18	23	3	-4
	1995-2011	1-Day Persistence	18	41	33	36
		Daily Climatology	4	20	11	2
		Flow Regime Probability	9	19	14	1
June	1989-2011	1-Day Persistence	37	46	47	35
		Daily Climatology	10	18	24	8
		Flow Regime Probability	-2	12	14	7
	1995-2011	1-Day Persistence	51	47	55	53
		Daily Climatology	14	0	16	14
		Flow Regime Probability	5	4	0	7

Status

Based on the May and June equation test results, Ms. Crawford will contact Mr. Volkmer at NWS MLB for guidance on how best to continue the task.

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.

Vandenberg AFB Upper-Level Wind Launch Weather Constraints (Ms. Shafer)

The 30th Operational Support Squadron Weather Flight (30 OSSWF) provides comprehensive weather services to the space program at VAFB in California. One of their responsibilities is to monitor upper-level winds to ensure safe launch operations of the Minuteman III ballistic missile. The 30 OSSWF tasked the AMU to analyze VAFB sounding data with the goal of determining the PoV for their upper-level thresholds of wind speed and shear constraints specific to this launch vehicle, and to develop a tool that will calculate the PoV of each constraint on the day of launch.

Ms. Shafer developed the interactive GUI for this project in Microsoft Excel using Visual Basic for Applications (VBA). The GUI displays the critical sounding data easily and quickly for the LWOs on the day of launch. This tool will replace the existing one used by the 30 OSSWF, assist the LWOs in determining the probability of exceeding specific wind threshold values, and help to improve the overall forecast. See the previous

AMU Quarterly Report (Q2 FY12) for details on GUI development and use.

Although not part of the original task plan, Ms. Shafer and Mr. Brock discussed adding model sounding output data to the GUI. This will provide additional insight to the LWOs on launch day when determining if a wind constraint violation will occur over the next few hours. Mr. Brock agreed this would be valuable information, so Ms. Shafer added this to the tool. The RAP model was selected for the 30 OSSWF application. This model was developed for users needing frequently updated short-term weather forecasts. It replaced the Rapid Update Cycle (RUC) as the operational National Oceanic and Atmospheric Administration (NOAA) hourly-updated assimilation/modeling system at the National Centers for Environmental Prediction (NCEP) on 1 May 2012. The latest RAP sounding data are available from Iowa State University (http://mtarchive.geol.iastate.edu) every hour and normally updated by 1 hour and 45 minutes after the hour.

The RAP tab in the GUI, shown in Figure 3, displays two sounding profiles: one for wind speed and one for wind direction. Each graph displays the data for the current sounding profile plus 12 1-hour RAP forecast soundings. The RAP initialization time is based on the current UTC time.

Final Report

Ms. Shafer is writing the final report and will complete it in the next Quarter. Once complete and approved by NASA, it will be posted on the AMU website at http://science.ksc.nasa.gov/amu/.

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

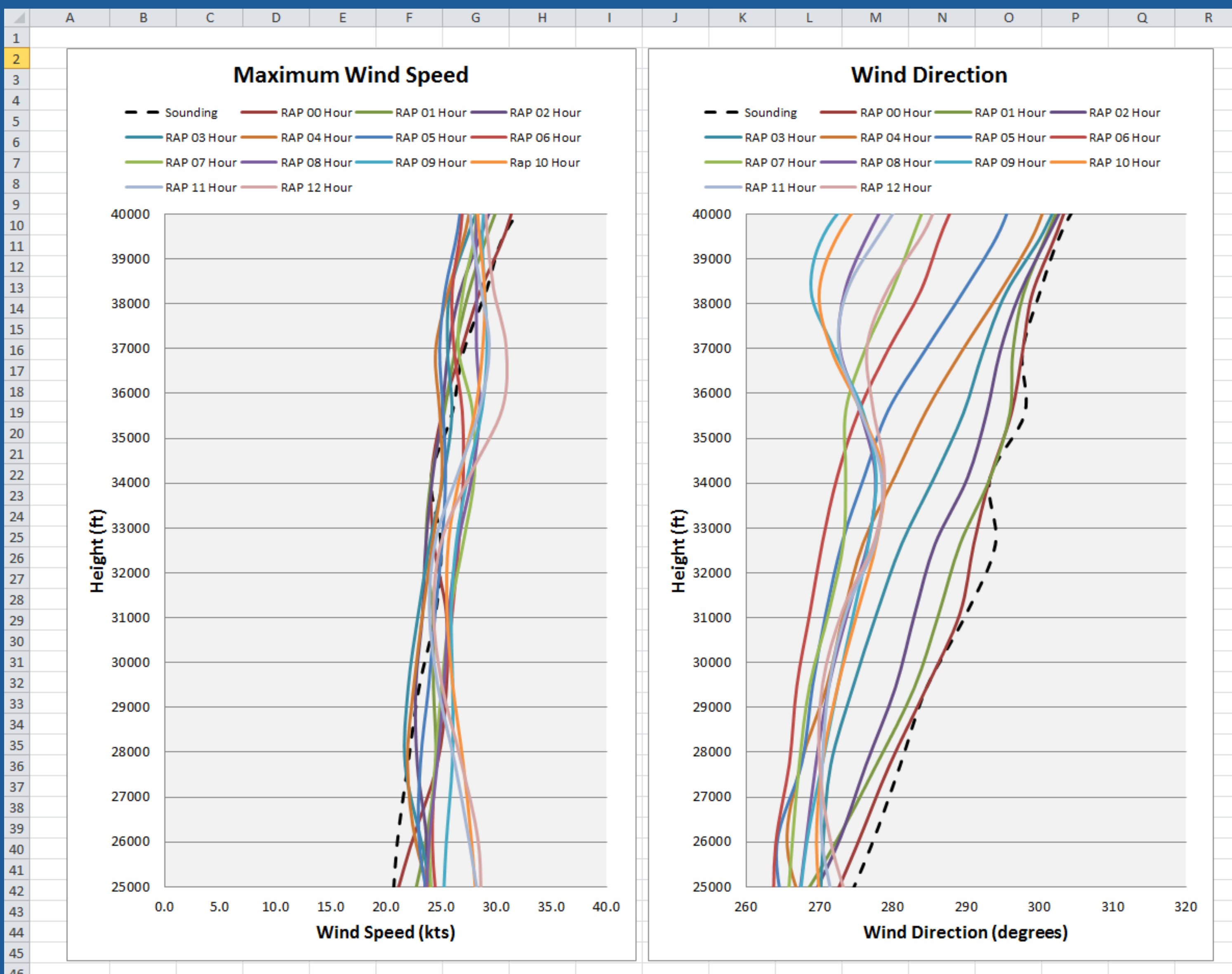


Figure 3. Screen shot of the RAP tab in GUI showing the observed (dashed black line) and model forecast (solid lines) profiles of wind speed (left) and direction (right).

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), RUC and Global Forecast System (GFS) models to assess the performance of these models.

Data Availability

At the beginning of this task, Mr. Wheeler determined the model point data for the CCAFS sounding (XMR) located at the Iowa University Archive Data Server (http://mtarchive.geol. iastate.edu) was in a format that can be ingested into Excel. When Dr. Bauman demonstrated the initial version of the GUI to the LWOs for feedback, Mr. McAleenan of the 45 WS asked Dr. Bauman if he had tested data acquisition on the 45 Space Wing (SW) network because the 45 SW has more stringent restrictions to websites than the NASA network. Upon testing, Dr. Bauman discovered that access to the Iowa State University Archive Data Server was restricted by the 45 SW. To overcome this restriction, Dr. Bauman received permission from the KSC Weather Office to have the model point data retrieved from Iowa State by KSC and hosted on the NASA/KSC Spaceport Weather Data Archive web site (http://trmm.ksc.nasa.gov). The data could then be acquired via File Transfer Protocol (FTP) on the 45 SW network.

While coordinating the hosting of model point data on the NASA/KSC Spaceport Weather Data Archive website, Dr. Bauman was told the website and its uniform resource locator (URL) was changing because NASA would no longer permit data transfer by FTP due to security issues. However, the new NASA/KSC website (http://wxarchive.ksc.nasa.gov), called the Spaceport Weather Archive, will allow data transfer via Hypertext Transfer Protocol (HTTP). When the new website is complete, Dr. Bauman will update the Excel VBA scripts to invoke HTTP instead of FTP to transfer the data into the Excel GUI described in the previous AMU Quarterly Report (Q2 FY12).

On 1 May 2012 beginning with the 1200 UTC model run, NCEP changed the RUC model to the RAP model. Dr. Bauman updated the Excel VBA scripts that retrieved the RUC model point data to account for the model change so the GUI will retrieve, process and display the RAP model point data.

Excel GUI

For this quarter, Dr. Bauman had six primary goals for the GUI development:

- Add 915 MHz wind profiler observations,
- Add AMPS observations,
- Add model initialization data,
- Add model forecast data,
- Test the VBA scripts, and
- Develop a point-and-click user interface.

915 MHz Wind Profiler

Dr. Bauman developed code in Excel VBA to ingest and format the 915 MHz wind profiles from the Spaceport Weather Data Archive to supplement the 50 MHz wind profiler observations below 9,000 ft. The 915 MHz profiler files are in American Standard Code for Information Interchange (ASCII) format and were ingested into Excel as shown in Figure 4a. The VBA code then removes all unneeded parameters and reformats the profiler observations as shown in Figure 4b. Dr. Bauman's code quality controls the profiler observations by finding and replacing missing obser-

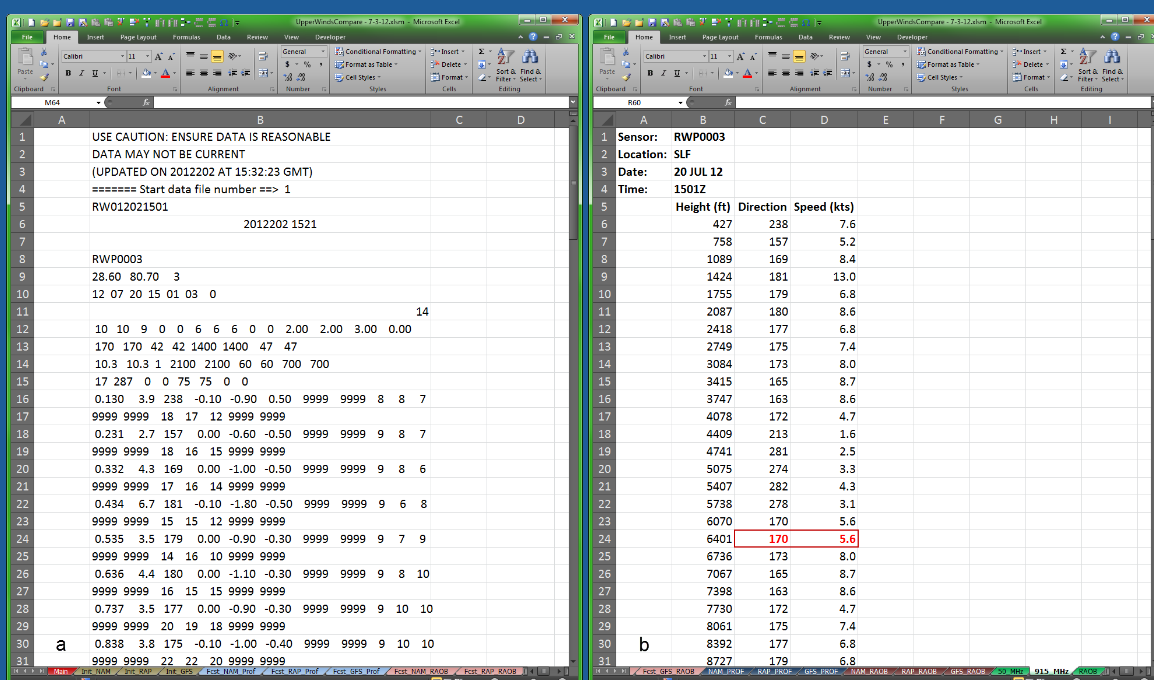


Figure 4. 915 MHz profiler observations (a) after being ingested into Excel and (b) after unneeded parameters were removed and data was quality controlled, displaying the sensor type and location, date, time, height, wind direction and speed. The red text surrounded by the red box in (b) shows that it was copied from the height below (line above) to replace missing data.

vations coded as "999" or "9999" with the observations from the height immediately below the missing data. The replaced observation is changed to red text to highlight the changes for the LWOs as shown by the text inside the red rectangle in Figure 4b.

From the reformatted 915 MHz profiler observations, another VBA script creates wind speed and direction profiles and overlays them on the existing 50 MHz profile charts as shown in Figure 5. The 915 MHz profiles are shown by the orange lines and the 50 MHz profiles are shown by the red lines. The 915 MHz profiles are plotted from the first available observation height of approximately 400 ft to the bottom of the 50 MHz profile height at approximately 9,000 ft. Dr. Bauman did not match or interpolate the data to smooth the differences in wind speed or wind direction at the interface height of the two sensors.

AMPS

Dr. Bauman developed code in Excel VBA to ingest and format the AMPS XMR radiosonde observations from the Spaceport Weather Data Archive. The AMPS files are also in ASCII format and were ingested into Excel as a text file. After downloading and ingesting the files, the VBA code removes all unneeded parameters and reformats the AMPS data similar to the 915 MHz profiler observations as shown in Figure 4b. From the reformatted data, another VBA script creates wind speed and direction profiles of AMPS and overlays them on the existing 50 MHz/915 MHz profile charts as shown in Figure 6. The AMPS profiles are shown by the blue lines and the 50 MHz profiles and 915 MHz profiles are as shown in Figure 5.

Model Initialization Data

Dr. Bauman developed VBA scripts to download, ingest and process the RAP, NAM and GFS model data to compare their initializations against the AMPS and profiler observations. The LWOs do this in operations to determine which model has the most accurate initialization. As with the observation files, Dr. Bauman processed the model files in Excel by ingesting the ASCII files, removing unneeded data, and then organizing them in a format suitable to create the wind speed and wind direction charts. He processed each model's analysis, or 0-hour forecast, wind profile for the LWOs initialization of the models against the observations as well as all wind profiles for each model's forecast interval.

From the reformatted data, another VBA script creates wind speed and direction profiles of the model 0-hour forecast and overlays them on the existing AMPS/50 MHz/915

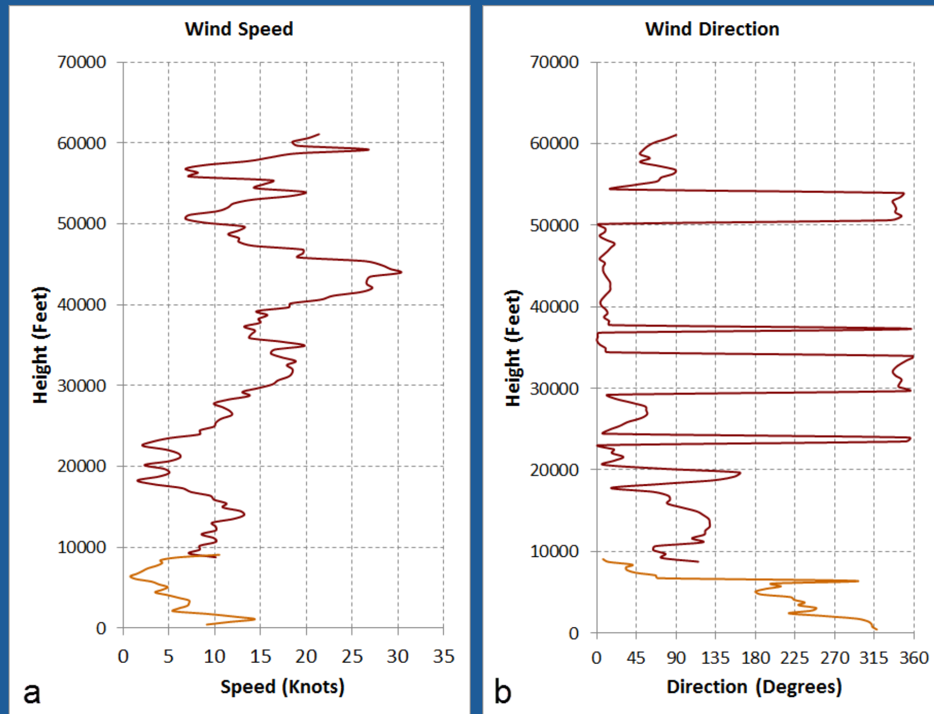


Figure 5. Wind speed (a) and wind direction (b) profiles from the 1201 UTC 3 Jul 2012 915 MHz profiler (orange lines) and the 1155 UTC 3 Jul 2012 50 MHz profiler (dark red lines) plotted in Excel.

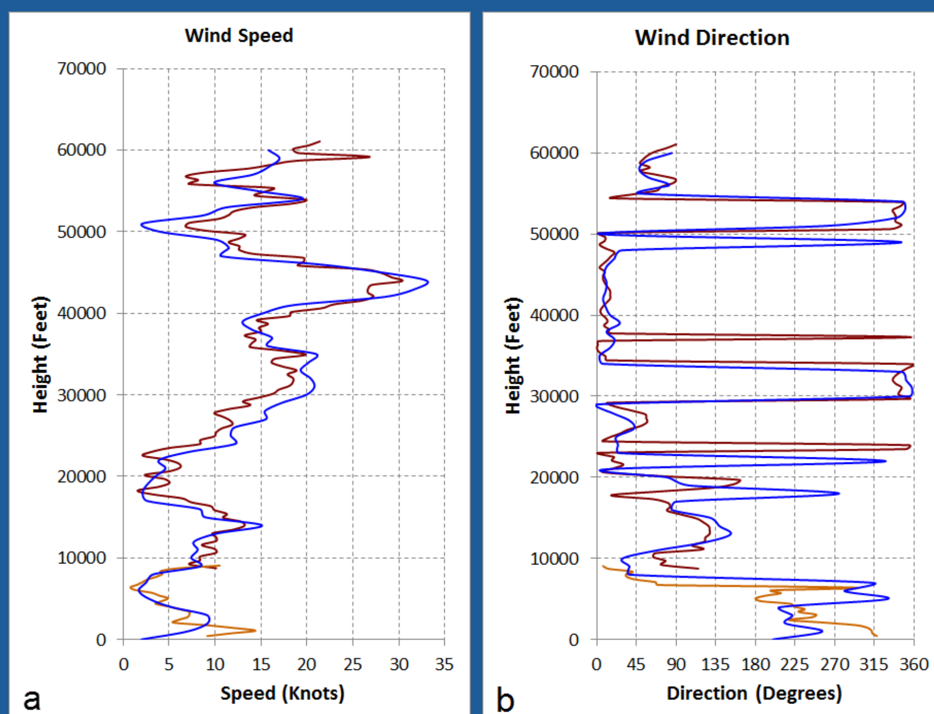


Figure 6. Wind speed (a) and wind direction (b) profiles from 1018 UTC 3 Jul 2012 AMPS (blue lines) and the 50 MHz and 915 MHz profiles as in Figure 5..

MHz profile charts as shown in Figure 7. The RAP 0-hour forecast profiles are shown by the red dashed line, and the AMPS, 50 MHz and 915 MHz profiles are as shown in Figure 6.

Model Forecast Data

The ultimate goal of this task is to provide the LWO with a capability to overlay model forecast wind profiles up to 12 hours after the latest observational data valid time at each model's highest temporal resolution to assess the upper-level wind changes on day-of-launch and to provide that information to the launch directors and other decision makers. Dr. Bauman wrote another VBA script that creates wind speed and direction profiles of the model forecast intervals from the reformatted model forecast data and overlays them on the existing observational profile charts as shown in Figure 5. The LWOs have the option of overlaying each model's forecast profiles on either the AMPS profile or the 50 MHz/915 MHz profile. Figure 8 shows an example of the workbook tab "Fcst_NAM_Prof" that displays the 50 MHz profile (solid red line) at 1355 UTC 3 Jul 2012 with the NAM model hourly forecasts initialized at 1200 UTC (dashed lines) valid for the 12 hours 1400 UTC 3 Jul 2012 to 0100 UTC 4 Jul 2012. To unclutter the model forecast profiles, the LWO can right-click on any line and delete it from the chart.

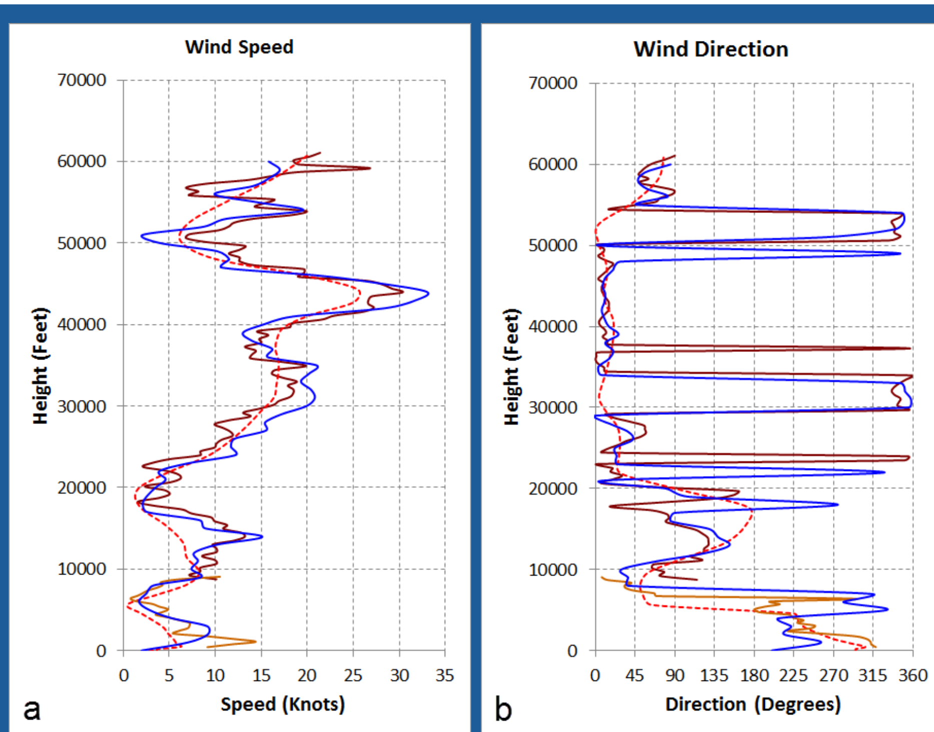


Figure 7. Wind speed (a) and wind direction (b) profiles at the RAP model initial time of 1200 UTC 3 Jul 2012 (dashed red line) overlaid on the observations from AMPS, 50 MHz and 915 MHz profiles as in Figure 3.

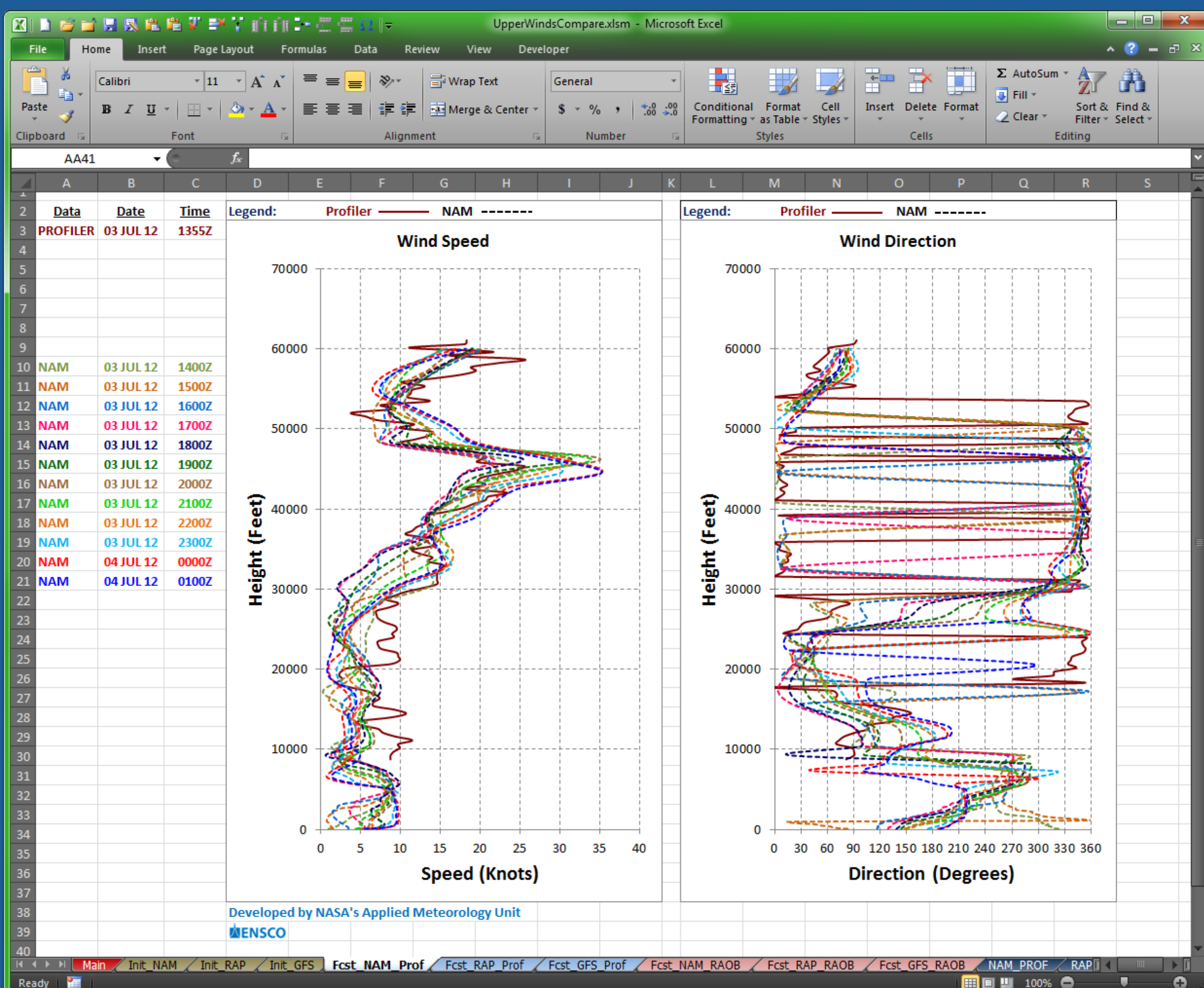


Figure 8. Wind speed (left) and wind direction (right) profiles from the 1355 UTC 3 Jul 2012 50 MHz profiles as in Figure 3 plus the 1400 UTC 3 Jul 2012 – 0100 UTC 4 Jul 2012 NAM model forecasts (dashed lines) plotted in Excel.

VBA Script Tests

The primary challenge with using near real-time data in Excel was to ensure the latest available model data was being accessed and that it was time-matched to the observations. Therefore, Dr. Bauman needed to test the VBA scripts throughout the day to make sure they worked as they were designed for all model initialization times. NCEP runs the RAP model every hour, and the NAM and GFS models every six hours at 0000, 0600, 1200, and 1800 UTC. Dr. Bauman determined that the RAP model forecasts are available from the Iowa State data server about 1 hour, 45 minutes after each hour, the NAM model forecasts are available about 3.5 hours after each initialization time, and the GFS model forecasts are available about 5 hours after each initialization time.

To ensure the latest model data is acquired by the GUI, the current UTC time must be known based on the local time of the user's computer. To determine the current UTC time, Dr. Bauman first needed to check whether or not the current date was in Standard Time or Daylight Saving Time. Dr. Bauman downloaded an Excel module from Pearson Software Consulting, LLC (http://www. cpearson.com/excel/DaylightSavings.htm) that does this calculation. He then wrote a VBA script to automatically run this module every time the GUI is started. The UTC time is then determined by subtracting either 5 hours for Eastern Standard Time or 4 hours for Eastern Daylight Time (EDT) from the local time obtained from the user's computer using the Excel built-in function "=NOW()". The UTC time is saved in the Excel GUI and accessed by each script that needs to determine which model data and observations to download.

Dr. Bauman tested the GUI VBA scripts at random times at all hours of the day to ensure the correct model data and observations were downloaded based on model initialization and availability times. There were occasions when the model data or observations were not available. Therefore, he put error checks into the scripts so the software would not fail but instead return a message to the user that the data or observation was not available, allowing them a choice to leave it out or check for it later. Based on the testing and the occasional missing data, Dr. Bauman decided to create an interface for the user permitting them to download and process one data type at a time so they could skip data that was unavailable yet continue to process other data types.

Dr. Bauman's tests also revealed that the Spaceport Weather Data Archive website presents two significant challenges for data access. First, the website only acquires observational data once per hour from MIDDS via a dial-up modem. This presents a potential problem with the AMPS observations because a sounding may only be partially complete when the files are acquired from MIDDS resulting in an incomplete sounding profile on the website. While the VBA script will download and process the incomplete AMPS file, the height of the wind speed and direction profile will be limited to the height the radiosonde obtained when the file was acquired from MIDDS. In these instances, the LWO will have to wait one hour for the complete AMPS profile to be available for download from the Spaceport Weather Data Archive website. Second, there are intermittent times when a file exists but contains no data. Because the file exists on the server, the VBA script will download it but will not be able to process it.

Point-and-Click User Interface

After testing all the VBA scripts, Dr. Bauman developed a user interface on the Main tab in the Excel workbook as shown in Figure 9 (next page). The second row in the Main tab displays the current date, local time, UTC time and the results of the test for EDT. There are three primary point-and-click boxes containing user-selectable model data and observations. The first box is designed to display each of the three models with the 50 MHz profiler, 915 MHz profiler and AMPS observations so the LWOs can determine which model 0-hour forecast is more accurate. The second box allows the LWO to compare each of the three model forecasts to the 50 MHz and 915 MHz profiler observations. The third box allows the LWO to compare each of the three model forecasts to the AMPS observations. In order to preserve the layout of the data and charts in each tab of the workbook, there are two buttons used to exit the GUI and Excel. One button will exit Excel and not save the file while the other button will exit Excel but first save a copy of the file including all data and charts but no macros. It also automatically creates a filename for the saved file using the current date-time. A message box is then displayed to the LWO showing the filename and directory path to the file.

Next Steps

Dr. Bauman will demonstrate the GUI to the LWOs to get their feedback and make any requested changes. Then he will provide the GUI to the LWOs for testing on their systems and network.

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

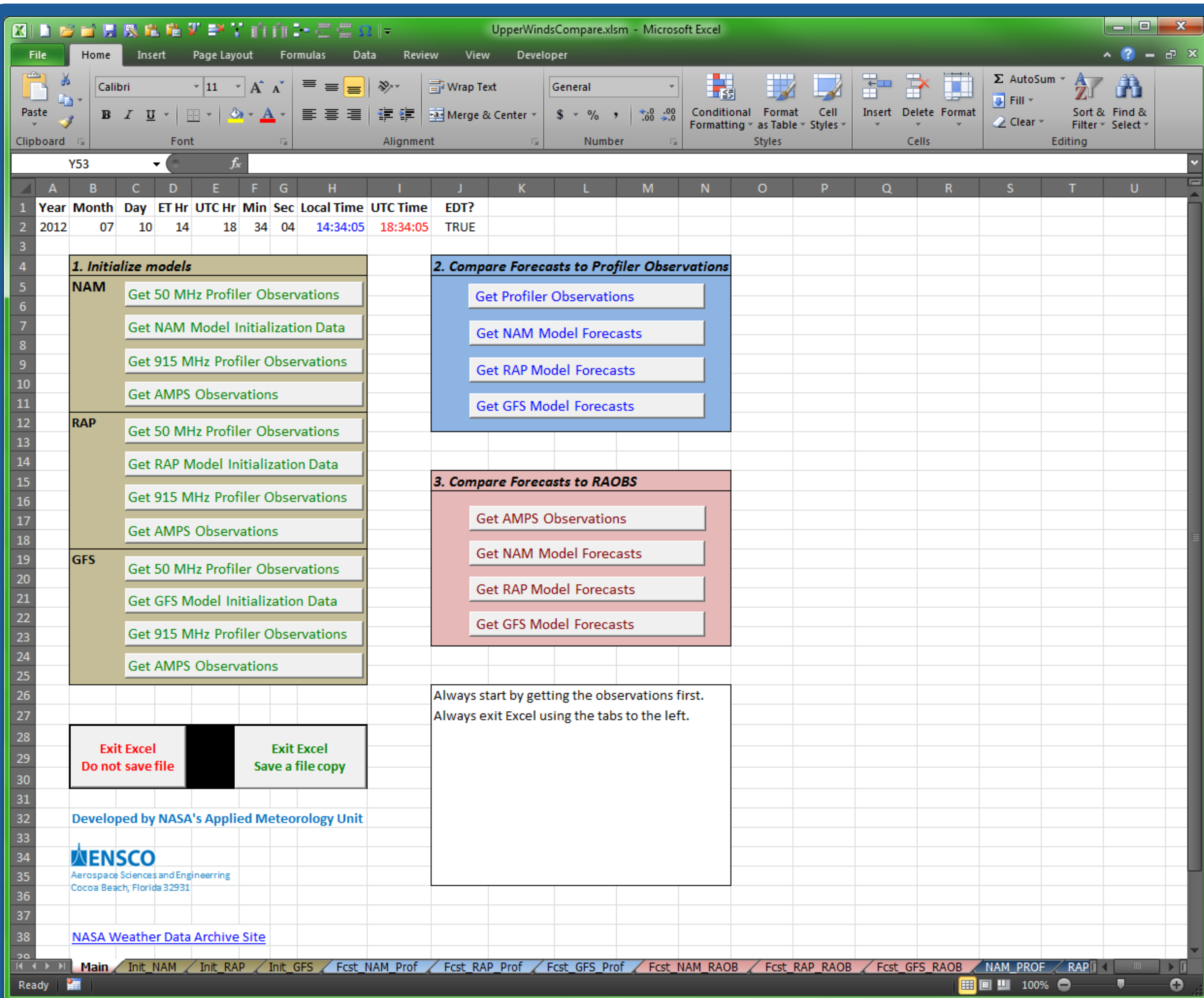


Figure 9. Main tab of the GUI in the Excel workbook shows the primary user interface for selecting model data and observations to display.

INSTRUMENTATION AND MEASUREMENT

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 all other lightning probability techniques 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 will determine 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.

Data Preparation

The three data types to be used in this task are from the Cloud-to-Ground Lightning Surveillance System (CGLSS), the GPS IPW data from the sensor at Cape Canaveral, Fla., and the lightning probabilities from the AMU Objective Lightning Probability tool. Since data from the GPS IPW site are not available before 2000, the POR is 2000-2011 for the warm-season months of May-October. These data were plotted by month and half hour interval for each month and year in the POR in order to identify any data gaps and outliers. Example plots for June 2003 are shown in Figures 10 and 11. The statistical method to calculate daily lightning occurrence probabilities will likely be logistic regression, but will depend on the results found from an exploratory analysis of the data. The equations will produce a probability of lightning occurrence during the day between 0700-0000 EDT. All data will be processed and equations developed using either the S-PLUS® software package (TIBCO 2010) or MINITAB® (Minitab, Inc. 2003).

CGLSS

This data set will be used as the predictand in the equations, determining whether or not lightning occurred on a particular day and during a particular half-hour interval in the database. These data were provided to Dr. Huddleston by Ms. Crawford .

The CGLSS data were filtered to include only lightning strikes recorded during the warm season between 0700-0000 EDT and only within the 5 NM lightning warning circles shown in Figure 12 (Lambert 2007).

Development of the predictand and climatology were based on whether lightning was observed in the time period and the warning circles on each day. The calculations did not consider how many lightning strikes were detected. Calculation of the predictand was straightforward: a '1' was assigned as the predictand if lightning was detected within the defined time frame and spatial area on a specific day, otherwise a '0' was assigned (Lambert 2007).

GPS IPW

The GPS IPW data from May-October 2000-2011 were downloaded from the Earth System Research Laboratory (ESRL) Ground-Based GPS Meteorology website http://gpsmet.noaa.gov/cgi-bin/gnuplots/rti.cgi. While the physical site near the Cape Canaveral Lighthouse remained approximately the same over the 12-year POR, the 4-letter site identification changed when there were significant changes/upgrades in the equipment. Mr. Seth Gutman of ESRL provided the information as to when these changes/upgrades occurred.

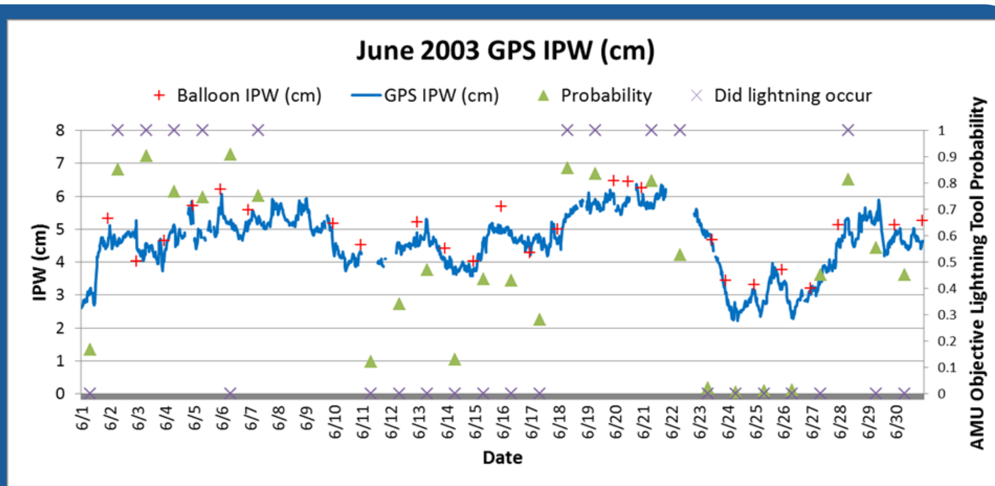


Figure 10. The June 2003 time series of IPW in centimeters (cm) from GPS observations made at the Cape Canaveral, Fla., site (left vertical axis, blue line), integrated precipitable water from the CCAFS soundings (red pluses), the AMU Objective Lightning Probability tool daily output (right vertical axis, green triangles), and lightning occurrence (purple Xs) within the 5 NM KSC/CCAFS lightning warning circles (see Figure 12).

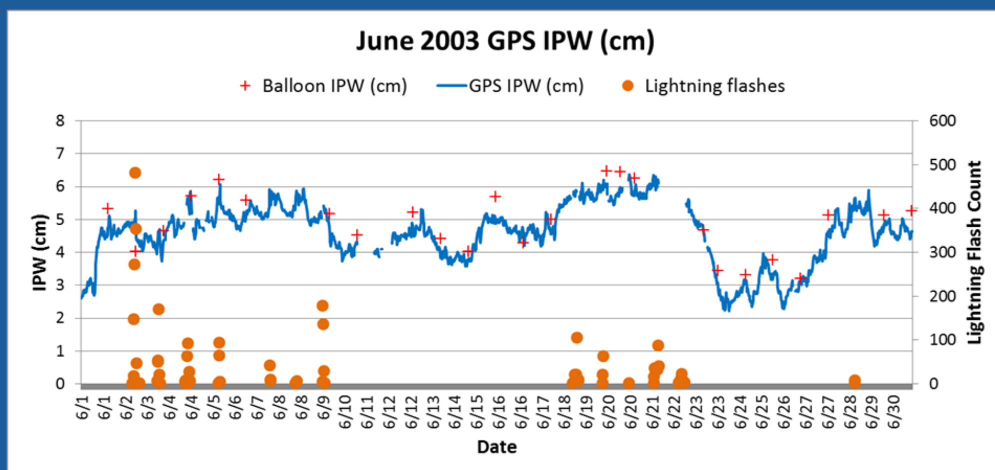


Figure 11. The June 2003 time series of IPW in centimeters (cm) from GPS observations made at the Cape Canaveral, Fla., site (left vertical axis, blue line), integrated precipitable water from the CCAFS soundings (red pluses), and the CGLSS flash count (right vertical axis, orange circles) of lightning that occurred within the 5 NM KSC/CCAFS lightning warning circles (see Figure 12).

AMU Objective Lightning Probability Tool

Ms. Crawford provided the probability output from the AMU Objective Lightning Probability tool. Along with the probability, the data included year, month and day for each of the warm season months, whether lightning occurred on each day (0 if no, 1 if yes), and the flow regime name for each day. The tool provides the

Figure 12. The 5 NM lightning warning circles on KSC (blue) and CCAFS (red).

probability of lightning for the entire day (valid between 0700-0000 EDT), so there is only one value per day.

Exploratory Data Analysis

The 45 WS personnel requested equations with lead times of two and nine hours to support various operational requirements, similar to those developed in Kehrer et al. (2008). Dr. Huddleston plotted the AMU tool probability values against the 24-hour change in the GPS IPW values for each month in all years in the POR. Figure 13 is a plot of these data for June 2000-2011 and the 2-hour lead time. The red squares indicate data for which no lightning occurred and the blue diamonds indicate data for which lightning did occur. As in Figure 13, no ΔIPW trends or associations with lightning occurrence were evident for any of the warm season months plotted for either the two- or nine-hour lead times.

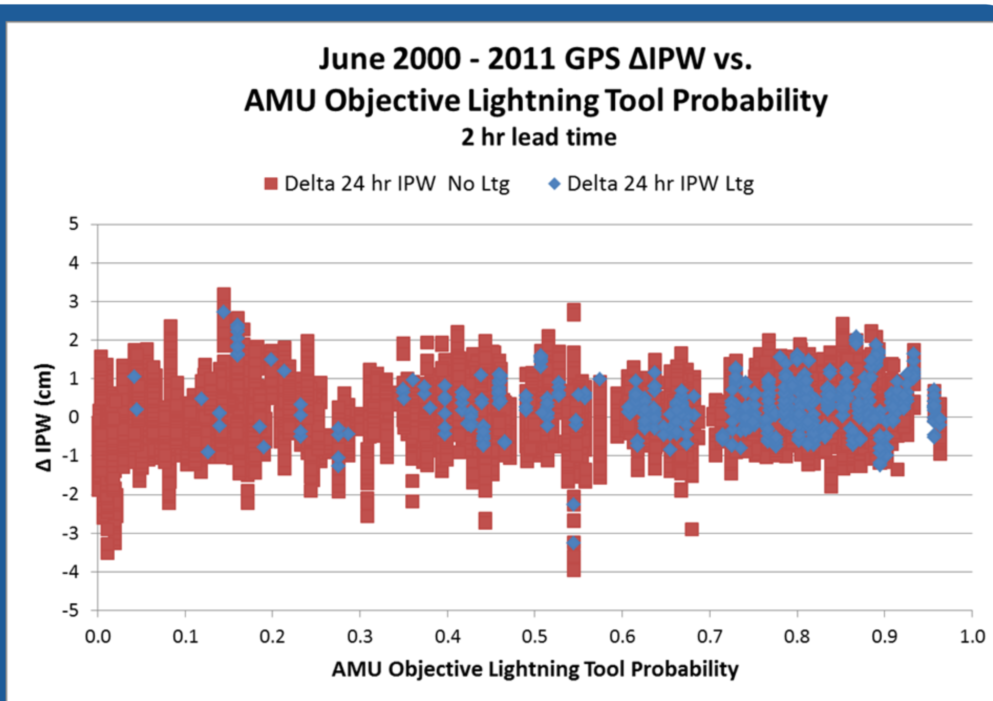


Figure 13. Scatter plot of AMU Objective Lightning Probability tool daily probability vs. ΔIPW over a 24-hour period and a 2-hour lead time before a CGLSS flash occurred (blue diamond, lightning occurred) and when a CGLSS flash did not occur (red square, lightning did not occur) for the month of June during the entire POR.

When visual trends are not evident, mean differences can be used to determine statistical significance between those days with lightning and those without. Dr. Huddleston calculated the 24-hour ΔIPW means and medians then tested for significance of the difference between them using parametric and non-parametric methods. Table 3 shows the results of the parametric test of the means difference (z-test) and the results showed a significant difference between ΔIPW means on lightning and non-lightning days. However, the skewness of the distributions (not shown) suggests that the data are not Gaussian distributed. A test for normality also indicated that the distribution cannot be assumed to be Gaussian, therefore a non-parametric test would be appropriate. Table 4 shows the results of the Mann-Whitney non-parametric test for the means difference, also showing significant differences between ΔIPW values for lightning and non-lightning days. The means difference, while significant, is not large enough to detect trends in scatter plots such as that in Figure 13.

Future Data Analysis

Even though adding the AMU Objective Lightning Probability tool output and change in GPS IPW as predictors to the logistic regression equations as developed by Mazany, et al. (2000), and Kehrer, et al. (2008) do not look promising, the equations will be re-evaluated with the new variables to quantify any improvements to model performance.

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

Table 3. Parametric z-Test for two-sample means for the difference in ΔIPW means over a 24-hour period plus a 2-hour lead when a CGLSS lightning flash occurs vs. when a flash does not occur over the entire POR.

Statistics	*Lightning Occurrence*	
	Yes	No
Mean	0.33	-0.02
Known Variance	0.41	0.67
Number of Samples	2407	62358
Hypothesized Mean Difference	0	
z	25.90	
P(Z<=z) two-tail	0	
z Critical two-tail	1.96	

Table 4. Non-parametric Mann-Whitney test for two sample means for the difference in ΔIPW means over a 24-hour period plus a 2-hour lead when a CGLSS lightning flash occurs vs. when a CGLSS flash does not occur over the entire POR.

Lightning Occurrence	# Samples	Median
Yes	2407	0.29 (1)
No	62,358	0.01 (2)
Point estimate for Median1-Median2 is 0.30000		
W Statistic = 97,429,943.0		
Median1 = Median2 vs Median1 not = Median2 is significant at 0.0000		
The test is significant at 0.0000 (adjusted for ties)		

MESOSCALE MODELING

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.

ER Grid Configuration

While Dr. Watson was on maternity leave, Dr. Bauman continued to run model test cases for WFF using data from 1-30 April 2012. Using the domain configurations selected by Dr. Watson and with her guidance, he ran different model configurations varying the dynamical core, grid spacing and domain size to determine the optimal configuration. Such a configuration would allow the largest domain size and highest resolution for a 24-hour forecast to be run in under one hour. He ran the following configurations, which completed twice daily (0000 and 1200 UTC model initialization times) for 1-30 April 2012:

- 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).

Since Dr. Watson had already determined the ARW core performed better than the NMM core, per her suggestion, Dr. Bauman ran an abbreviated set of test cases using the following configuration for 0000 and 1200 UTC model initialization times for 1-7 April 2012.

- 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 used instructions from Dr. Watson to process the model output generated by Dr. Bauman. The processed data are in the same format as the observations to facilitate calculating verifications statistics.

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

AMU ACTIVITIES

AMU Operations

Visitors

The AMU staff attended a presentation on ensemble modeling by Mr. Evan Kuchera from the Air Force Weather Agency (AFWA) at Offutt AFB in Nebraska. The AMU staff then discussed the AMU modeling task with Mr. Kuchera and determined that AMU personnel should visit AFWA to gain an more understanding of their modeling efforts and how they may help the AMU develop an operational model for KSC/CCAFS.

Dr. Bauman provided an overview briefing of the AMU to Dr. Murphree from the Naval Post Graduate School, who is the thesis advisor to Capt Greg Strong, formally of the 45 WS. AMU personnel also attended Capt. Strong's presentation of his thesis: "Thick Cloud LCC Climatology and Sensitivity Analysis."

Dr. Bauman provided the same briefing and tour of the AMU lab to Dr. Lanicci and his meteorology students from Embry-Riddle Aeronautical University.

Conferences/Training

Ms. Crawford attended Vaisala's International Lightning Data Conference/International Lightning Meteorology Conference in Broomfield, Colo., 2-5 April.

Dr. Bauman attended the 45 WS Training Day and presented briefings on the AMU Situational Lightning Climatology Tool and on Advanced Weather Interactive Processing System familiarization.

Security

Mr. Bob Davis, 45 SW Chief of Industrial Security, completed the annual Industrial Security Review with Dr. Bauman and Ms. Crawford. His review found the AMU to be in-compliance with the National Industrial Security Program.

Dr. Huddleston, Dr. Bauman and Ms. Shafer received IT Security Vulnerability Scanning training from NASA IT so AMU personnel can scan the AMU system on their own. Dr. Bauman and Ms. Shafer completed IT Security Vulnerability Scanning of the AMU system. They also completed the annual IT Security Continuous Monitoring task and updated the AMU IT System Security Plan for FY12 (Contract DRD 007).

The AMU staff participated in annual Contingency Training for IT Security by reviewing the AMU Contingency Plan and restoring files from the AMU server to a PC.

Other

Dr. Watson began 12 weeks of maternity leave on 14 May.

AMU Chief's Technical Activities (Dr. Huddleston)

Dr. Huddleston and Dr. Merceret began measuring and recording total column water vapor using a portable infrared thermometer pointed at a cloud-free sky. She also helped Mr. McAleenan of the 45 WS with an Excel VBA program to collect MOS data for 45 WS forecast validation statistics, and attended the KSC Climate Change Coordination Meeting on 18 June.

REFERENCES

Crawford, W., 2010: Objective Lightning Probability Forecasting for Kennedy Space Center and Cape Canaveral Air Force Station, Phase III. NASA Contractor Report CR-2010-216292, Kennedy Space Center, FL, 34 pp. [Available from ENSCO, Inc., 1980 N. Atlantic Ave., Suite 830, Cocoa Beach, FL, 32931, and http://science.ksc.nasa.gov/amu/final-reports/objective-ltg-fcst-phase3.pdf.]

Inoue, H. and T. Inoue, 2007: Characteristics of the Water-Vapor Field over the Kanto District Associated with Summer Thunderstorm Activities, *SOLA*, **3**, 101-104.

Kehrer, K., B. Graf, and W. Roeder, 2008: Glorbal Positiong System (GPS) Precipitable Water in Forecasting Lightning at Spaceport Canaveral, *Wea. Forecasting,* **23**, 219-232.

Mazany, R., S. Busing, S. Gutman, and W. Roeder, 2002: Operational Multiple-Doppler Wind Retrieval Inferred from Long-Range Radial Velocity Measurements, *Wea. Forecasting*, **17**, 1034-1047.

Lambert, W. and M. Wheeler, 2005: Objective lightning probability forecasting for Kennedy Space Center and Cape Canaveral Air Force Station. NASA Contractor Report CR-2005-212564, Kennedy Space Center, FL, 54 pp. [Available from ENSCO, Inc., 1980 N. Atlantic Ave., Suite 830, Cocoa Beach, FL, 32931, and http://science.ksc.nasa.gov/amu/final-reports/objective-ltg-fcst-phase1.pdf.]

Lambert, W., 2007: Objective Lightning Probability Forecasting for Kennedy Space Center and Cape Canaveral Air Force Station, Phase II. NASA Contractor Report CR-2005-214732, Kennedy Space Center, FL, 57 pp. [Available from ENSCO, Inc., 1980 N. Atlantic Ave., Suite 830, Cocoa Beach, FL, 32931, and http://science.ksc.nasa.gov/amu/final-reports/objective-ltg-fcst-phase2.pdf.]

Minitab Inc. (2003). *Meet Minitab Release 14*, 138 pp. [Available online at http://pharmacy.ucsf.edu/irc/pdfs/METSTMTB.pdf.]

Suparta, W., J. Adnan, Mohd. Ali, M. A., 2011: Detection of lightning activity using GPS PWV measurements. *Proceedings of the 2011 IEEE International Conference on Space Science and Communication (IconSpace)*, 12-13 July, 2011, Penang, Malaysia, IEEE, 115-120.

Suparta, W., J. Adnan, Mohd. Ali, M. A., 2011: Monitoring the association between GPS PWV and lightning activity during the 2009 Winter Monsoon over Bangi Malaysia. *Proceedings of the 2011 International Conference on Environment Science and Engineering* (*ICESE 2011*), 28-30 Sep. 2011, Singapore, Singapore, IEEE, 101-106.

TIBCO, 2010: TIBCO Spotfire S+® 8.2 Programmer's Guide, TIBCO Software Inc., Seattle, WA, 532 pp.

Watson, L., 2011: Upgrade Summer Severe Weather Tool Phase III. NASA Contractor Report CR-2010-216282, Kennedy Space Center, FL. 15 pp. [Available from ENSCO, Inc. 1980 N. Atlantic Ave., Suite 830, Cocoa Beach, FL 32931 and http://science.ksc.nasa.gov/amu/final-reports/severe-tool-upgrade-II.pdf.]

LIST OF ACRONYMS

14 WS	14th Weather Squadron
30 SW	30th Space Wing
30 OSSWF	30th Operational Support Squadron Weather Flight
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
ASCII	American Standard Code for Information Interchange
CCAFS	Cape Canaveral Air Force Station
CGLSS	Cloud to Ground Lightning Surveillance System
Climo	Daily Climatological Lightning Frequency
CSR	Computer Sciences Raytheon
CT	Cross Totals
DE	Detection Efficiancy
EDT	Eastern Daylight Time
ER	Eastern Range
ESRL	Earth System Research Laboratory
FRProb	Flow Regime Lightning Probability
FSU	Florida State University
FTP	File Transfer Protocol
GFS	Global Forecast System
GPS	Global Positioning System
GUI	Graphical User Interface
HTTP	Hypertext Transfer Protocol
IPW	Integrated Precipitable Water
JSC	Johnson Space Center
KSC	Kennedy Space Center
KI	K Index
LCC	Launch Commit Criteria
LI	Lifted Index
LWO	Launch Weather Officer
MCO	Orlando International Airport 3-letter identifier
MIDDS	Meteorological Interactive Data Display System
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, FL
PAFB	Patrick Air Force Base
POR	Period of Record
PoV	Probability of Violation
RAP	Rapid Refresh model
RH	Relative Humidity
RUC	Rapid Update Cycle model
SMC	Space and Missile Center
SPoRT	Short-term Prediction Research and Transition Center
SS	Brier Skill Score
Tcl/Tk	Tool Command Language/Toolkit
TI	Thompson Index
TT	Total Totals
URL	Uniform Resource Locator
USAF	United States Air Force
VAFB	Vandenberg Air Force Base
VBA	Visual Basic for Applications
VT	Vertical Totals
WFF	Wallops Flight Facility
WRF	Weather Research and Forecasting
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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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. Sleeth
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
NOAA/NWS/OST12/SSMC2/ J. McQueen
NOAA Office of Military Affairs/ 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/J. Roberts
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./J. Clift
ENSCO, Inc./E. Lambert
ENSCO, Inc./A. Yersavich
ENSCO, Inc./S. Masters