Applied Meteorology Unit (AMU) Quarterly Report

31 July 2011 Third Quarter FY-11 Contract NNK06MA70C

In this issue:

STS-134: Shuttle Endeavour's Final Launch May 16, 2011 08:56 EDT (http://mediaarchive.ksc.nasa.gov/detail.cfm?mediaid=52897)

Launch Support

Mr. Wheeler and Dr. Merceret supported the Atlas V launch on 7 May.

Dr. Watson and Dr. Merceret supported the launch of Shuttle Endeavour on 16 May.

This Quarter's Highlights

The AMU Team completed one task and continued work on three others:

- Mr. Wheeler completed a study for the 30th Weather Squadron at Vandenberg Air Force Base in California in which he found precursors in weather observations that will help the forecasters determine when they will get strong wind gusts at their northern towers. The final report is now on the AMU website at http://science.ksc.nasa.gov/amu/final-reports/30ws-north-base-winds.pdf.
- Dr. Watson continued work on the second phase of verifying the performance of the MesoNAM weather model at Kennedy Space Center (KSC) and Cape Canaveral Air Force Station (CCAFS).
- Ms. Crawford continued work to improve the AMU peak wind tool by analyzing wind tower data to determine peak wind behavior during times of onshore and offshore flow.
- Dr. Bauman continued updating lightning climatologies for KSC/CCAFS and other airfields around central Florida and created new climatologies for moisture and stability thresholds.

ENSCO

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

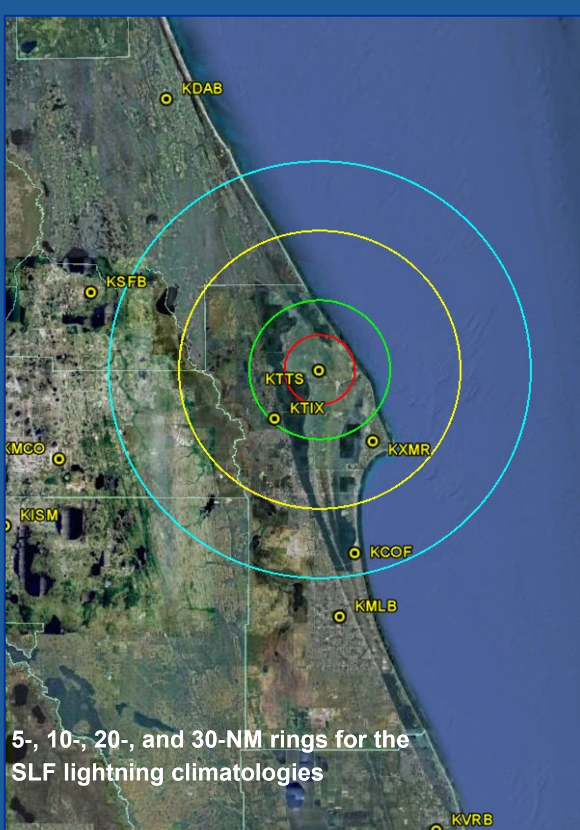
Quarterly Task Summaries

This section contains summaries of the AMU activities for the third quarter of Fiscal Year 2011 (April - June 2011). 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.

Peak Wind Tool for User LCC, Phase IV (Page 4)

Purpose: Recalculate the Phase III cool season peak wind statistics using onshore and offshore flow as an added stratification. Peak winds are an important forecast element for launch vehicles, but the 45th Weather Squadron (45 WS) indicates that they are challenging to forecast. The forecasters have noticed a difference in behavior of tower winds between onshore and offshore flow. Recalculating the statistics after stratifying by these flows could make them more robust and useful to operations.

Accomplished: The upwind sectors were determined for each tower sensor, and then the upwind data were stratified by onshore/offshore flow before calculating the hourly climatologies. Irregularities in the hourly values prompted a closer look at the tower locations and sensor orientations. New information about the towers led to changes in the upwind sector directions, and new hourly climatologies were calculated for each sensor, month and upwind stratification. The relationships between hourly gust factors and a solar parameter showed promise. Due to issues with the code used to calculate the mixed layer height, the goal of stratifying the data by stability was dropped in order to allow the task to be completed on time.



5-, 10-, 20-, and 30-NM rings for the SLF lightning climatologies

Situational Lightning Climatologies for Central Florida, Phase V (Page 7)

Purpose: Update the existing lightning climatology to improve operational weather support to Kennedy Space Center (KSC), Cape Canaveral Air Force Station (CCAFS), Patrick Air Force Base (PAFB), and commercial and general aviation across central Florida. The update includes adding more years of data to the database, adding more sites and adding stratifications for moisture and stability parameters. These updates will provide climatologies for new sites for which the 45 WS and National Weather Service (NWS) have forecast responsibility, and to help forecasters distinguish lightning days that are more active from those that are less active within the same flow regime.

Accomplished: Completed lightning climatologies for all 34 primary and backup sites with the precipitable water stratification and extended period of record. Updated the graphical user interface (GUI) and delivered it to the customers. Selected Thompson Index (TI) as the stability parameter stratification and tested the TI stratification on one site to assess the impact to the climatologies due to the reduced sample size.

Quarterly Task Summaries
(continued)

Delta II at VAFB
Photo by Thom Baur/Boeing

Vandenberg Air Force Base North Base Wind Study (Page 10)

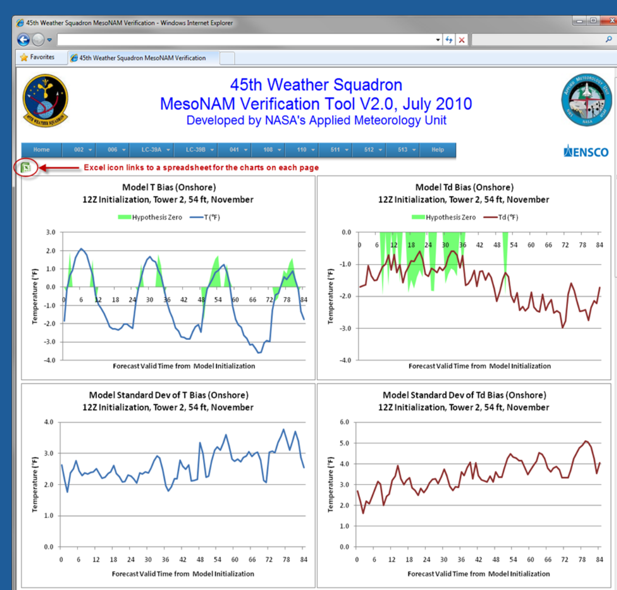
Purpose: Analyze local wind tower, surface, upper air and sounding data from Vandenberg Air Force Base (VAFB) to find precursors to high wind events in the north base towers. The 30 WS states that terrain influences the unpredicted strong northeast winds that have been measured on several of the north base wind towers and exceed their 35 kt warning criteria. This study will examine those influences and document any precursors that may be found that will assist forecasters in analyzing their wind warning criteria.

Accomplished: The VAFB wind tower data analysis was completed. The final report was completed after making modifications suggested in the internal MAU and external customer review and is now available on the AMU website: http://science.ksc.nasa.gov/amu/final-reports/30ws-north-base-winds.pdf.

MesoNAM Verification Phase II (Page 11)

Purpose: Update the current tool that provides objective verification statistics of the 12-km North American Mesoscale (NAM) model (MesoNAM) for CCAFS and KSC. This tool helps the Launch Weather Officers understand the model's performance when they use it to evaluate launch commit criteria (LCC) during launch operations. The modifications include adding a year of observations and model output data to the original database. The objective analysis consists of comparing the MesoNAM forecast winds, temperature and moisture to the observed values at the KSC/CCAFS wind towers used to evaluate LCC.

Accomplished: Modified the existing Phase I scripts to reformat and process MesoNAM forecast and wind tower data into Excel worksheets. The modifications were to stratify the tower data by onshore and offshore flow and compute the daily bias. All the data from Phase I were merged with the data from this task to compute the bias, standard deviation of bias, root mean square error and hypothesis zero tests. Also, three more months of data were added to the period of record.



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

Peak Wind Tool for User LCC, Phase IV (Ms. Crawford)

The peak winds are an important forecast element for the Expendable Launch Vehicle and Space Shuttle programs. As defined in the Launch Commit Criteria (LCC) and Shuttle Weather Flight Rules, each vehicle has peak wind thresholds that cannot be exceeded in order to ensure safe launch and landing operations. The 45th Weather Squadron (45 WS) and the Spaceflight Meteorology Group (SMG) indicate that peak winds are a challenging parameter to forecast, particularly in the cool season. To alleviate some of the difficulty in making this forecast, the AMU calculated cool season wind climatologies and peak speed probabilities for each of the towers used to evaluate LCC (Figure 1) in Phase I (Lambert 2002). In Phase III (Crawford 2010), the AMU updated these statistics with six more years of data, added new time-period stratifications and created a graphical user interface (GUI) to display the desired values similar to that developed for SMG in Phase II (Lambert 2003). The 45 WS launch weather officers (LWOs) and forecasters have seen marked differences in the tower winds between onshore and offshore flow.Therefore, the 45 WS tasked the AMU to stratify the data by onshore/offshore flow and recalculate the climatologies and probabilities. These modifications will likely make the statistics more robust and useful to operations.

Upwind Stratification

As discussed in the previous AMU Quarterly Report (Q2 FY11),

Figure 1. Map showing the locations of the launch pads and LCC wind towers.

Dr. Merceret continued analyzing relationships between the onshore and offshore gust factors and a solar parameter. After experiencing difficulty in fitting a model to the data, he suggested calculating the hourly values using only observations with directions upwind to each sensor.

The tower geometry is important in determining the upwind sectors. Most of the LCC towers are square and made with scaffold construction. Air can flow through the scaffolding, but will be disturbed as it does. This is reflected in the downwind sensor observations as higher standard deviations in speed and direction and less accurate mean and peak wind values. Figure 2 is a schematic showing the scaffold tower and sensor configuration. The sides of the tower face the cardinal directions of north (0°), west (270°), south (180°) and east (90°). The northwest sensor is mounted on a boom extending west from and parallel to the north face and the southeast sensor is mounted on a boom extending east from and parallel to the south face.

If upwind is defined solely as flow not through the tower, the sector for the northwest sensor would be 180° through 90° moving clockwise, and 0° through 270° for the southeast sensor. However, flow along the edge of the tower can also be turbulent and cause erroneous wind speeds and directions. In operations, the upwind sector is 204° through 68° for the northwest sensor and 23° through 248° for the southeast sensor (Bauman 2010). This provides a buffer of 22°-24° away from the tower sides in order to eliminate this source of turbulence.

Tower 2

The upwind sectors for Tower 2 in this analysis are different than the other towers to the north (Figure 1). The coastline orientation just south of Tower 2 was used to determine upwind for each sensor. For the northwest sensor, the upwind and offshore sector is 226° through 45° (clockwise); for the southeast sensor, the upwind and onshore sector is 46°-225°. These are both 180° sec-

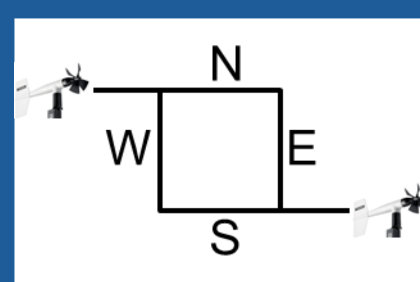


Figure 2. Sensor configuration on the scaffold towers (not to scale).

tors as opposed to the approximate 225° upwind sector described in the previous section. The onshore sectors for the northwest sensor would have been 46°-68° and 204°-225°, 22° and 21° sectors, respectively, for a total of 43° of onshore flow. This is too small to derive meaningful onshore statistics for the northwest sensor. A similar argument can be made for offshore flow at the southeast sensor.

Tower 108

Tower 108 is a scaffold tower, but only has sensors on the southeast side. Therefore, all statistics for this tower will be from the upwind sector for the southeast sensor, 23°-248°, divided into onshore and offshore flow. There will be no statistics calculated for winds from the sector 249°-22°.

Towers 39X

The wind sensors at Space Launch Complex (SLC) 39A and B are mounted at the top of masts, or solid poles, not on scaffold towers as illustrated in Figure 2. Therefore, the upwind sector is all directions 0°-360°. These data were stratified only by onshore and offshore flow as defined in the previous AMU Quarterly Report (Q2 FY11).

Tower Data Issues

Ms. Crawford stratified the upwind sectors by hour and onshore/offshore flow sectors defined in the previous AMU Quarterly Report (Q2 FY11), and then calculated the hourly means and gust factors. Dr. Merceret was able to attain a better fit with linear models using the new values, but found differences between the opposing sensors at some of the towers for onshore flow. He and Ms. Crawford visited the sites and took photos of the towers and the surrounding vegetation and buildings to try and determine the cause of the differences. They did not discover anything that could disturb the flow at any of the towers. They later looked at Google Earth images of the towers and determined that the distance to the coastline for onshore flow was, on average, farther for the southeast sensors than the northwest sensors. Ms. Crawford varied the coastline orientation in the code, but the difference in values remained. Dr. Merceret theorized that the roughness length difference between the sensors due to the difference in distance to the coast is the likely cause.

SLC 41 Towers and Sensors

When visiting the tower sites, they also discovered potential issues with the sensors at SLC 41 due to tower construction and orientation, and sensor placement. The wind sensors at SLC 41 are mounted at 230 ft on two of the four lightning protection towers surrounding the launch pad. The towers are triangular and of lattice construction, and would experience the same issues of disturbed flow through the towers as with scaffold construction. The launch complex is orientated 10°-190°, just 10° east and west of north and south, respectively. The four towers surround the pad with two on the north side and two on the south side. The wind sensors are on the northwest and southeast towers. Figure 3a is a Google Earth image of the lightning protection towers and Figure 3b shows the individual tower shape and orientation, and the location of the sensors on the towers.

Based on data provided by the 45 WS, Ms. Crawford assumed the towers were equilateral triangles and that one side of each sensor tower was parallel to the pad orientation. She also assumed that the sensor booms extended out from the point of the triangles and not parallel to one side. Using these assumptions, the sensor on the northwest tower is on the triangle point directed at 280° and the sensor on the southeast tower is on the point directed at 220° (Figure 3b). The upwind directions for the northwest sensor, including along the sides of the tower, would be 130° through 70° (clockwise), and for the southeast sensor 70° through 10° (clockwise).

Downwind Sector

If a buffer similar to that for the scaffold towers is introduced, there would be a sector to the northeast that would not be upwind from either sensor. For a 20° buffer along each edge, the upwind sector would be 150° through 50° for the northwest sensor and 90° through 350° for the southeast sensor. This leaves a 40°

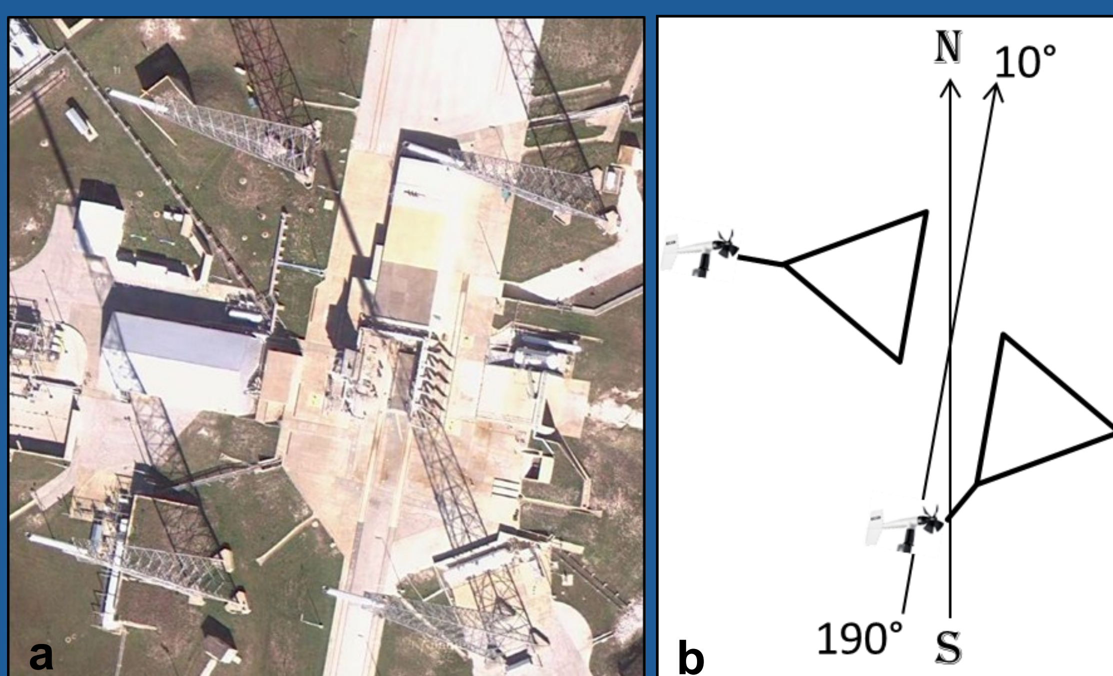


Figure 3. a) Google Earth image of the lightning protection towers at SLC 41 and b) tower shape and orientation, and sensor location. The drawing in 3b is not to scale.

sector from 50°-90° that would be downwind from both sensors and, therefore, not included in the analysis. The winds from this sector have had the lowest peak wind thresholds for some of the launches, making it an important sector from which to have reliable wind observations. Ms. Crawford will use the upwind sectors without a buffer so that all directions can be included in the analysis. This may introduce error into the statistics.

Boom Length

Another issue noted by Dr. Merceret is the length of the boom in relation to the width of the tower. The boom on the southeast tower is shown in Figure 4 extending to the left of the tower. It appears shorter than the width of the tower. A boom that is too short would require the buffer angle from the tower sides be larger. Head winds could also cause a problem due to turbulent back-eddies from wind buffeting the tower. A boom of proper length would put the sensor beyond such a turbulent zone. The World Meteorological Organization (WMO) states that a boom length should be at least three times the width of the tower (WMO 2008) to alleviate exposure to turbulence from the tower. The WMO is not explicit about the type of tower, whether solid or lattice, and it could be that the effective width of the SLC 41 towers is smaller than the actual width. This should be determined so the effects on the resulting wind observations can be evaluated.

Solutions

The simplest and lowest cost solution to solving the downwind sector issue is to move the sensor on the southeast tower to the eastern-most point on that tower. This would ensure that winds from the east-northeast would be upwind of this sensor. The same can be accomplished by moving the sensor on the northwest tower to the northern-most point. Either solution would work, but only one should be chosen so that winds from the east-northeast will be upwind for one of the sensors.

Figure 4. The SLC 41 southeast lightning protection tower and wind sensor, looking west-northwest. The top of the southwest lightning tower is in the background.

The boom length issue should be investigated to determine an optimal length. Depending on length, the boom may also have to be supported to minimize wobble. At the very least, the effects of the current exposure should be determined so LWOs can understand the impacts on the observations they are using to evaluate the LCC.

Upwind, Onshore/ Offshore Sectors

Using the tower and sensor location information discussed above, Ms. Crawford determined the onshore and offshore flow sectors within the upwind sectors for each sensor, shown in Table 1. The line dividing the onshore and offshore sectors for Tower 2 is oriented 45° to 225° parallel to the coastline closest to it (Figure 1). The coastline nearest Towers 6, 108 and 110, and SLCs 39A/B and 41 is oriented approximately 315° to 135°.

Table 1. The LCC wind towers, upwind sector for each side, and the onshore and offshore sectors within the upwind sector. All direction ranges are clockwise.

Tower and Side	*Upwind Sector*	*Upwind Onshore*	*Upwind Offshore*
0020 NW	226°-45°	—	226°-45°
0021 SE	46°-225°	46°-225°	—
0061 NW	204°-68°	316°-68°	204°-315°
0062 SE	23°-248°	23°-135°	136°-248°
SLC 41 NW	130°-70°	316°-70° 130°-135°	136°-315°
SLC 41 SE	70°-10°	316°-10° 70°-135°	136°-315°
108 SE	23°-248°	23°-135°	136°-248°
1101 NW	204°-68°	316°-68°	204°-315°
1102 SE	23°-248°	23°-135°	136°-248°
0393 NW	0°-360°	316°-135°	136°-315°
0394 SE	0°-360°	316°-135°	136°-315°
0397 NW	0°-360°	316°-135°	136°-315°
0398 SE	0°-360°	316°-135°	136°-315°

Stability Determination

Mr. Kienzle of ENSCO's GeoSystem Solutions Division calculated the mixed layer (ML; Stull 1988) height using algorithms developed for transport and diffusion models. Ms. Crawford intended to use the ML height as the proxy for the height of the boundary layer in determining the local scale stability over Kennedy Space Center (KSC) and Cape Canaveral Air Force Station (CCAFS). He delivered the ML data in April and Ms. Crawford began working with them in May. She found a difference between the way the Richardson number was calculated for the ML data and the formula she used previously. Mr. Kienzle determined that the version of the Richardson number he used assumed a wind speed of 0 at the surface. He modified the code with a new version of the Richardson number that uses the wind speed at the first layer of the sounding and began testing the algorithm. He had not completed testing by the end of June, and Ms. Crawford determined that it would be difficult to complete the task on time if she waited for these data to complete this milestone. She met with Mr. Roeder of the 45 WS to discuss the issues, and he directed the AMU to move forward with the onshore/offshore stratifications using only the upwind sectors for each sensor.

Ms. Crawford sent the data stratified as described above to Dr. Merceret for his continued development of a model relating the gust factors (GFs) to a solar parameter – a possible proxy for stratifying by stability. He was able to create good fits of linear models to the GFs and GF standard deviations with the values created from the upwind stratifications. The next step was to compare the probabilities calculated by his models to the Gumbel distribution used in the previous phase (Crawford 2010) and requested by the 45 WS to be used in the current task. Ms. Crawford sent the Gumbel parameters and the stratified data used to create them to Dr. Merceret so he could begin a performance comparison of the two methods.

Statistics

Ms. Crawford completed calculating the hourly climatologies of the 5-minute mean and peak speeds for each month and sensor using the upwind data stratified by onshore and offshore flow. These data are ready for input to the graphical user interface (GUI). Because of the new upwind onshore/offshore stratification, the GUI will be redesigned for the climatologies and probabilities. Ms. Crawford began modifying the GUI to access the new stratifications for the climatology portion.

She also modified and ran the scripts to calculate the Gumbel distributions for the onshore/offshore stratifications to facilitate Dr. Merceret's investigation. At the meeting mentioned above, Mr. Roeder directed the AMU to deliver the Gumbel distributions in the final product and to not wait for the comparison between the Gumbel distributions and the solar parameter models being created by Dr. Merceret.

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

Situational Lightning Climatologies for Central Florida, Phase V (Dr. Bauman)

The threat of lightning is a daily concern during the warm season in Florida. Research has revealed distinct spatial and temporal distributions of lightning occurrence that are strongly influenced by large-scale atmospheric flow regimes. The 45 WS, SMG and National Weather Service in Melbourne, Fla. (NWS MLB) have the responsibility of issuing weather forecasts for airfields located in central Florida. SMG and 45 WS share forecasting responsibility for the SLF depending on the mission. The 45 WS has forecasting responsibility for the CCAFS Skid Strip and Patrick Air Force Base (PAFB) while the NWS MLB is responsible for issuing terminal aerodrome forecasts (TAF) for airports throughout central Florida. In the previous phase (Bauman 2009), Dr. Bauman calculated lightning climatologies for the Shuttle Landing Facility (SLF) and eight other airfields in central Florida based on a 19-year record of cloud-to-ground (CG) lightning data from the National Lightning Detection Network (NLDN) for the warm season months of May through September (1989-2007). The climatologies included the probability of lightning at 5-, 10-, 20- and 30-NM distances from the center point of the runway at each site. The climatologies were stratified by flow regimes with probabilities depicted at 1-, 3-, and 6-hour intervals. This phase updates the previous work by adding 14 sites to the 9-site database including the CCAFS Skid Strip, PAFB and 12 commercial airports. It also adds three years of NLDN data resulting in a 22-year period of record (POR) for the warm season months from 1989-2010. In addition to the flow regime stratification, moisture and stability stratifications will be added to separate more active from less active lighting days within the same flow regime.

PWAT Stratification

Dr. Bauman created the lightning climatologies with the precipitable water (PWAT) stratification for the 34 sites requested by the AMU customers. Figure 5 shows the 34 sites and their locations within each NWS weather forecast office (WFO) area of responsibility. There are six sites in the NWS Jacksonville region, six sites within the NWS Tampa region, seven sites within the NWS Miami region and thirteen sites within the NWS MLB region. Within the NWS MLB region, the 45 WS and SMG share forecasting responsibility for KTTS (SLF) and the 45 WS has fore-

Figure 5. Map of Florida showing the locations of the sites within each of the four NWS WFO regions included in this lightning climatology. From north to south, NWS Jacksonville (cyan), NWS Tampa (green), NWS MLB (yellow) and MWS Miami (magenta). The 45 WS and SMG sites located within the NWS MLB region are shown in red.

casting responsibility for KXMR (CCAFS) and KCOF (PAFB).

Four sounding locations (Figure 6) were used to determine PWAT values for each day in the POR. Dr. Bauman assigned each site to one of the four soundings based on proximity of the site to the sounding location.

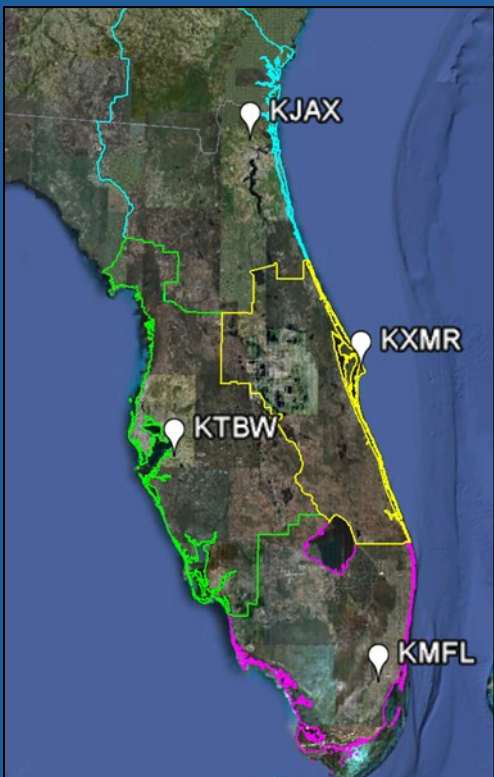


Figure 6. Map of Florida showing the locations of the soundings used to determine the PWAT threshold values. The WFO region outline colors are the same as in Figure 5.

The PWAT stratifications for each sounding location were derived from the climatological surface to 300 mb precipitable water plots (http://www.crh.noaa.gov/unr/?n=pw) created by Mr. Matthew Bunkers, the Science and Operations Officer at the Rapid City, S.D. NWS WFO. Based on discussions with NWS MLB, values below the 25th percentile were considered low, values above the 75th percentile were considered high, and the values between them and inclusive were considered average. The climatological PWAT plot from 1950-2009 for XMR is shown in Figure 7. Table 2 shows the PWAT threshold values for each warm season month from each of the four sounding locations.

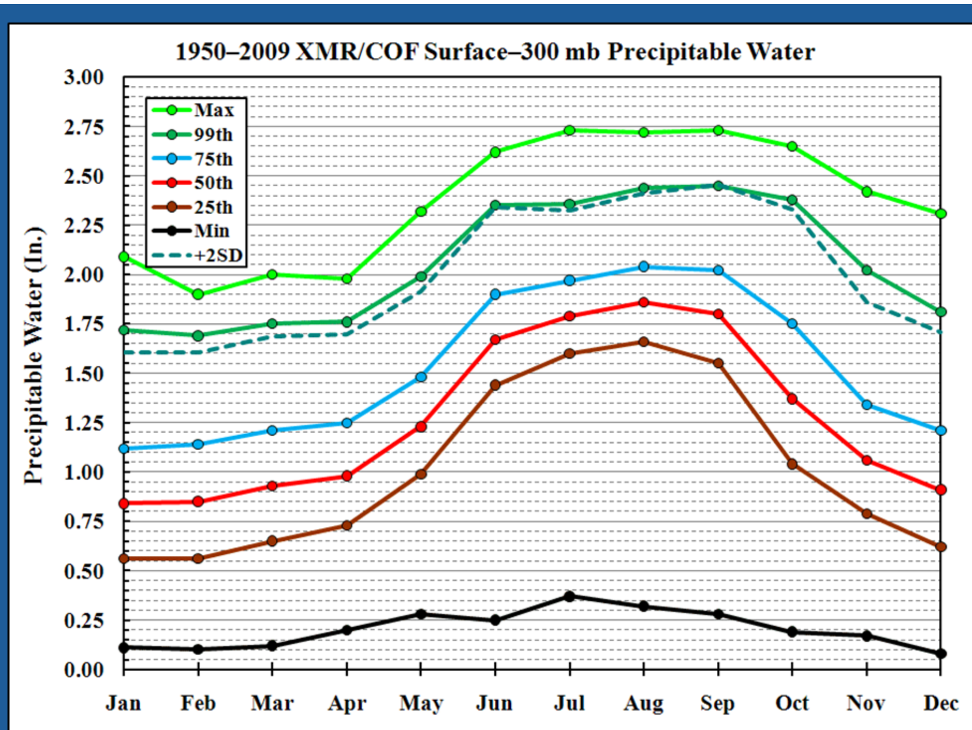


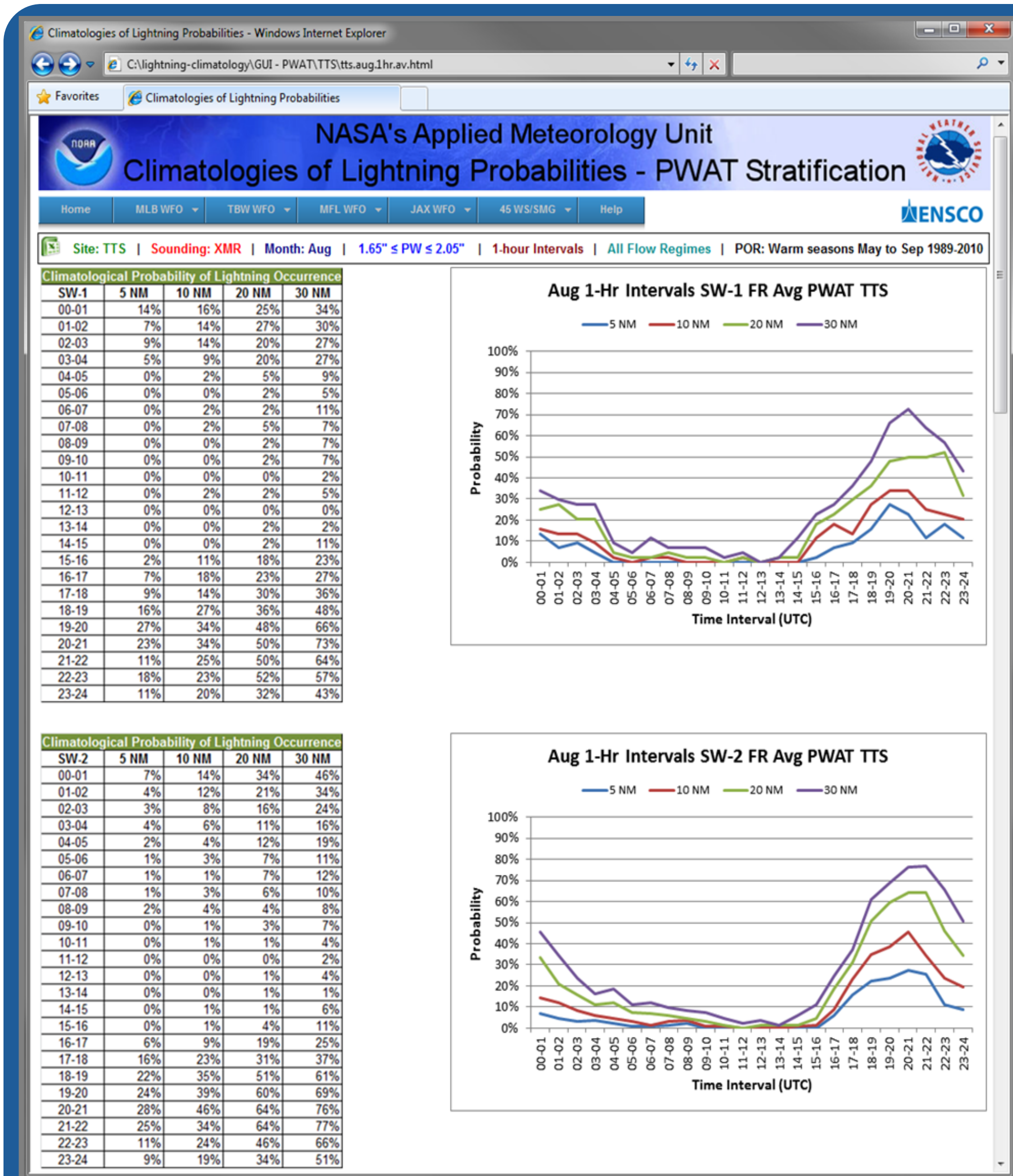
Figure 7. Climatological XMR Precipitable Water plot from the Rapid City, S.D. NWS WFO. The 25th percentile is shown by the brown curve and the 75th percentile by the cyan curve.

Updated GUI

Dr. Bauman updated the GUI with the PWAT stratification lightning probability values and delivered it to the customers prior to the start of the 2011 warm season. The updated GUI (Figure 8, next page) uses a drop-down menu for navigation among the various stratifications. Directly below the navigation menu, there is a data bar showing the site, sounding source, month, PWAT range, time interval, flow regime and POR for the data displayed on the page. On the left side of the data bar is a Microsoft Excel icon that links the user to the spreadsheets containing the all of the data used to create the page being viewed. Each page of the GUI with data shows tables of the climatological probabilities of lightning occurrence and a corresponding chart.

Table 2. PWAT threshold values for each warm season month from each of the four sounding locations. Colors for the low, average and high thresholds correspond to the percentiles in Figure 7.

XMR				JAX			
Month	Low	Average	High	Month	Low	Average	High
May	< 1.00”	1.00” to 1.50”	> 1.50”	May	< 0.90”	0.90” to 1.40”	> 1.40”
Jun	< 1.45”	1.45” to 1.90”	> 1.90”	Jun	< 1.30”	1.30” to 1.80”	> 1.80”
Jul	< 1.60”	1.60” to 1.95”	> 1.95”	Jul	< 1.60”	1.60” to 1.95”	> 1.95”
Aug	< 1.65”	1.65” to 2.05”	> 2.05”	Aug	< 1.60”	1.60” to 2.00”	> 2.00”
Sep	< 1.55”	1.55” to 2.00”	> 2.00”	Sep	< 1.35”	1.35” to 1.90”	> 1.90”
TBW				**MFL**			
Month	Low	Average	High	Month	Low	Average	High
May	< 1.00”	1.00” to 1.45”	> 1.45”	May	< 1.05”	1.05” to 1.55”	> 1.55”
Jun	< 1.40”	1.40” to 1.85”	> 1.85”	Jun	< 1.50”	1.50” to 1.90”	> 1.90”
Jul	< 1.60”	1.60” to 1.95”	> 1.95”	Jul	< 1.60”	1.60” to 1.95”	> 1.95”
Aug	< 1.65”	1.65” to 2.00”	> 2.00”	Aug	< 1.65”	1.65” to 2.00”	> 2.00”
Sep	< 1.55”	1.55” to 1.95”	> 1.95”	Sep	< 1.65”	1.65” to 2.05”	> 2.05”



Climatological Probability of Lightning Occurrence

SW-1	5 NM	10 NM	20 NM	30 NM
00-01	14%	16%	25%	34%
01-02	7%	14%	27%	30%
02-03	9%	14%	20%	27%
03-04	5%	9%	20%	27%
04-05	0%	2%	5%	9%
05-06	0%	0%	2%	5%
06-07	0%	2%	2%	11%
07-08	0%	2%	5%	7%
08-09	0%	0%	2%	7%
09-10	0%	0%	2%	7%
10-11	0%	0%	0%	2%
11-12	0%	2%	2%	5%
12-13	0%	0%	0%	0%
13-14	0%	0%	2%	2%
14-15	0%	0%	2%	11%
15-16	2%	11%	18%	23%
16-17	7%	18%	23%	27%
17-18	9%	14%	30%	36%
18-19	16%	27%	36%	48%
19-20	27%	34%	48%	66%
20-21	23%	34%	50%	73%
21-22	11%	25%	50%	64%
22-23	18%	23%	52%	57%
23-24	11%	20%	32%	43%

Climatological Probability of Lightning Occurrence

SW-2	5 NM	10 NM	20 NM	30 NM
00-01	7%	14%	34%	46%
01-02	4%	12%	21%	34%
02-03	3%	8%	16%	24%
03-04	4%	6%	11%	16%
04-05	2%	4%	12%	19%
05-06	1%	3%	7%	11%
06-07	1%	1%	7%	12%
07-08	1%	3%	6%	10%
08-09	2%	4%	4%	8%
09-10	0%	1%	3%	7%
10-11	0%	1%	1%	4%
11-12	0%	0%	0%	2%
12-13	0%	0%	1%	4%
13-14	0%	0%	1%	1%
14-15	0%	1%	1%	6%
15-16	0%	1%	4%	11%
16-17	6%	9%	19%	25%
17-18	16%	23%	31%	37%
18-19	22%	35%	51%	61%
19-20	24%	39%	60%	69%
20-21	28%	46%	64%	76%
21-22	25%	34%	64%	77%
22-23	11%	24%	46%	66%
23-24	9%	19%	34%	51%

Figure 8. An example of a web page for the SLF (TTS) from the updated GUI.

The first level of the navigation menu at the top of the GUI displays links to the home page, the sites for each organization (four NWS WFOs and the 45 WS/SMG) and the help page. The sites associated with each organization are part of the first sub-menu. Figure 9 shows an example of a fully expanded drop-down menu from the menu bar for the SLF (TTS). To navigate to a particular data stratification, the user moves the mouse over the menu bar to choose an organization and a list of the sites drops down. Then the user moves the mouse over a site and the Month/Warm Season menu opens, followed by the PWAT stratification based on the sounding associated with the site of choice. The last menu displayed is for the 1-, 3- or 6-hr time interval or flow regime stratification.

Stability Stratification

Dr. Bauman, working with AMU customers, selected Thompson Index (TI) as the stability parameter stratification. The TI was selected based on its use in the Objective Lightning Tool and Severe Weather Tool AMU tasks. In both tools, the TI was objectively selected as a good predictor of lightning and severe weather associated with thunderstorms. The thresholds for TI were derived from those used in the Severe Weather Tool as this was the only source of TI threshold values. Unlike the PWAT thresholds, the TI thresholds were not available for each month but instead were valid for the entire warm season.

Before fully implementing the stability stratification, Dr. Bauman updated scripts for one site, PAFB, with

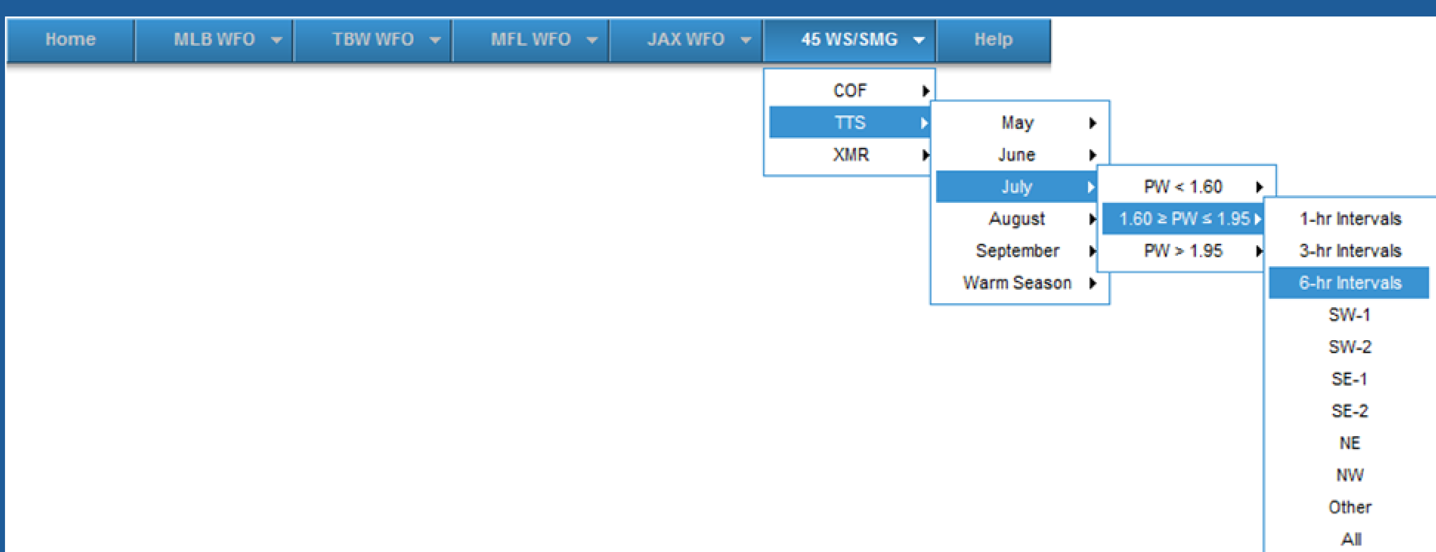


Figure 9. The menu bar used to navigate the GUI (blue bar at top) and an example of an expanded menu bar depicting navigating to the SLF (TTS) during July, for an average PWAT, for a 6-hr time interval.

the TI stratification to assess if adding this stratification to the others already in use in the tool would reduce the sample size to the point where they are statistically insignificant. Based on this one site, it appears that some flow regimes will not have enough days to be statistically significant, but these are the lowest lightning-producing regimes of northeast, northwest and southeast flow. The southwest flow regimes appear to have enough days in the climatology. Therefore, Dr. Bauman will provide the COF files to the customers to assess the results before adding the stability stratification to other sites.

Additional Sites

The NWS MLB requested two more sites be added to the climatology. This request was based on NWS Headquarters Technical Implementation Notice 11-24 dated 9 June 2011 that stated, in part, "Effective Thursday, October 20, 2011, at 1200 Universal Coordinated Time (UTC), the NWS office at Ruskin FL, will begin TAF service for Punta Gorda Regional Airport (KPGD) in Punta Gorda, FL, and for Lakeland Linder Regional Airport (KLAL) in Lakeland, FL." Therefore, NWS MLB will be responsible for issuing TAF service for these sites as part of their backup to the Tampa WFO in Ruskin, FL.

Dr. Bauman requested the NLDN data for these two sites for May-September 1989-2010 from Mr. Roeder of the 45 WS. The 14th Weather Squadron prepared the NLDN data files and Dr. Bauman downloaded them from their servers. While waiting for AMU customer assessment of the TI stratification, Dr. Bauman will add Punta Gorda and Lakeland to the PWAT stratification and update the GUI.

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

Vandenberg Air Force Base North Base Wind Study (Mr. Wheeler)

The 30th Weather Squadron (30 WS) states that terrain influences along the extreme northern fringes of Vandenberg Air Force Base (VAFB) make it difficult for forecasters to issue timely and accurate high wind warnings for that part of the base during northeasterly wind events. These events tend to occur during the winter or early spring when they are under the influence of the Great Basin high pressure weather regime. The LWOs have seen these rapid wind increases in Towers 60, 70 and 71 (Figure 3) along the northern edge of VAFB in excess of the 35 kt warning threshold. For this task, the 30 WS requested the AMU analyze data from days when these towers reported winds in excess of 35 kt and determine if there are any precursors in the observations that would allow the LWOs to better forecast and warn their operational customers of these wind events.

Status

Mr. Wheeler completed the draft of the final report and then modified it after receiving comments from the AMU internal and external customer reviews. He then distributed the report to the customers and submitted the request to NASA for public release of the report. Once approved for public release, Mr. Wheeler posted the final report on the AMU web site.

For more information contact Mr. Wheeler at 321-853-8205 or wheeler.mark@ensco.com.

MesoNAM Verification Phase II (Dr. Watson)

The 45 WS LWOs use the 12-km resolution North American Mesoscale (NAM) model (MesoNAM) text and graphical product forecasts extensively to support launch weather operations. In Phase I of this task (Bauman 2010), the AMU measured the actual performance of the model objectively by conducting a detailed statistical analysis of model output compared to observed values. The model products included hourly forecasts from 0 to 84 hours based on model initialization times of 00, 06, 12 and 18 UTC. The objective analysis compared 3.5 years of MesoNAM forecast winds, temperature and dew point, as well as the changes in these parameters over time, to the observed values from the sensors in the KSC/CCAFS wind tower network. For this task, the 45 WS requested the AMU modify the current tool by adding an additional year of model output to the database and recalculating the verification statistics. The AMU will also update the GUI with the new statistics. This tool helps the LWOs understand the model's performance when they use it to evaluate LCC during launch operations.

Wind Tower Data and MesoNAM Forecast Products

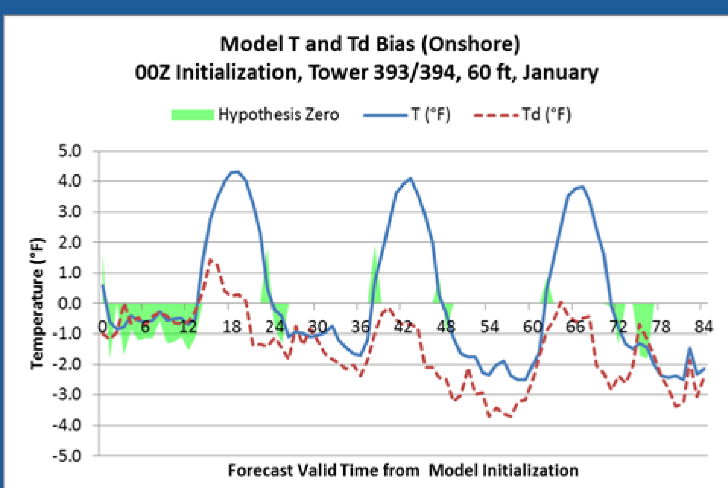
Dr. Watson modified Visual Basic (VB) scripts written by Dr. Bauman that process and reformat the MesoNAM forecasts and wind tower data and prepare them for the objective statistical analysis. Each MesoNAM forecast file contains the initialization and hourly forecasts to 84 hours at a single model initial time of 00, 06, 12 and 18 UTC. As a first step, Dr. Watson reformatted a VB script to split the monthly tower data files into daily files that contain separate Excel worksheets for observations starting each day at 00, 06, 12 and 18 UTC, and extending out to 84 hours to match the MesoNAM forecasts. Next, Dr. Watson modified a script to import the MesoNAM files into Excel spreadsheets and reformat them to match the wind tower observation spreadsheets. This included converting the temperature and dew point from Celsius to Fahrenheit and moving rows and columns in the MesoNAM spreadsheets to match the wind tower spreadsheets. She then merged the wind tower observations spreadsheets with the MesoNAM spreadsheets.

Dr. Watson modified previously written VB scripts to stratify tower data by onshore and offshore flow and to compute the daily bias for each Excel worksheet. She then merged all data from Phase I of this task (Bauman 2010) with the new bias data. The merged Excel worksheets were reformatted to calculate the bias, standard deviation of bias, root mean square error, and hypothesis zero tests of the MesoNAM verification statistics for all towers from Phase I and II of this task.

After completing the statistical analysis for the POR from February 2010 to January 2011, Dr. Watson had enough time to add three more months of data. She followed the steps outlined above for the new data, bringing the POR for Phase II of the task to 15 months (February 2010-April 2011) and the total POR for Phase I and II to 4 years and 7 months (September 2006-April 2011).

Verification Examples

As in Phase I, the model bias of temperature (T) and dew point temperature (Td) showed a diurnal fluctuation for onshore and offshore flow. Figure 1 shows charts of the offshore and onshore model bias of T and Td for SLC 39A using sensors from Towers 0393 (northwest sensor) and 0394 (southeast sensor) for January. The model bias of T was most pronounced with a warm bias of up to 4°F, which is similar to the Phase I results. The model dew point follows the same general trend as the tem-



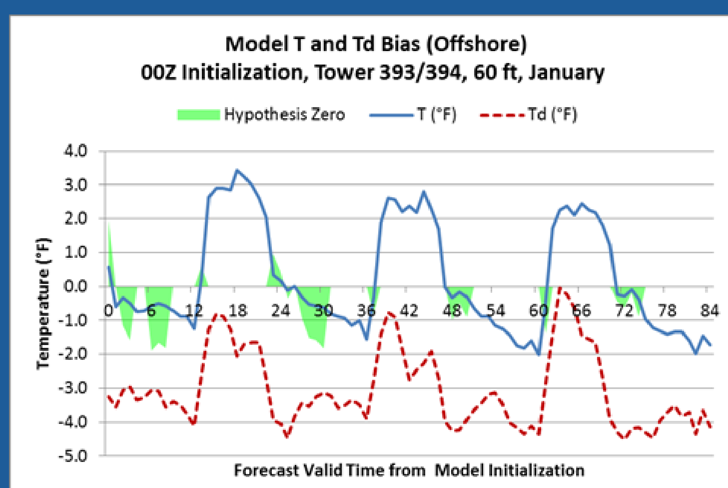


Figure 1. Onshore (left) and offshore (right) charts showing model bias of T (blue line) and Td (red dashed line) and the hypothesis zero results (green) from a 00 UTC model initialization at SLC 39A using observations from sensors at Towers 0393 and 0394 at a height of 60 ft for January 2007-2011.

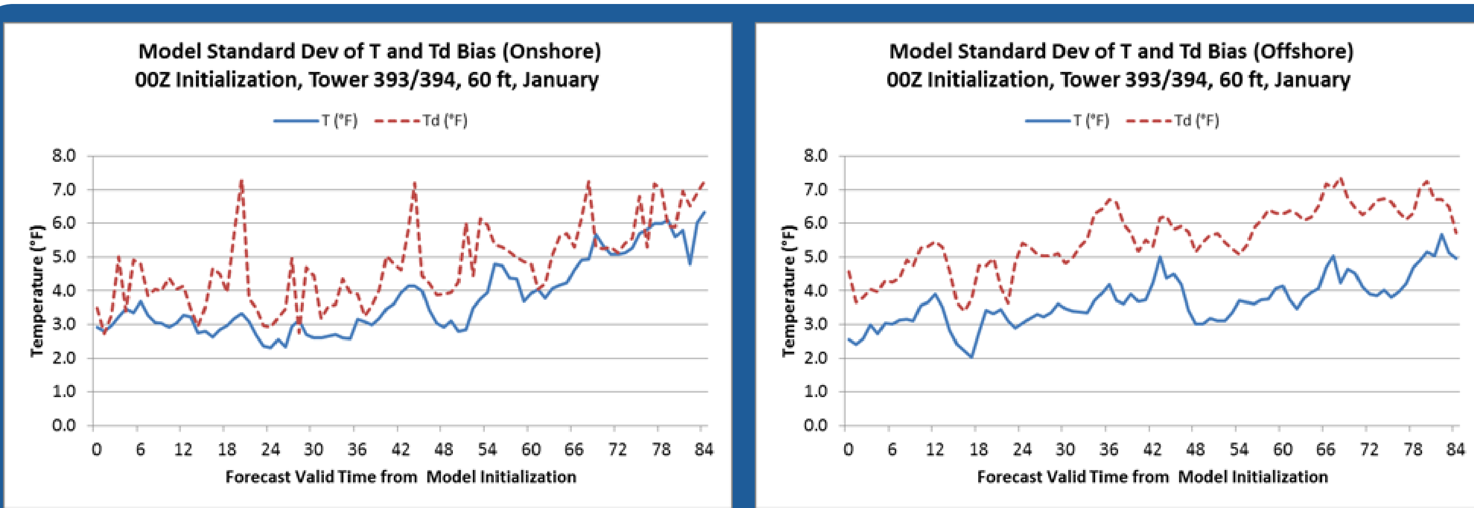


Figure 2. As in Figure 1 except for standard deviation of bias.

perature, but has a negative bias. The green shaded regions indicate the forecast times during which the hypothesis zero test was true. This test was true when the bias at that point was not statistically significantly different from zero and the model forecast for that point was considered to have no error. Figure 2 shows the standard deviation of the bias of T and Td and indicates the model error increased with the forecast period for both parameters with the variance of Td being higher.

The bias of wind speed and wind direction did not show the same diurnal fluctuation as T and Td. Similar to Phase I, the trend of the model error increased during the forecast period for both wind speed and wind direction during January as shown in Figures 3 and 4 for onshore and offshore flow at SLC 39A.

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

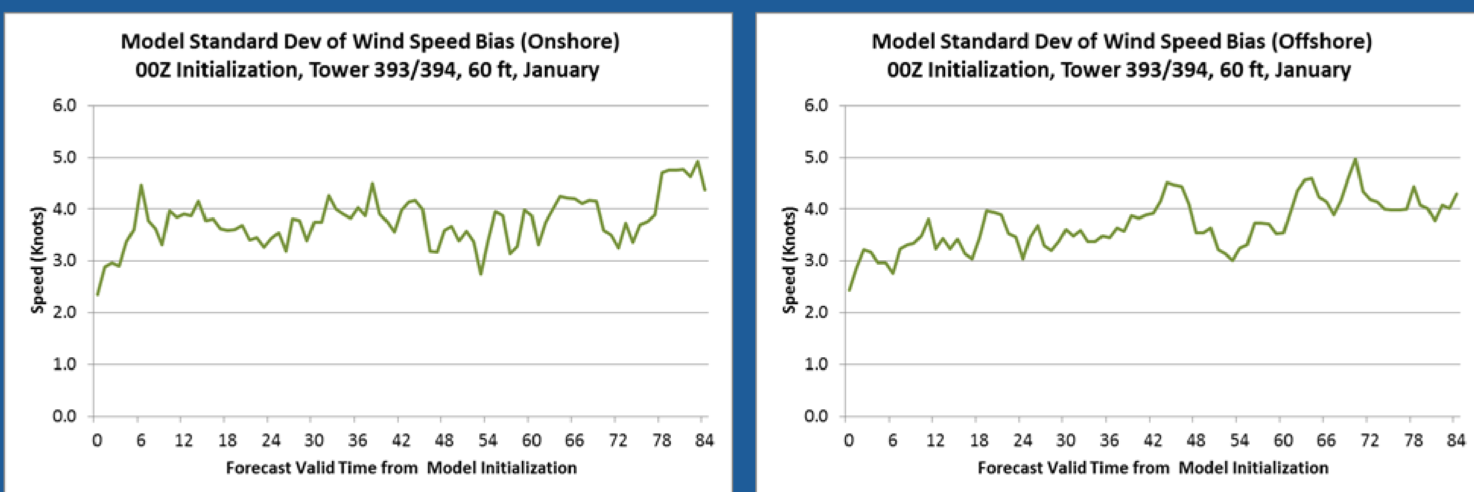


Figure 3. Onshore (left) and offshore (right) charts showing model standard deviation of bias of wind speed from a 00 UTC model initialization at SLC 39A using observations from sensors at Towers 0393 and 0394 at a sensor height of 60 ft for January 2007-2011.

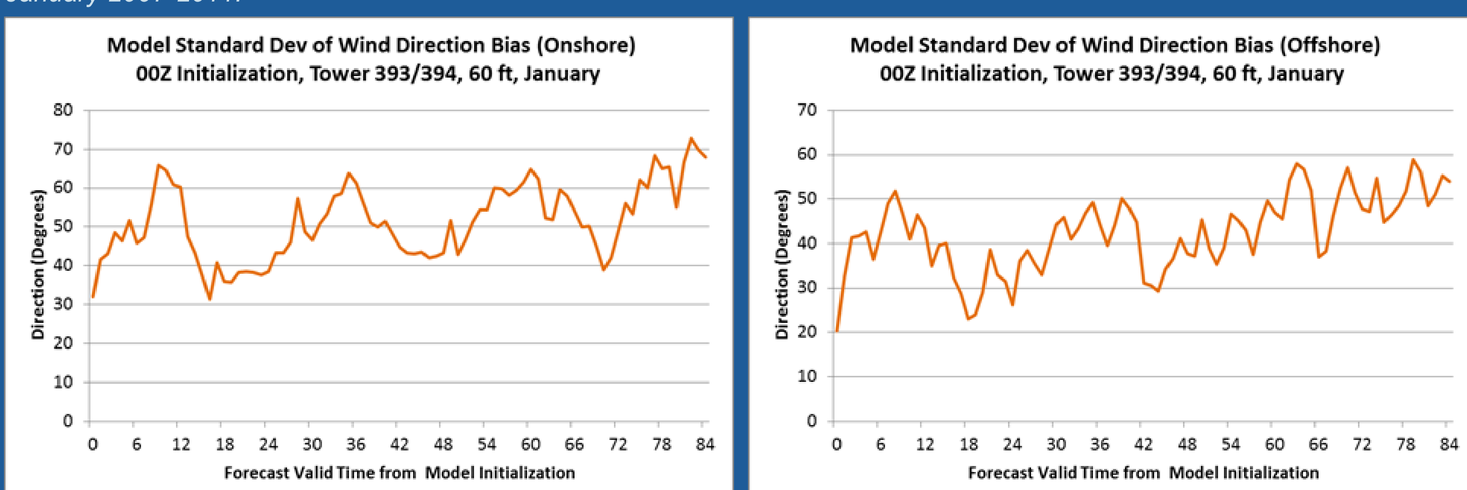


Figure 4. As in Figure 3 except for wind direction.

AMU ACTIVITIES

AMU Chief's Technical Activities (Dr. Huddleston)

After taking over the position of AMU chief from Dr. Merceret in March, Dr. Huddleston continued to become familiarized with the needs of the 45WS and the activities of the AMU. She fixed the 45 WS lightning spreadsheet to account for an error that occurred if a lightning stroke occurred at precisely the same latitude and longitude as the center of the area of interest.

Dr. Huddleston provided an update to the interpolation tool for the Range Reference Atmosphere (RRA) rawinsonde climatology for the 45 WS. The RRA gives mean u-wind, v-wind and wind speed, but does not provide mean wind direction. She added the interpolated mean wind direction for both the temperature and height options.

Dr. Huddleston wrote an Excel Visual Basic program for Mr. Roeder to iterate through two seasons of Total Threat Scores (TTS) from the AMU's Severe Weather Tool with the goal of providing a best fit curve that converts TTS to probability of severe weather.

Dr. Huddleston completed a draft paper of the lightning probability algorithm for the Journal of Spacecraft and Rockets and submitted it for approval.

REFERENCES

Bauman, W. H. III, 2009: Situational Lightning Climatologies for Central Florida: Phase IV. NASA Contractor Report CR-2009-214763, Kennedy Space Center, FL, 39 pp. [Available from ENSCO, Inc., 1980 N. Atlantic Ave., Suite 830, Cocoa Beach, FL 32931 and http://science.ksc.nasa.gov/amu/final-reports/lightning-climo-phase4.pdf.]

Bauman, W. H. III, 2010: Verify MesoNAM Performance. NASA Contractor Report CR-2010-216287, Kennedy Space Center, FL, 31 pp. [Available from ENSCO, Inc., 1980 N. Atlantic Ave., Suite 830, Cocoa Beach, 32931, and at http://science.ksc.nasa.gov/amu/final.html.]

Crawford, W., 2010: Statistical Short-Range Guidance for Peak Wind Forecasts on Kennedy Space Center/Cape Canaveral Air Force Station, Phase III. NASA Contractor Report CR-2010-216281, Kennedy Space Center, FL, 33 pp. [Available from ENSCO, Inc., 1980 N. Atlantic Ave., Suite 830, Cocoa Beach, FL 32931 and http://science.ksc.nasa.gov/amu/final-reports/windstats-phase3.pdf.]

Lambert, W., 2002: Statistical Short-Range Guidance for Peak Wind Speed Forecasts on Kennedy Space Center/ Cape Canaveral Air Force Station: Phase I Results. NASA Contractor Report CR-2002-211180, Kennedy Space Center, FL, 39 pp. [Available from ENSCO, Inc., 1980 N. Atlantic Ave., Suite 830, Cocoa Beach, FL 32931 and http://science.ksc.nasa.gov/amu/final-reports/windstats-phase1.pdf.]

Lambert, W., 2003: Extended Statistical Short-Range Guidance for Peak Wind Speed Analyses at the Shuttle Landing Facility: Phase II Results. NASA Contractor Report CR-2003-211188, Kennedy Space Center, FL, 27 pp. [Available from ENSCO, Inc., 1980 N. Atlantic Ave., Suite 830, Cocoa Beach, FL 32931 and http://science.ksc.nasa.gov/amu/final-reports/windstats-phase2.pdf.]

Stull, R. B, 1988: *An Introduction to Boundary Layer Meteorology.* Kluwer Academic Publishers, Dordrecht, The Netherlands, 670 pp.

World Meteorological Organization, 2008: Guide to Meteorological Instruments and Methods of Observation, WMO-No. 8, Seventh Edition. [Available online at http://www.wmo.int/pages/prog/www/IMOP/publications/CIMO-Guide/CIMO_Guide-7th_Edition-2008.html.]

LIST OF ACRONYMS

14 WS	14th Weather Squadron
30 SW	30th Space Wing
30 WS	30th Weather Squadron
45 RMS	45th Range Management Squadron
45 OG	45th Operations Group
45 SW	45th Space Wing
45 SW/SE	45th Space Wing/Range Safety
45 WS	45th Weather Squadron
AFSPC	Air Force Space Command
AFWA	Air Force Weather Agency
AMU	Applied Meteorology Unit
BSS	Brier Skill Score
CCAFS	Cape Canaveral Air Force Station
CG	Cloud-to-Ground lightning
CSR	Computer Sciences Raytheon
FSU	Florida State University
FY	Fiscal Year
GF	Gust Factor
GSD	Global Systems Division
GUI	Graphical User Interface
JSC	Johnson Space Center
KCOF (COF)	PAFB 4(3)-letter identifier
KSC	Kennedy Space Center
KTTS (TTS)	SLF 4(3)-letter identifier
KXMR (XMR)	CCAFS 4(3)-letter identifier
LCC	Launch Commit Criteria
LWO	Launch Weather Officer
MesoNAM	12-km North American Mesoscale model
ML	Mixed Layer
MSFC	Marshall Space Flight Center
NCEP	National Centers for Environmental Prediction
NLDN	National Lightning Detection Network
NOAA	National Oceanic and Atmospheric Administration
NWS MLB	National Weather Service in Melbourne, FL
PAFB	Patrick Air Force Base
POR	Period of Record
PWAT	Precipitable Water
RRA	Range Reference Atmosphere
SLC	Space Launch Complex
SLF	Shuttle Landing Facility
SMC	Space and Missile Center
SMG	Spaceflight Meteorology Group
TAF	Terminal Aerodrome Forecast
TI	Thompson Index
TTS	Total Threat Score
USAF	United States Air Force
VAFB	Vandenberg Air Force Base
VB	Visual Basic
WFO	Weather Forecast Office
WMO	World Meteorological Organization

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

AMU Quarterly Reports are available on the Internet at http://science.ksc.nasa.gov/amu/.

They are also available in electronic format via email. If you would like to be added to the email distribution list, please contact Ms. Winifred Crawford (321-853-8130, crawford.winnie@ensco.com).

If your mailing information changes or if you would like to be removed from the distribution list, please notify Ms. Crawford or Dr. Lisa Huddleston (321-861-4952, Lisa.L.Huddleston@nasa.gov).

Distribution

NASA HQ/AA/ W. Gerstenmaier
NASA KSC/AA/R. Cabana
NASA KSC/KT-C/J. Perotti
NASA KSC/LX/P. Phillips
NASA KSC/MK/L. Cain
NASA KSC/NEM50/ L. Huddleston
NASA KSC/PH/ R. Willcoxon
NASA KSC/PH/M. Leinbach
NASA KSC/PH/S. Minute
NASA KSC/PH-A2/D. Lyons
NASA KSC/PH-3/J. Madura
NASA KSC/PH-3/F. Merceret
NASA KSC/PH-3/J. Wilson
NASA KSC/SA/M. Wetmore
NASA KSC/SA/H. Garrido
NASA KSC/SA/B. Braden
NASA KSC/VA/A. Mitskevich
NASA KSC/VA-2/C. Dovale
NASA JSC/WS8/F. Brody
NASA JSC/WS8/B. Hoeth
NASA JSC/WS8/ K. Van SpeyBroeck
NASA MSFC/EV44/D. Edwards
NASA MSFC/EV44/B. Roberts
NASA MSFC/EV44/R. Decker
NASA MSFC/EV44/H. Justh
NASA MSFC/MP71/G. Overbey
NASA MSFC/SPoRT/ G. Jedlovec
NASA DFRC/RA/E. Teets
NASA LaRC/M. Kavaya
45 WS/CC/S. Cahanin
45 WS/DO/L. Shoemaker
45 WS ADO/W. Whisel
45 WS/DOR/M. McAleenan
45 WS/DOR/M. Buchanan
45 WS/DOR/J. Smith
45 WS/DOR/R. Parker
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/SYA/J. Saul
45 WS/SYR/W. Roeder
45 RMS/CC/T. Rock
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
CSR 4500/J. Osier
CSR 4500/T. Long
CSR 7000/M. Maier
SLRSC/ITT/L. Grier
SMC/RNP/M. Erdmann
SMC/RNP/T. Nguyen
SMC/RNP/R. Bailey
SMC/RNP(PRC)/K. Spencer
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/ C. Cantrell
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 WS/DO/J. Roberts
30 WS/DOR/D. Vorhees
30 WS/OSS/OSWS/ M. Schmeiser
30 WS/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/C. Donohue
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/FRB/GSD/J. McGinley
Office of the Federal Coordinator for Meteorological Services and Supporting Research/ R. Dumont
Boeing Houston/S. Gonzalez
Aerospace Corp/T. Adang
ITT/G. Kennedy
Timothy Wilfong & Associates/ T. Wilfong
ENSCO, Inc/J. Clift
ENSCO, Inc./E. Lambert
ENSCO, Inc./A. Yersavich
ENSCO, Inc./S. Masters