

# **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**

William H. Bauman III \*

NASA Applied Meteorology Unit / ENSCO, Inc. / Cape Canaveral Air Force Station, Florida

Clay Flinn

USAF 45th Weather Squadron / Patrick Air Force Base, Florida

## **1. INTRODUCTION**

On the day of launch, the 45th Weather Squadron (45 WS) Launch Weather Officers (LWOs) monitor the upper-level winds for their launch customers. During launch operations, the payload/launch team sometimes asks the LWOs if they expect the upper-level winds to change during the countdown. The LWOs used numerical weather prediction model point forecasts to provide the information, but did not have the capability to quickly retrieve or adequately display the upper-level observations and compare them directly in the same display to the model point forecasts to help them determine which model performed the best. The LWOs requested the Applied Meteorology Unit (AMU) develop a graphical user interface (GUI) that will plot upper-level wind speed and direction observations from the Cape Canaveral Air Force Station (CCAFS) Automated Meteorological Profiling System (AMPS) rawinsondes with point forecast wind profiles from the National Centers for Environmental Prediction (NCEP) North American Mesoscale (NAM), Rapid Refresh (RAP) and Global Forecast System (GFS) models to assess the performance of these models. The AMU suggested adding observations from the NASA 50 MHz wind profiler and one of the US Air Force 915 MHz wind profilers, both located near the Kennedy Space Center (KSC) Shuttle Landing Facility, to supplement the AMPS observations with more frequent upper-level profiles. Figure 1 shows a map of KSC/CCAFS with the locations of the observation sites and the model point forecasts.

## **2. DATA**

The goal of this work was to build a GUI that would allow the LWOs to compare model wind profile output to observed wind profiles closest in time to the 0-hour model forecasts. This permits them to determine which model has the best performance, i.e. to initialize the models. Their requirement is to display model forecasts in 3-hour intervals from the current time through 12 hours.

The AMU reviewed the availability of the observational and model data in the 45 WS Meteorological Interactive Data Display System (MIDDS). They determined MIDDS could not be used as

the data ingest and display for this work because the model point data is not ingested by the AMU MIDDS server. Therefore, Microsoft Excel was considered for downloading, ingesting, formatting and displaying the data. The observational data was available from NASA at the KSC Spaceport Weather Archive website (<http://kscwxarchive.ksc.nasa.gov/>), which consists of all locally collected weather observations at KSC and CCAFS. The best source for model forecast point data for CCAFS (XMR) was available from the Iowa State University Weather Archive Server website (<http://mtarchive.geol.iastate.edu>). After discussing this with the 45 WS, all agreed that the AMU would develop an Excel GUI that would ingest data from the Spaceport Weather Data Archive and Iowa State University Weather Archive Server with scripts developed using Visual Basic for Applications (VBA) in Excel.

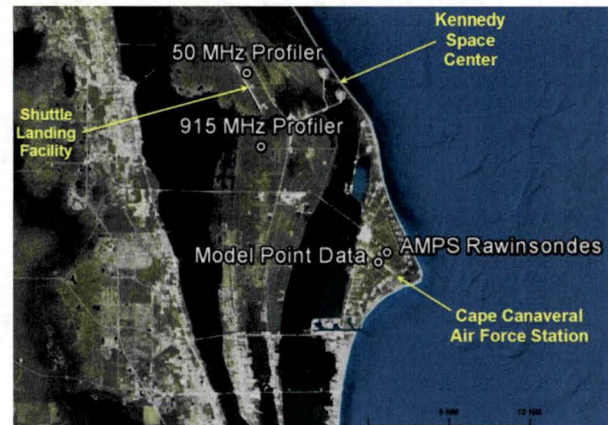


Figure 1. Map of KSC/CCAFS showing locations of the observations from the 50 MHz and 915 MHz profilers at KSC and AMPS at CCAFS. The location of the model point data forecasts is shown at CCAFS.

### **2.1 Data Acquisition**

One challenge with using near real-time data in Excel was to ensure the latest available model data was being acquired and that it was time-matched to the observations. NCEP runs the RAP model every hour and the NAM and GFS models every six hours at 0000, 0600, 1200, and 1800 UTC. Each model produces forecasts at least 12 hours beyond the initial time. The RAP and NAM models output forecasts at 1-hour intervals while the GFS model outputs forecasts at 3-hour intervals. Since each model has a different run

\*Corresponding author address: William H. Bauman III, ENSCO, Inc., 1980 N. Atlantic Ave, Suite 830, Cocoa Beach, FL 32931; e-mail: [bauman.bill@ensco.com](mailto:bauman.bill@ensco.com)



time to complete the entire forecast cycle, the AMU conducted tests regarding the data availability of the files on the Iowa State server to determine how long after model initialization time the files were ready for download. The conclusion was that the RAP model forecasts are available from the Iowa State 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.

Acquiring observational files from the Spaceport Weather Data Archive website presented two significant challenges for real-time 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. The VBA script that processes the observational data will download and process an incomplete AMPS file, which means 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. 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 the file but will not be able to process it.

## **2.2 Data Processing**

Before the data files are retrieved, several scripts are run to determine the current UTC time to ensure the latest model data is downloaded for processing. All time conversions used in the VBA scripts are based on the local time of the user's computer. However, before converting local time to UTC, a check was needed to determine if the current date was within Standard Time (ST) or Daylight Saving Time (DST). This turned out to be a complicated programming effort in VBA, so the AMU researched and downloaded an Excel DST module from Pearson Software Consulting, LLC (<http://www.cpearson.com/EXCEL/DaylightSavings.htm>) to do this calculation. To make use of this module, the AMU used the Excel built-in function "=NOW()" to obtain the local time from the user's computer. Next, the DST module is called to determine whether local time is in ST or DST using the function "=IsDateWithinDST()". Finally, to determine the correct UTC, the VBA code adds 5 hours to local time during ST or 4 hours during DST. 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. The AMU wrote a VBA script to automatically run the time calculation when the GUI is started. In Excel VBA, naming a macro "Auto-Open" will automatically run all of the code within that macro each time the macro-enabled Excel file is opened.

The LWOs requested using the observations for two applications. First, they want to use them to initialize

the models 0-hour forecasts by comparing the observations to each model and determine which model is performing the best. Second, they want to use them to show the launch team how the upper-level winds are forecast to change by displaying the model forecast valid at or near the same time of the most recent observation plus the model forecasts for the next 0-12 hours.

### **2.2.1. Model Initialization**

For the LWOs to initialize the models against the observations based on UTC, a VBA script retrieves the latest available model runs by issuing a File Transfer Protocol (FTP) command to download the observations closest to the model time. Since the observations will be compared to the model 0-hour forecasts, the observations should time-match each model's start time as close as possible. The AMU developed VBA scripts to download, ingest and format the profiler and AMPS observations from the Spaceport Weather Data Archive server. The data files on the server are in American Standard Code for Information Interchange (ASCII) format and are ingested into Excel as a text file. After downloading and ingesting the data files, the VBA code removes all unneeded parameters and reformats the data to prepare it for creating charts. A 50 MHz profiler data file as ingested into Excel is shown in Figure 2a and the reformatted data is shown in Figure 2b.

Another VBA script extracts the observation's height, wind direction and speed, data type, location, date and time from the reformatted data and creates charts containing the vertical profiles of wind speed and direction as shown in Figure 3. The data type, date and time of the observation are displayed in the upper left of the chart.

The AMU tested GUI VBA scripts at random times throughout the day to ensure the correct files were downloaded based on model initialization and availability times. There were occasions when the model data or observations were not available. Therefore, error checks were put into the scripts so the software would not fail but return an informative message to the user.

The 50 MHz profiler collects data from 8,000-60,000 ft while the 915 MHz profiler collects data from 400-10,000 ft. To provide a more-or-less continuous wind profile from these two instruments, a VBA script downloads, ingests and processes the 915 MHz profiler files in the same manner as for the 50 MHz profiler files. Due to the nature of the 915 MHz profilers, quality control parameters were added to the observations by finding and replacing missing data with data from the height immediately below the missing data. The replaced observation is changed to red text in the spreadsheet to highlight the changes for the LWOs. From the reformatted 915 MHz profiler observations, another VBA script creates wind speed and direction profiles and adds them to the existing 50 MHz profile charts as shown in Figure 4. The 915 MHz profiles are shown by the orange lines and the 50 MHz profiles are shown by the dark red lines.



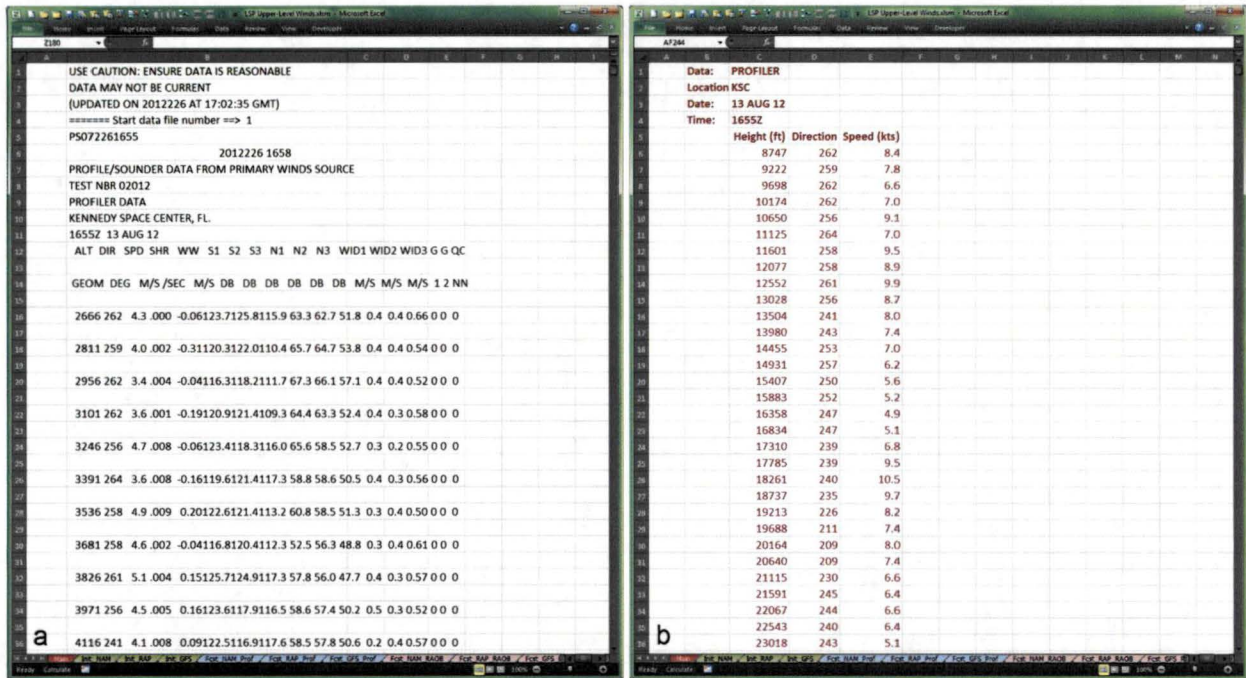


Figure 2. a) Data from the 50 MHz profiler after being ingested into Excel and b) after unneeded parameters were removed, displaying the sensor type and location, date, time, height, wind direction and speed.

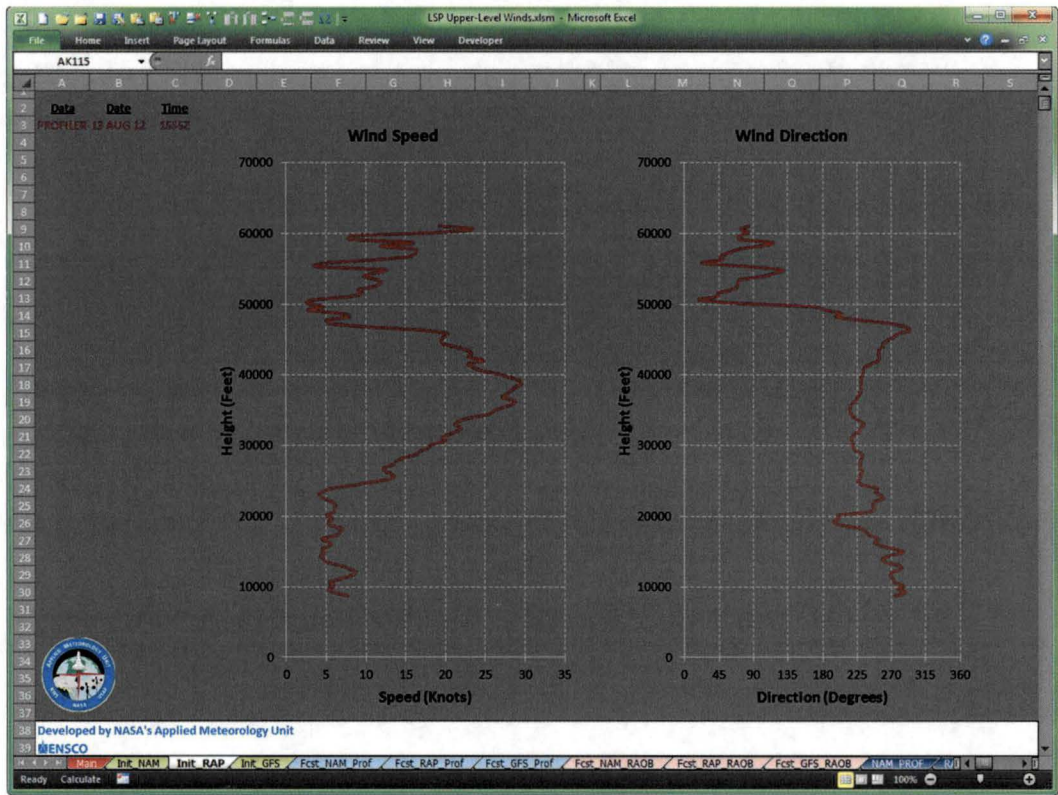


Figure 3. Wind speed (left) and wind direction (right) profiles at 1555 UTC 13 August 2012 from the 50 MHz wind profiler (dark red lines) plotted in Excel. Data type, date and time are shown in the upper left of the chart.

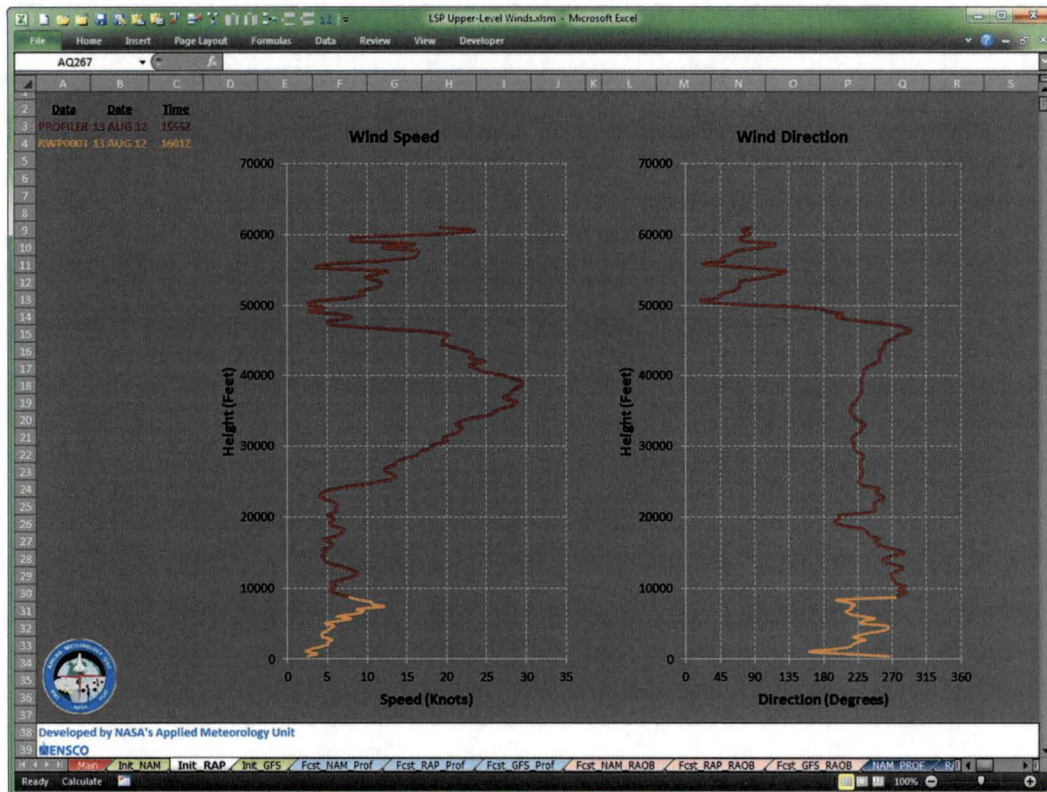


Figure 4. As in Figure 3 with the addition of the 1601 UTC 13 August 2012 915 MHz wind profiler (orange lines) plotted in Excel.

Another VBA script downloads, ingests and reformats the AMPS XMR radiosonde observations from the Spaceport Weather Data Archive. The AMPS files are also in ASCII format and are ingested into Excel as a text file. After downloading and ingesting the files, the VBA code removes all unneeded parameters and reformats the AMPS observations similar to the 50 MHz and 915 MHz profiler observations. 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 5. The AMPS profiles are shown by the green

lines and the 50 MHz profiles and 915 MHz profiles are as shown in Figure 4.

Additional VBA scripts download and process the model forecast point data from the Iowa State University server. The data files are in ASCII format and ingested into Excel as text files. Each script reformats the files and displays the tabular data to the user. From the reformatted data, the next VBA script creates wind speed and direction profiles of the model forecast point data and overlays the data on the 50 MHz profiler charts as shown in Figure 6.



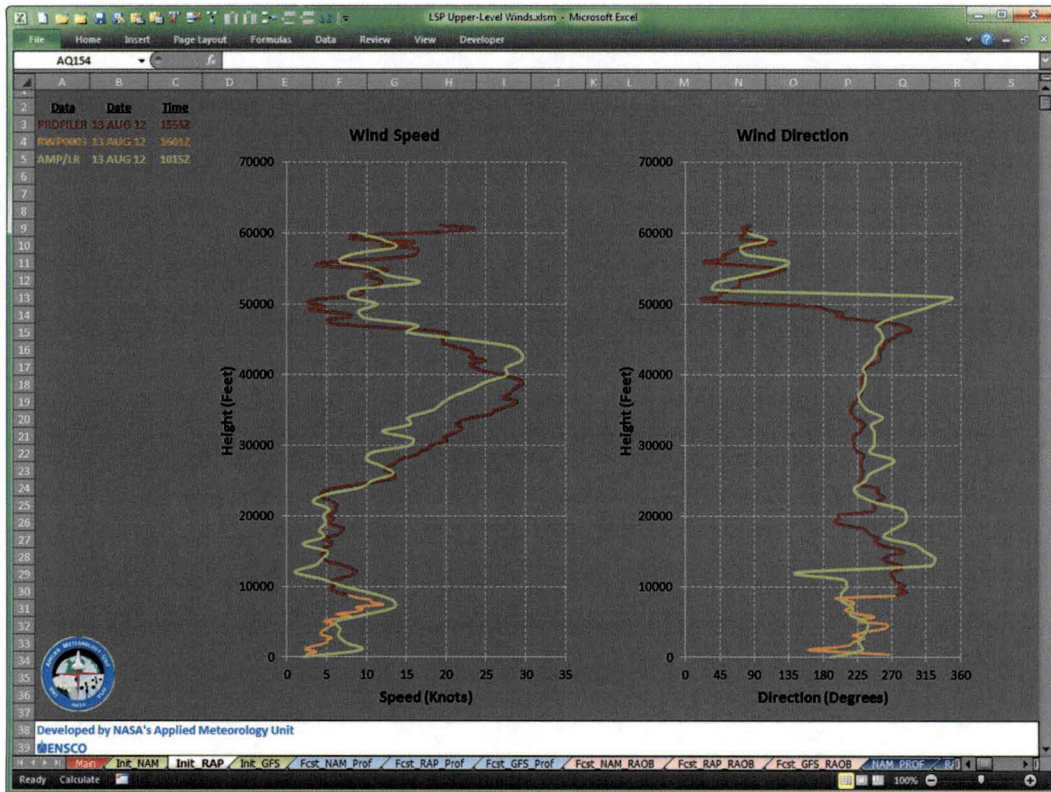


Figure 5. As in Figure 4 with the addition of the 1015 UTC 13 August 2012 AMPS (green lines) plotted in Excel.

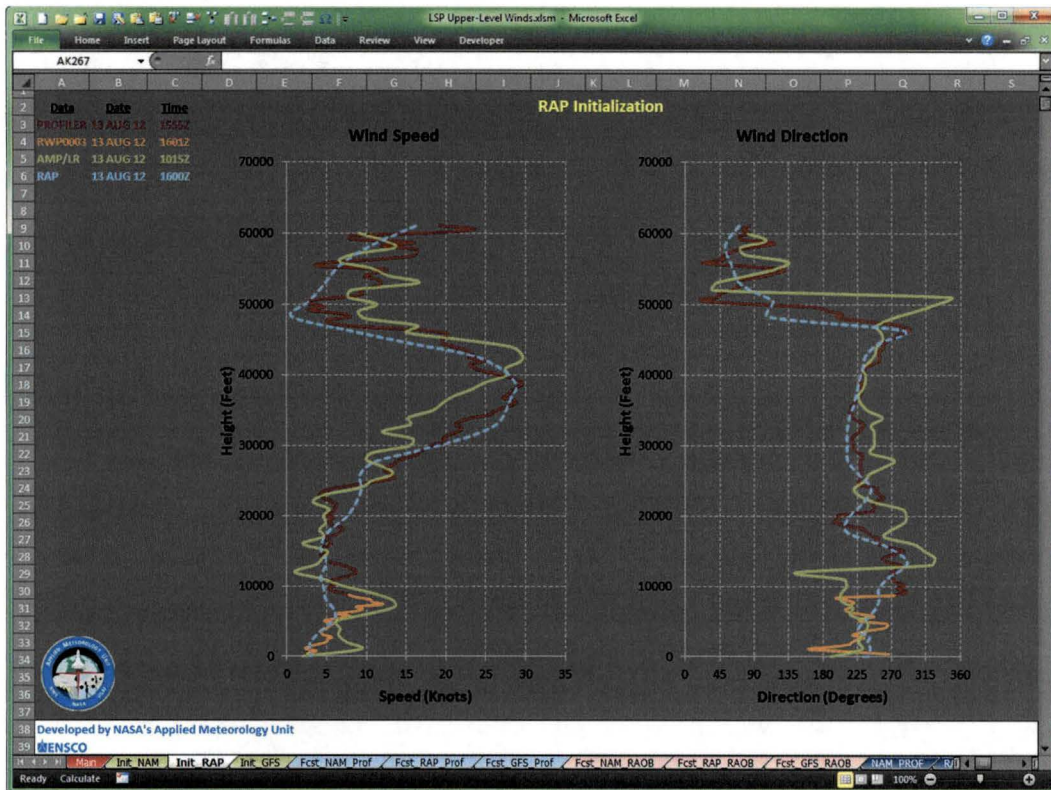


Figure 6. As in Figure 5 with the addition of the 1600 UTC 13 August 2012 RAP model 0-hour forecast (light blue dashed lines) plotted in Excel.



## 2.2.2. Model Forecasts

Since the requirement is to provide the LWOs with a GUI to overlay model forecasts in 3-hour intervals from the current time through 12 hours, the AMU developed VBA scripts to display the forecast wind profiles up to 12 hours after the latest observation at each model's highest temporal resolution to assess the upper-level wind changes on day-of-launch for the launch directors. To keep the forecast charts uncluttered, the model forecast point data is overlaid on the AMPS and profiler observations on separate charts.

The VBA script that creates wind speed and direction profiles of the model forecast time intervals also overlays them on the AMPS observation profile charts as shown in Figure 7. The AMPS observation

(solid dark red lines) at 1944 UTC 13 August 2012 is plotted with the NAM model hourly forecasts (dashed lines) based on the 1800 UTC 13 August 2012 model run valid from 2000 UTC 13 August 2012 to 0500 UTC 14 August 2012 in three-hour intervals. Even though the NAM forecasts are available hourly, forecast profiles valid every three hours are plotted on the chart to reduce clutter. The model forecast profiles are always plotted in four different shades of blue ranging from light (first model forecast valid time) to dark (last model forecast valid time) making it easier for the user to discern between the model forecast valid times. The forecast profile colors match the colors of the text showing data type, date and time displayed on the chart. To unclutter the model forecast profiles, the LWO can right-click on any line and delete it from the chart.

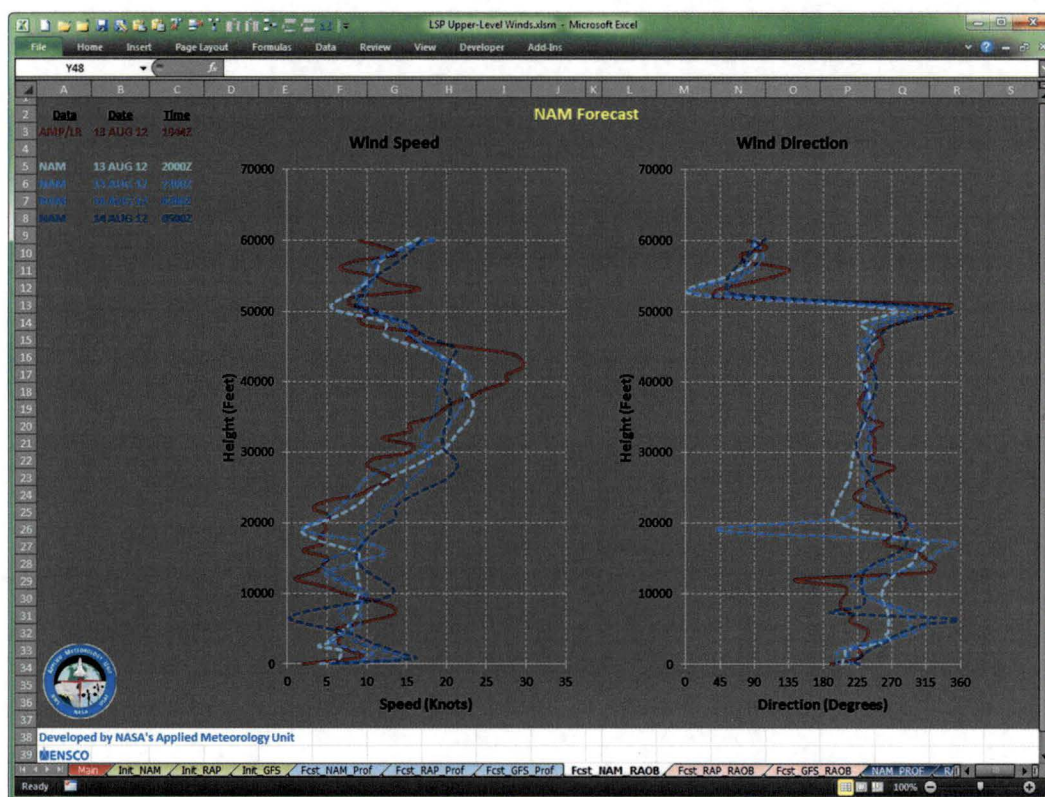


Figure 7. Wind speed (left) and wind direction (right) profiles from the 1944 UTC 13 August 2012 AMPS observation (dark red lines) and NAM model forecasts (dashed blue lines) valid every three hours from 2000 UTC 13 August 2012 through 0500 UTC 14 August 2012 plotted in Excel. Data type, date and time are shown in the upper left of the chart.

The model forecast point data profiles are also overlaid on the 50 MHz and 915 MHz profiler charts as shown in Figure 8. The 50 MHz profiler observation (solid red line) from 1655 UTC 13 August 2012 and the 915 MHz profiler observation from 1701 UTC 13 August 2012 are plotted with the NAM model hourly forecasts (dashed lines) from the 1800 UTC 13 August 2012

model run and valid from 1900 UTC 13 August 2012 to 0400 UTC 14 August 2012 in three-hour intervals. As before, only the NAM forecasts on the chart valid every three hours are plotted on the chart to reduce clutter using the color scheme described previously. To unclutter the model forecast profiles, the LWO can right-click on any line and delete it from the chart.



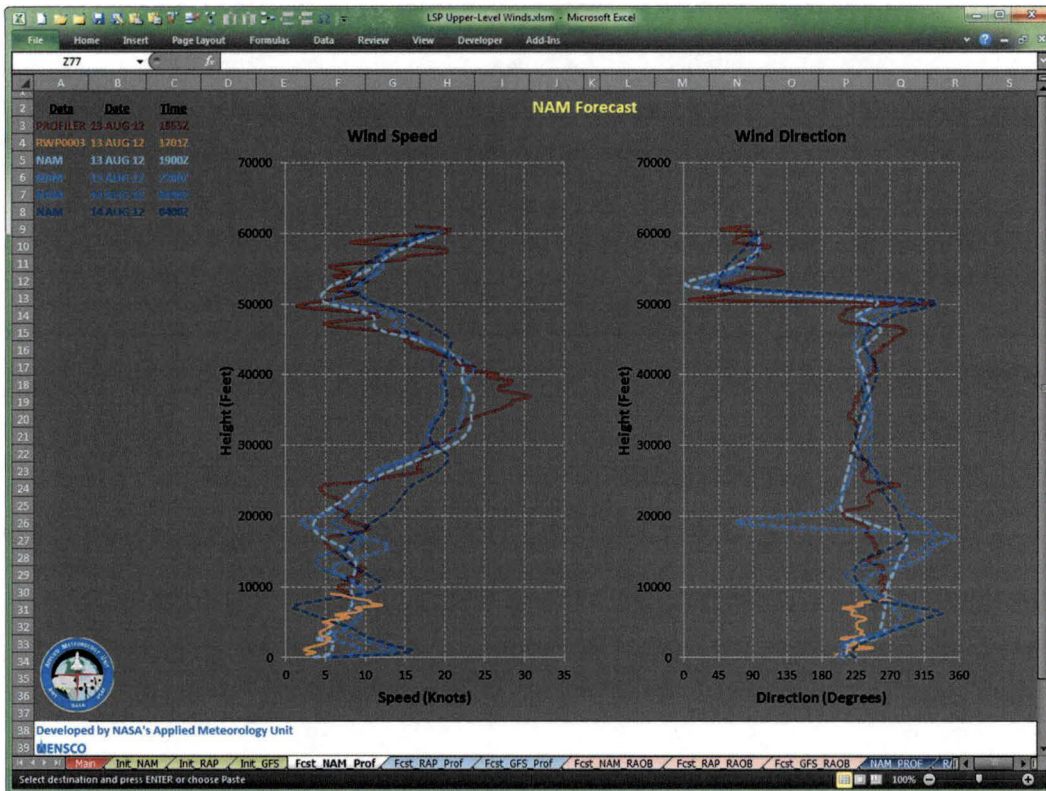


Figure 8. Wind speed (left) and wind direction (right) profiles from the 1655 UTC 13 August 2012 50 MHz profiler observation (dark red lines), 1701 UTC 13 August 2012 915 MHz profiler observation (orange lines) and NAM model forecasts (dashed blue lines) valid every three hours from 1900 UTC 13 August 2012 through 0400 UTC 14 August 2012 plotted in Excel. Data type, date and time are shown in the upper left of the chart.

### 3. GRAPHICAL USER INTERFACE

A single Excel workbook file serves as the GUI consisting of 25 tabs, or individual worksheets, that process and format the observations and model data as well as display tabular and graphic information. Within the Excel workbook are 21 modules containing the VBA scripts that control all aspects of the GUI operations based on user input.

#### 3.1. User Interface

The AMU developed a menu on the Main tab in the Excel GUI as shown in Figure 9. Upon opening the Excel workbook file, the Main tab is displayed and VBA scripts automatically run to determine and display the date, local time, UTC time and the results of the test for DST (Eastern time since the tool will only be used in the Eastern Time zone) in the second row of the worksheet. There are three menus containing user-selectable model data and observations. The first menu, "Initialize models", is designed to allow the LWOs to compare each model's 0-hour forecast to the 50 MHz profiler, 915 MHz profiler and AMPS observations to determine

which model is most accurate. The second menu, "Compare Forecasts to Profiler Observations", allows the LWOs to compare each model's 12 hour forecasts in 3-hour time increments to the latest available 50 MHz and 915 MHz profiler observations. The third menu, "Compare Forecasts to RAOBS", allows the LWOs to compare each of the model's 12 hour forecasts in 3-hour time increments to the latest available 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. The original file is never overwritten when the user chooses one of these buttons to exit. The button with green text will exit Excel and save a non-macro copy of the file in .xlsx format (Excel 2010) without any VBA code, but it will include all data and charts in the 25 tabs created during the session. 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. The button with red text will exit Excel and will not save any version of the file.



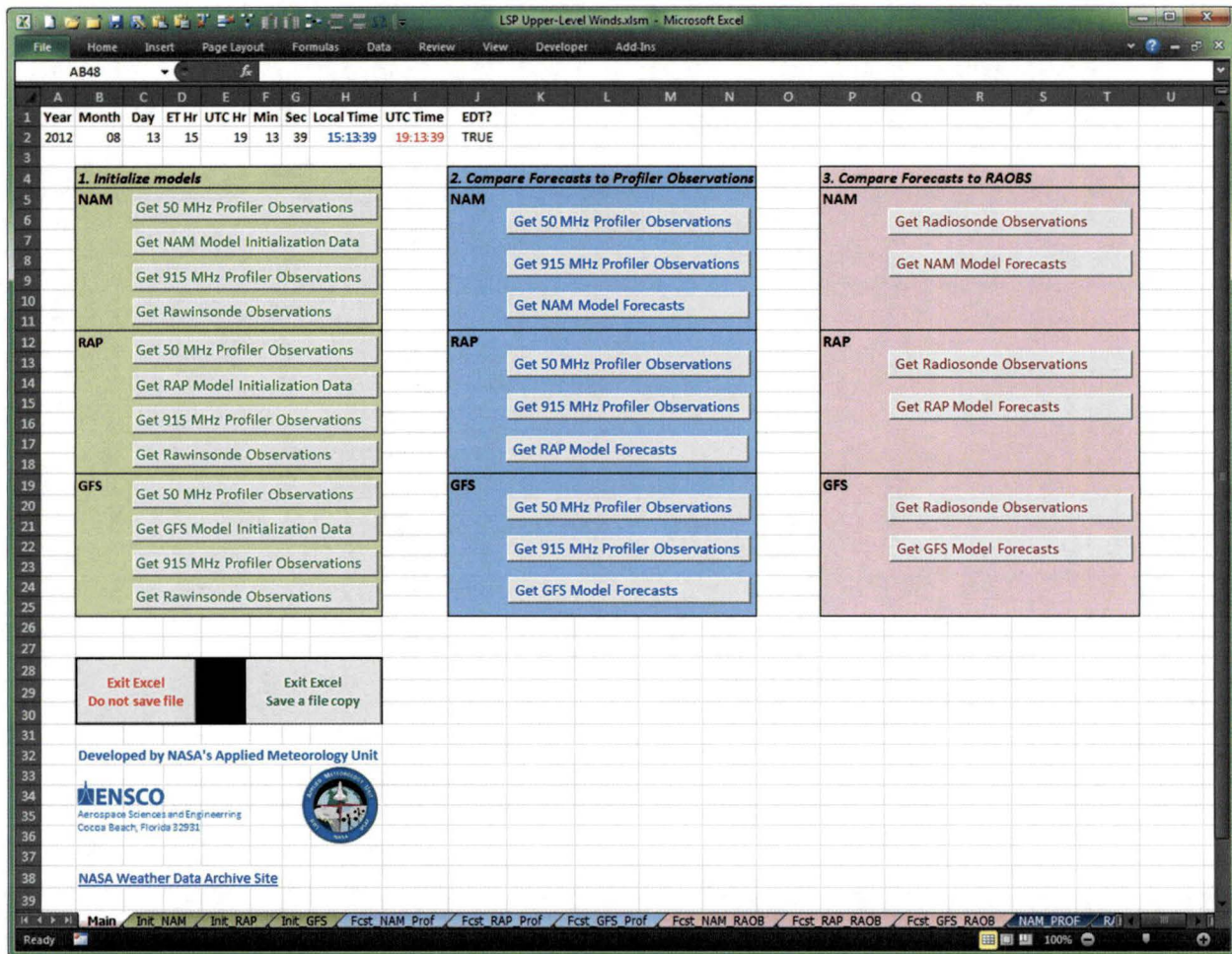


Figure 9. Main tab of the Excel GUI shows the primary user interface for selecting model data and observations to display in the other tabs of the workbook.

### 3.2. Data Display

Multiple tabs were used to organize and process the textual and graphics data and displays. As shown in Figure 9, the tabs along the bottom of the workbook are color-coded to help users identify common displays or actions. The first nine tabs following the Main tab are color-coded to match the three colored menus on the Main tab. For example, the second light blue tab after the Main tab called "Fcst\_RAP\_Prof" corresponds to the light blue menu used to compare the RAP model forecasts to the profiler observations, while the third pink tab after the Main tab called "Fcst\_GFS\_RAOB" corresponds to the pink menu used to compare the GFS model forecasts to the AMPS observations. After the LWO makes a choice from a menu, the resulting charts are displayed in the tab corresponding to the menu color, model and observation type.

Textual observation and model data are stored in separate tabs based on the model data start time that

the observations will be compared to. This insures the observations are time-matched to each model. When an LWO chooses a model/observation pair from the menu, a VBA script automatically retrieves the observation and model data files from their respective servers, saves the raw data in the appropriate tabs, and then reformats the data to create charts and make the textual data easy for the LWO to read. An example of a reformatted textual observation data file from AMPS at 1500 UTC on 13 August 2012 is shown in Figure 10. Similarly, an example of a reformatted textual GFS model data file from the 1200 UTC 13 August 2012 model run is shown in Figure 11. Besides looking at the example charts shown in Figures 3-8 that are created from the reformatted text data, the LWO can inspect the observations and model data displayed in neatly organized Excel spreadsheets in formats they are familiar with.



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Height (ft)	Direction	Speed (kts)
16	220	7.0
1000	215	9.7
2000	222	9.6
3000	238	10.7
4000	232	14.1
5000	239	13.8
6000	236	13.2
7000	227	11.5
8000	240	13.9
9000	242	15.0
10000	238	14.9
11000	235	17.2
12000	233	23.7
13000	227	24.3
14000	241	20.6
15000	248	19.0
16000	243	14.9
17000	243	12.2
18000	224	9.9
19000	185	8.5
20000	177	5.8
21000	195	2.9
22000	145	2.2
23000	8	6.0
24000	41	11.2
25000	38	10.3
26000	50	8.3

Figure 10. AMPS data after being ingested into Excel and reformatted displaying the sensor type and location, date, time, height, wind direction and speed.

LSP Upper-Level Winds.xlsm - Microsoft Excel

FileHomeInsertPage LayoutFormulasDataReviewViewDeveloperAdd-Ins

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A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Model:	GFS			Model:	GFS				Model:	GFS			
2	Location:	74794			Location:	74794				Location:	74794			
3	Date:	13 AUG 12			Date:	13 AUG 12				Date:	13 AUG 12			
4	Time:	1200Z			Time:	1500Z				Time:	1800Z			
5		Height (ft)	Direction	Speed (kts)		Height (ft)	Direction	Speed (kts)			Height (ft)	Direction	Speed (kts)	
6		90	214	6.3		90	223	4.3			88	167	5.4	
7		256	213	6.5		254	225	4.4			255	170	5.5	
8		443	213	6.5		444	225	4.7			444	174	5.5	
9		659	212	6.6		659	227	4.8			663	178	5.4	
10		900	212	7.1		904	228	5.2			907	192	5.6	
11		1179	210	7.7		1180	229	5.7			1185	205	6.0	
12		1492	210	8.5		1494	231	6.5			1501	217	6.8	
13		1847	212	9.6		1850	235	7.4			1858	226	7.6	
14		2245	216	10.6		2249	239	8.2			2259	233	8.3	
15		2697	220	11.4		2701	242	9.2			2714	237	9.3	
16		3205	223	12.2		3210	245	10.3			3221	241	10.2	
17		3774	224	13.1		3777	246	11.1			3793	244	11.0	
18		4412	224	13.9		4414	246	11.7			4432	245	12.0	
19		5124	225	14.6		5127	243	12.3			5142	245	13.3	
20		5916	226	14.8		5916	240	12.8			5933	243	14.2	
21		6792	229	15.2		6793	237	13.4			6809	242	14.9	
22		7759	232	15.6		7757	235	14.4			7779	241	16.3	
23		8821	232	16.9		8820	232	16.5			8840	240	18.0	
24		9982	229	18.7		9978	230	19.2			10000	239	20.1	
25		11246	229	20.7		11240	230	21.8			11263	239	22.1	
26		12612	231	21.8		12608	231	23.6			12633	237	23.5	
27		14082	235	20.9		14076	232	22.7			14103	235	22.9	
28		15658	238	16.0		15653	234	16.7			15678	238	18.3	
29		17341	238	10.3		17333	235	9.9			17361	242	11.6	
30		19129	197	2.0		19123	189	2.6			19155	231	4.0	
31		21026	73	4.1		21015	87	3.5			21046	45	1.1	
32		23013	28	4.6		23004	15	6.0			23038	17	6.5	

Ready

For RAP RADOB For GFS RADOB NAM\_PROF RAP\_PROF GFS\_PROF NAM\_RADOB RAP\_RADOB GFS\_RADOB NAM\_50\_MH RAP\_50\_MH GFS\_50\_MH

100%

Figure 11. GFS model three-hour forecast data after being ingested into Excel and reformatted displaying the model type and location, date, time, height, wind direction and speed for each three-hour forecast interval.



#### 4. SUMMARY AND FUTURE WORK

The LWOs requested the AMU develop a capability in the form of a GUI that would allow them to plot upper-level wind speed and direction observations and then overlay point forecast profiles from the NCEP NAM, RAP and GFS models to assess the performance of these models. The AMU developed an Excel-based GUI for the LWOs to rapidly assess the model forecast of upper-level winds by comparing them to the CCAFS AMPS rawinsondes and the KSC 50 MHz and 915 MHz wind profilers and provide that information to the launch directors and other decision makers. The GUI allows the LWOs to first initialize the models by comparing the 0-hour model forecasts to the observations and determine which model has the best performance. The LWOs can then display the desired model forecasts in 3-hour intervals from the current time through 12 hours.

The AMU wrote Excel VBA scripts that drive the GUI by automatically acquiring, downloading and processing the observations and model point forecast data, and then displaying the resulting output in text format in Excel spreadsheets and in graphic format as

Excel charts. The output of the observational data provides the LWO with the observation type and location, date and time, height, and wind direction and speed. The output of the model data provides the LWO with the model name and forecast point location, date and time of the model start and forecast intervals, height, and wind direction and speed.

In the future, the AMU would like to add wind profile forecasts from a local high resolution version of the Weather Research and Forecasting (WRF) model. The AMU is working on a task to assess and implement a high temporal and horizontal resolution WRF to be run locally. The intent of this task is to determine the optimum physics schemes and data assimilation methods to run WRF over east-central Florida on a routine basis. Once WRF is running routinely, the WRF forecasts could be added to this tool and used in the same manner as the NCEP NAM, RAP and GFS model forecasts.

The final report for this work is available on the AMU website at <http://science.ksc.nasa.gov/amu>.

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