AMU

Applied Meteorology Unit

Quarterly Report
Second Quarter FY-13
30 April 2013

Infusing Weather Technology Into Aerospace Operations

Contract NNK12MA53C/DRL-003 DRD-004

In this issue:

Atlas 5 launching the NASA / USGS LDCM on 11 February 2013 at VAFB, CA (http://www.nasa.gov/mission_pages/landsat/launch/gallery/Gallery-index.html/, image credit: NASA/Kim Shiflett)

This Quarter's Highlights

The AMU team worked on seven tasks for their customers:

- Ms. Crawford continued work on the objective lightning forecast task for airports in east-central Florida, and began work on developing a dual-Doppler analysis with local Doppler radars.
- Ms. Shafer continued work for Vandenberg Air Force Base on an automated tool to relate pressure gradients to peak winds.
- Dr. Huddleston continued work to develop a lightning timing forecast tool for the Kennedy Space Center/Cape Canaveral Air Force Station area.
- Dr. Bauman continued work on a severe weather forecast tool focused on east-central Florida.
- Mr. Decker began developing a wind pairs database for the Launch Services Program to use when evaluating upper-level winds for launch vehicles.
- Dr. Watson began work to assimilate observational data into the high-resolution model configurations she created for Wallops Flight Facility and the Eastern Range.

Launch Support

Ms. Shafer and Dr. Merceret supported the Atlas 5 launch on 30 January.

Dr. Watson and Dr. Merceret supported the Falcon 9 launch on 1 March.

Dr. Bauman and Dr. Huddleston supported the Atlas 5 launch on 19 March.

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Quarterly Task Summaries

This section contains summaries of the AMU activities for the second quarter of Fiscal Year 2013 (January-March 2013). The accomplishments on each task are described in more detail in the body of the report starting on the page number next to the task name.

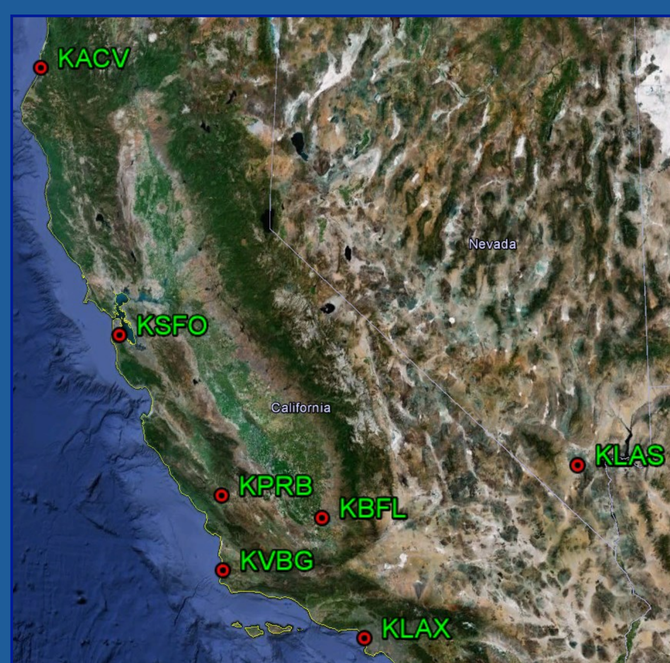
Objective Lightning Probability Forecasts for East-Central Florida Airports (Page 5)

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

Purpose: Develop an objective lightning probability forecast tool for commercial airports in east-central Florida to help improve the lightning forecasts in the warm season. The forecasters at the National Weather Service in Melbourne, FL (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 45th Weather Squadron (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: Modified the graphical user interface (GUI) to display the output from the lightning probability forecast equation for each station, month and time period stratification, and added a feature to output the probability values for all time periods in one form. Tests by NWS MLB forecasters indicated the GUI will be useful in operations.

Vandenberg AFB Pressure Gradient Wind Study (Page 7)



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

Accomplished: Developed a mean sea level pressure (MSLP) database containing observations from seven regional observing stations identified by the 30 OSS. These data were quality controlled and organized by synoptic regime and observing station pair to evaluate PGs between stations when peak winds ≥ 40 kt were observed. Began evaluating PGs for each station pair organized by synoptic regime.

Quarterly Task Summaries
(continued)

First Cloud-to-Ground Lightning Timing Study (Page 10)


http://spaceweather.com/swpod2009/31may09/Schaefers1.jpg

Purpose: Develop a tool that provides the distribution of first cloud-to-ground (CG) lightning times in the Kennedy Space Center (KSC)/Cape Canaveral Air Force Station (CCAFS) lightning warning circles to assist the 45 WS customers when planning potentially hazardous outdoor activities. The AMU will determine if there is a relationship between speed-stratified flow regimes and the time of the first CG strike. This relationship, if it exists, would be used in a final tool to assist forecasters in determining when the first CG lightning will occur on KSC/CCAFS.

Accomplished: Performed statistical tests on the associations between the first CG strike and the speed-stratified flow regime of the day. Created a GUI using the Slicers feature in Excel 2010 showing the number of times the first strike occurred in each hour for any combination of stratifications, including the sea breeze flow regime, speed, month, and whether lightning occurred

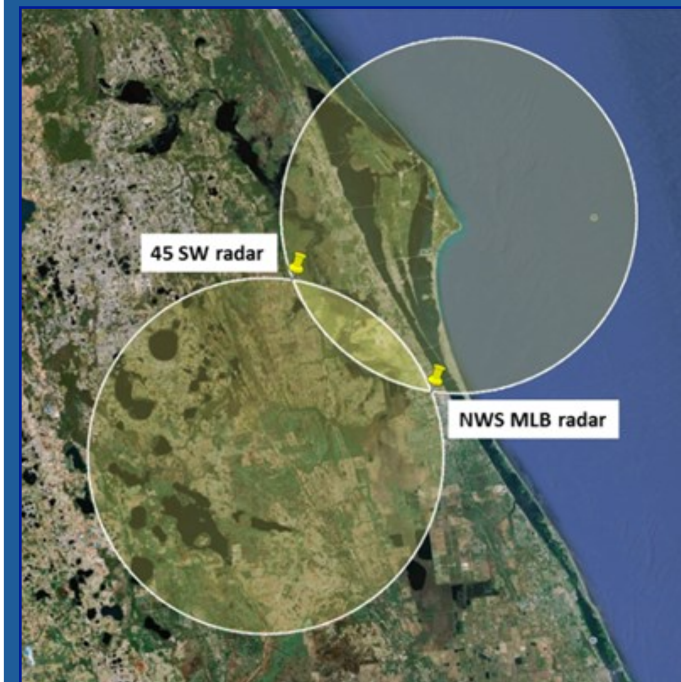
Severe Weather Tool using 1500 UTC CCAFS Sounding (Page 13)

Purpose: Develop a Meteorological Interactive Data Display System (MIDDS) capability to assess the daily severe weather threat during the warm season months of May-September at KSC/CCAFS based on the late morning, 1500 UTC, CCAFS (XMR) sounding. Using the late morning sounding for this capability instead of the early morning, 1000 UTC, sounding will provide a the 45 WS forecasters with a more accurate assessment of the atmospheric instability each day leading to a better assessment of the severe weather threat.

Accomplished: Generated stability parameters to use as severe weather indices for the warm season months in the years 1989-2012 from the 1500 UTC soundings. Determined severe thresholds for each sounding parameter and developed an objective total threat score based on the thresholds.

Quarterly Task Summaries
(continued)

Configuration and Evaluation of a Dual-Doppler 3-D Wind Field System (Page 16)



Purpose: Develop a dual-Doppler system using freely available software to create a three-dimensional (3-D) wind field over KSC/CCAFS using data from the three local Doppler radars. Space vehicle operations are halted when winds exceed defined thresholds and when lightning is a threat. A display of the wind field to reveal areas of high winds or convergence, especially over areas where no observations exist, would be useful to forecasters in predicting the onset of vehicle-critical weather phenomena, and can also be used to initialize a local mesoscale numerical weather prediction model to improve the model forecast of these phenomena. A dual-Doppler wind field display will aid in using ground processing and space launch resources more efficiently by stopping or starting work in a timelier manner.

Accomplished: Acquired information about two dual-Doppler analysis software packages and the computing resources required to run them.

Wind Pairs Database for Persistence Modeling (Page 17)

Purpose: Develop upper-level (UL) wind profile temporal pair databases and conduct a statistical analysis of wind changes at the Eastern Range (ER), Western Range (WR) and Wallops Flight Facility (WFF) for use by NASA's Launch Services Program (LSP) space launch vehicle teams in their commit-to-launch decisions. Their current assessments are based on UL wind data obtained earlier in the launch count, which may not represent the winds the vehicle will ascend through. This uncertainty can be mitigated by a statistical analysis of wind change over time periods of interest using historical data from the launch range. The intent of these databases is to help LSP improve the accuracy of launch commit decisions by applying wind change statistics based on measured historical data, as opposed to modeled data, into UL wind assessments.

Accomplished: Compiled databases of wind profiles at WFF and WR. Applied quality control (QC) algorithms to remove suspect wind profiles. Developed wind profile pair database and determined number of wind profile pairs for each time period for WFF and WR.

Quarterly Task Summaries
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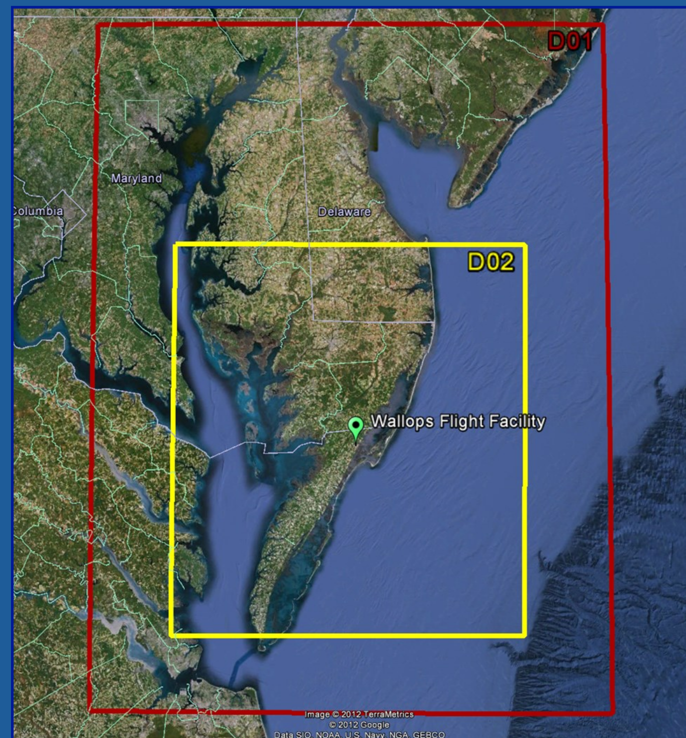
Range-Specific High-Resolution Mesoscale Model Setup (Page 19)



Purpose: Establish a high-resolution model with data assimilation (DA) for the ER and 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: Installed and tested the Gridpoint Statistical Interpolation (GSI) software on the local AMU modeling cluster. Began acquiring data to assimilate into the model.

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 Forecasts for East-Central Florida Airports (Ms. Crawford)

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 National Lightning Detection Network (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 areas needed by the NWS MLB forecasters in the warm season months, defined in this task as May-September.

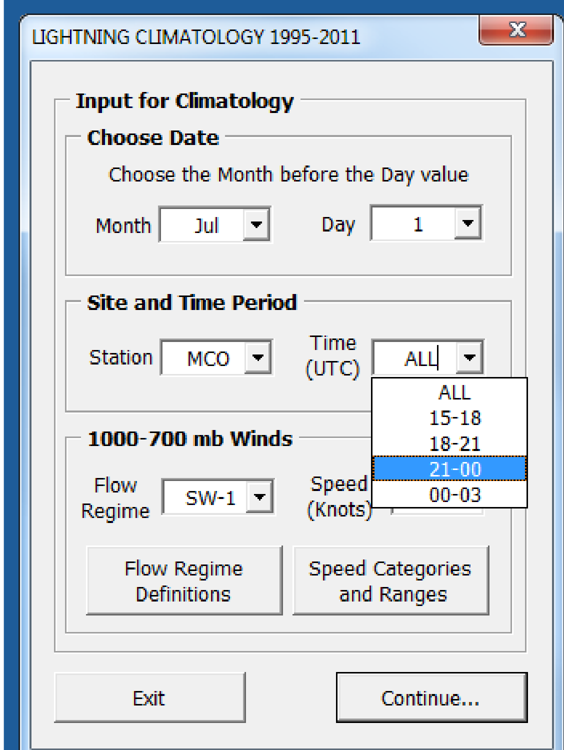


Figure 1. The initial GUI input form. The user makes choices in each box and then clicks the "Continue…" button to get equation input form. The chosen wind speed value, covered by the time period drop-down list, is 10 kt.

Graphical User Interface

Ms. Crawford added the lightning probability forecast equations to the GUI (AMU Quarterly Report Q1 FY13) and delivered it to Mr. Volkmer at NWS MLB. In addition to the equation output, the GUI displays the daily climatology and flow regime values for each stratification: month, station, time period, flow regime, and speed. Figure 1 shows the initial input form with the time period drop-down list displayed. If the user chooses 21-00 for the time period and clicks the "Continue…" button, the predictor input form for the 2100-0000 UTC equation in July at Orlando International Airport (MCO) is displayed (Figure 2). The list of predictors in each equation is at the top of the equation input form. In this example, there are four predictors: three-speed flow regime probability, precipitable water (PW), one-day persistence, and daily climatology. The flow regime probability and daily climatology are retrieved from a table by the GUI using the information provided in the initial form (Figure 1). The user inputs the PW from the 1000 UTC CCAFS sounding and Yes or No for one-day persistence indicating whether lightning occurred the previous day during the same time period.

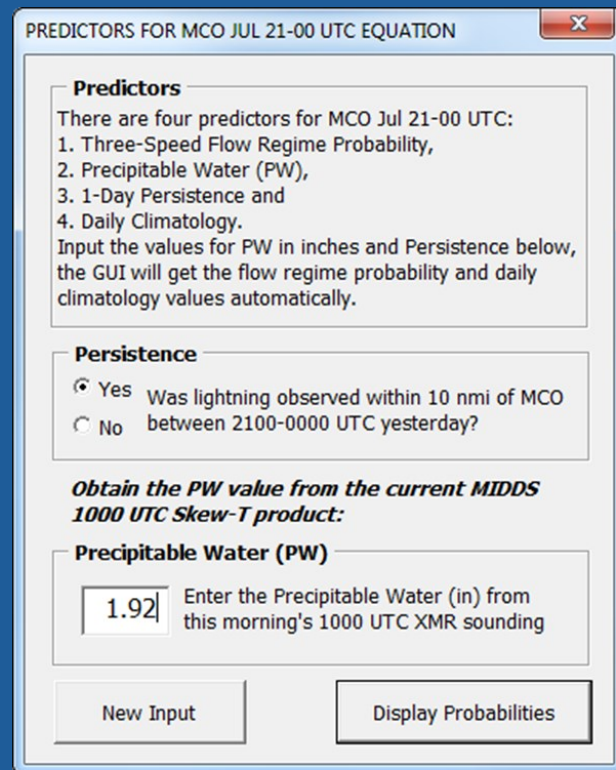


Figure 2. The input form for the predictor values in the July MCO 2100-0000 UTC equation. The user makes choices in each category and clicks the "Display Probabilities" button to open the output form. The "New Input" button closes the form and returns control to the initial input form (Figure 1).

After making choices in the equation input form, the user clicks the “Display Probabilities” button to display the probability output form shown in Figure 3. The left panel in Figure 3 repeats the information from the input form and the daily climatology, flow regime, and equation lightning occurrence probabilities are shown in the right panel. The output form also contains two buttons that display informational forms when clicked. The “Flow Regime Definitions” button displays a form that describes the wind flow patterns of the seven flow regimes, and the “Speed Categories and Ranges” button displays a form containing the names of the flow regime wind speed categories and their ranges.

After his tests, Mr. Volkmer said it would be helpful if forecasters could see the probabilities of all four time periods in the same form. Ms. Crawford added “All” as a choice in the time period drop-down menu on the initial input form (Figure 1). The equation input form associated with choosing All time periods for the MCO July example is shown in Figure 4. The user chooses the values for the predictors in all four equations at once. In order to not crowd the form, the specific predictors for each time period are not listed as in the individual time period equation input form (Figure 2). The specific predictors for each time period are

- 1500-1800 UTC: Thompson Index (TI) and two-speed flow regime probability;
- 1800-2100 UTC: TI and one-day persistence;
- 2100-0000 UTC: Three-speed flow regime probability, PW, one-day persistence, and daily climatology; and
- 0000-0003 UTC: Flow regime probability (not speed related), daily climatology, and Lifted Index (LI).

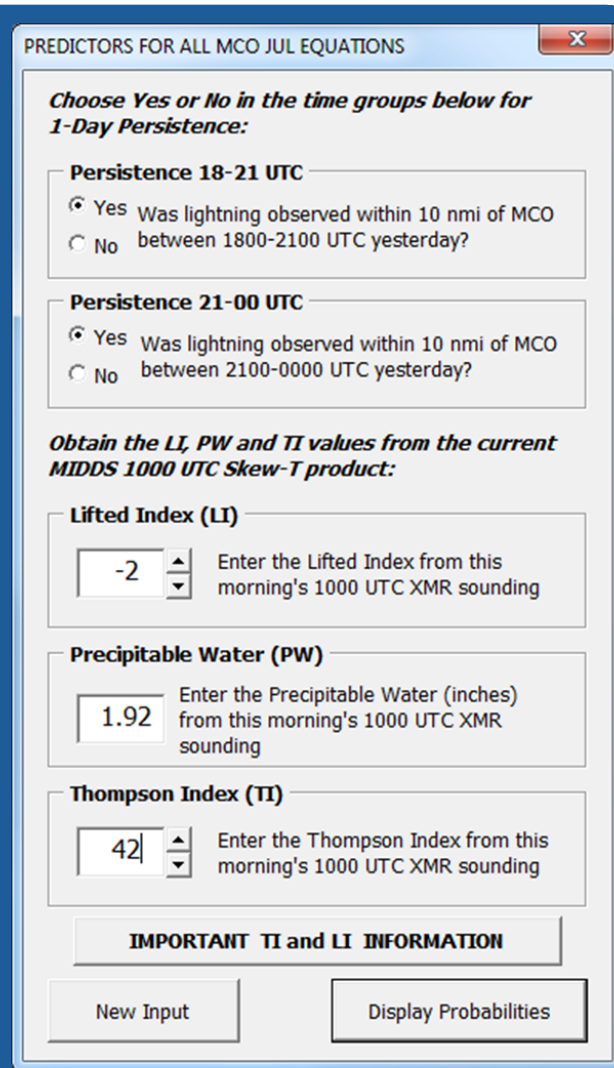


Figure 4. The GUI input form for the predictor values in the July MCO equations for all four time periods. The user makes choices in each category and clicks the “Display Probabilities” button to open the output form. The “New Input” button closes the form and returns control to the initial input form (Figure 1). The “Important TI and LI Information” button provides information about LI calculation differences in AWIPS and MIDDS.

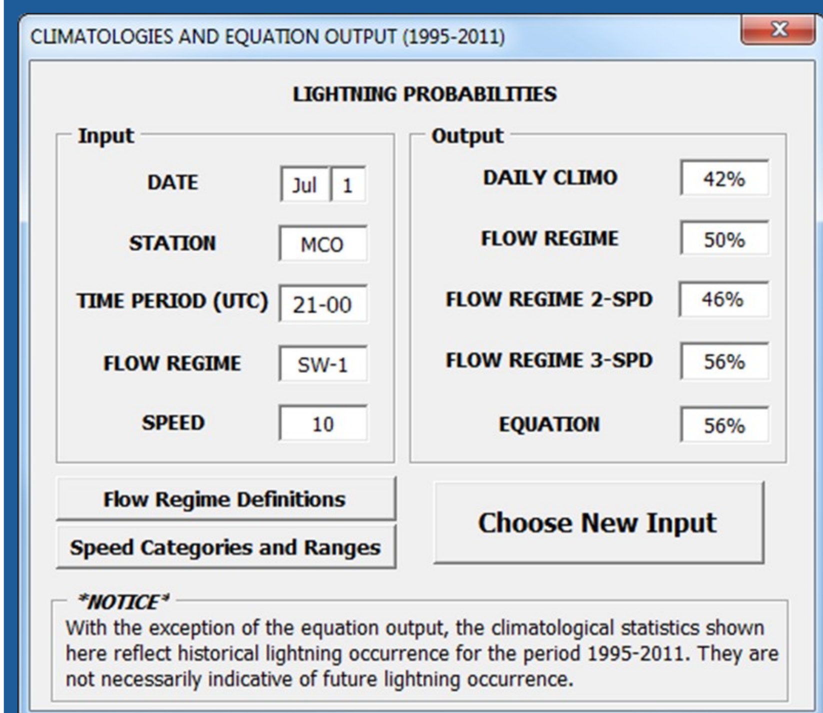


Figure 3. The GUI output form for July 2100-0000 UTC at MCO. The input choices from Figure 1 are in the left panel and the climatological and computed probabilities are in the right panel. The “Choose New Input” button closes the form and returns control to the equation input form input form (Figure 2). The “Flow Regime Definitions” and “Speed Categories and Ranges” buttons open message forms that provide definitions of these parameters.

The “Important TI and LI Information” button in Figure 4 provides information about differences in how LI is calculated between the Advanced Weather Information Processing System (AWIPS) used by NWS MLB and MIDDS used by the 45 WS. AWIPS uses the forecast maximum temperature for the surface parcel and MIDDS uses the 1000 UTC observed values. The equations were developed using the MIDDS value. The difference in the calculations would result in a lower, or more unstable, LI value in AWIPS. Use of the AWIPS LI would result in higher lightning probability values than what would be calculated with the MIDDS value. Since TI is the difference between K-Index and LI, it would behave similarly. This is important information for forecasters when choosing LI and TI values.

As for the individual time period equation input form, the user clicks the "Display Probabilities" button to display the output form shown in Figure 5. Similar to the individual time-period form, the left panel repeats the information from the initial input form. The right panel, however, displays the probabilities for all four time periods.

Ms. Crawford delivered this version of the GUI to Mr. Volkmer for testing. He indicated this version will be useful to forecasters and had no further suggestions for modifications.

Status

In late March, the Air Force stopped releasing rawinsondes at 1000 UTC from CCAFS due to budget issues. This is effective until the end of the 2013 fiscal year on 30 September. The forecasters at NWS MLB understand that the tool may not perform optimally with other data, but they plan to use high temporal resolution model analysis soundings as close to 1000 UTC and CCAFS as possible, and will also use the Cape Canaveral Global Positioning System PW data available from the site http://www.suominet.ucar.edu/.

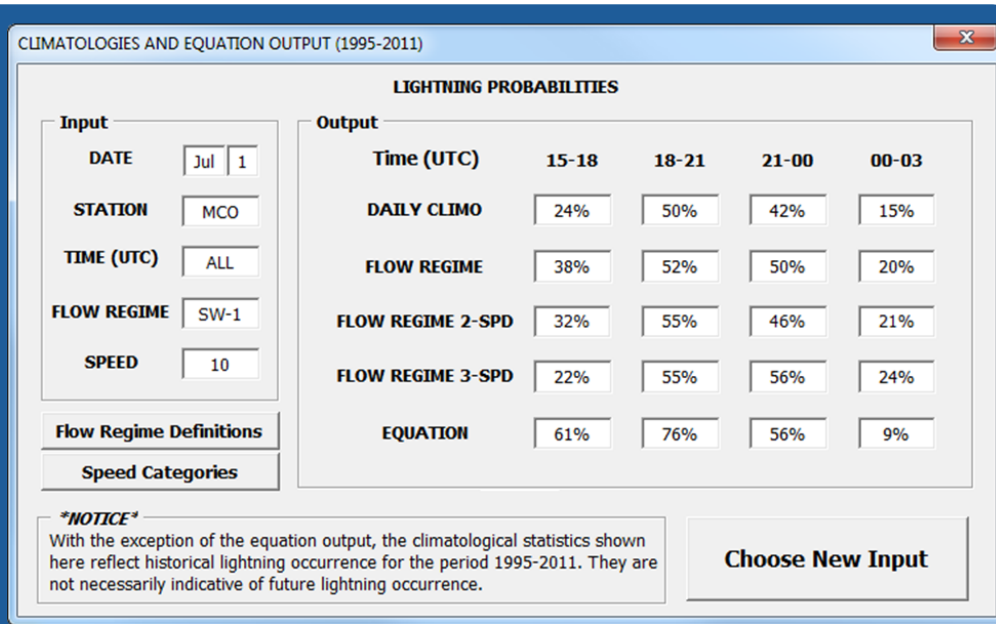


Figure 5. The GUI output form for all four time periods. The input choices are in the left panel and the climatological and computed probabilities for all four time periods are in the right panel. The "Choose New Input" button closes the form and returns control to the equation input form for the four time periods (Figure 4). The "Flow Regime Definitions" and "Speed Categories" buttons open message forms that provide definitions of these parameters as in Figure 3.

When the 1000 UTC sounding is reinstated, they will resume using that data. It is important to note that the climatological values output with the equation probabilities are still valid as they do not depend on current sounding data.

Ms. Crawford continued writing the final report.

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

Vandenberg AFB Pressure Gradient Wind Study (Ms. Shafer)

Warning category winds can adversely impact day-to-day space lift operations at VAFB. For example, winds ≥ 30 kt can affect Delta II vehicle transport to the launch pad, Delta IV stage II attitude control system tank load, and other critical operations. The 30 OSS forecasters at VAFB use the MSLP from seven regional observing stations to determine the PG magnitude as a guide to forecast surface wind speed at VAFB. Their current method uses an Excel-based tool that is manually intensive and does not contain an objective relationship between peak wind and pressure gradient. They require a more objective and automated capability to help them forecast the onset and duration of warning category winds to enhance the safety of their customers' operations. The 30 OSS has requested that the AMU develop an automated Excel GUI that includes pressure gradient thresholds between specific observing stations under different synoptic regimes to aid forecasters when issuing wind warnings.

Data Acquisition and Processing

Last quarter, Ms. Shafer received historical wind data from the 30 OSS. After quality controlling and processing these data, she used them to determine all days where peak winds ≥ 30 kt were observed. Considering the number of ≥ 30 kt peak wind days was over 1,200, Mr. Brock requested Ms. Shafer to increase the peak wind threshold to ≥ 40 kt to reduce the number of days in the database. Per his request, Ms. Shafer determined all days where peak winds ≥ 40 kt were observed, 745 in all, and provided Mr. Brock a list of these dates. Mr. Brock organized the dates by synoptic regime and delivered this information to Ms. Shafer in an Excel spreadsheet. There are a total of 11 synoptic regimes that affect the weather at VAFB. Seven synoptic regimes were observed on the dates provided by Ms. Shafer. Table 1 shows the number of ≥ 40 kt days per synoptic regime.

At Ms. Shafer's request, Mr. Roeder of the 45 WS obtained the MSLP observations from the seven weather stations identified by 30 OSS for calculating PGs (Figure 6) from the 14th Weather Squadron (14 WS). Once received, Ms. Shafer developed an MSLP database containing hourly observations from each station on the days when peak winds ≥ 40 kt were observed. She then organized these observations by synoptic regime and determined the

Table 1. Number of days with peak winds ≥ 40 kt for each synoptic regime.

Synoptic Regime	Number of ≥ 40 kt days
North Pacific Low (NPL)	153
North Pacific High (NPH)	141
California High (CH)	81
California Low (CL)	81
Upper Trough (UT)	64
Pacific High (PH)	141
Great Basin High (GBH)	84

hourly PGs by station pair. The 30 OSS station pairs, distance between stations, and PG formula are in Table 2. The two station pairs listed below the green line are additional pairs the AMU included to further evaluate the relationship between peak wind and PG at VAFB.

Pressure Gradient Evaluation

In order to better understand the relationship between peak wind and PG at VAFB, Ms. Shafer created a series of graphs plotting PG and maximum peak wind (MPW) versus time for each of the synoptic regimes. The MPW was the maximum peak wind of all peak wind speeds observed at the 26 towers in each hour. She created a PG/MPW versus time graph for four days in each synoptic regime, each day representing a different time of the year in order to have a diverse collection of case studies when evaluating the PG and MPW relationship. Figure 7 is an example of the PG/MPW versus time graph for 14 July 2011 with a California High (CH) synoptic regime. The MPW is on the left y-axis, the PG is on the right y-axis, and time is on the x-axis. Included in the graph are the PGs from each of the 14 station pairs used in the task. In order to better highlight potential trends and/or relationships between PG and MPW, Ms. Shafer also plotted the absolute value (ABS) of the PGs versus time (Figure 8). For instance, consider the trend of MPW compared to the trends of the PG and ABS(PG) for the KPRB-KVBG station pair in Figure 7 and Figure 8, respectively. Notice the trends in ABS(PG) in Figure 8, particularly for the negative PG series (Figure 7), better matches the trends in MPW in this case. To see if these trends would assist in the analysis, Ms. Shafer created ABS(PG) versus time graphs for all days included in this evaluation.

Ms. Shafer's initial review of the PGs and MPW did not yield a clear relationship between the two variables. For the days selected, most PG and ABS(PG) trends did not follow the MPW trends as expected. She met with the AMU team and showed them the charts, and they discovered there may be a link between synoptic regime, MPW, and the PG orientation: north-south (NS) versus east-west (EW). As an example, Figure 9 is the

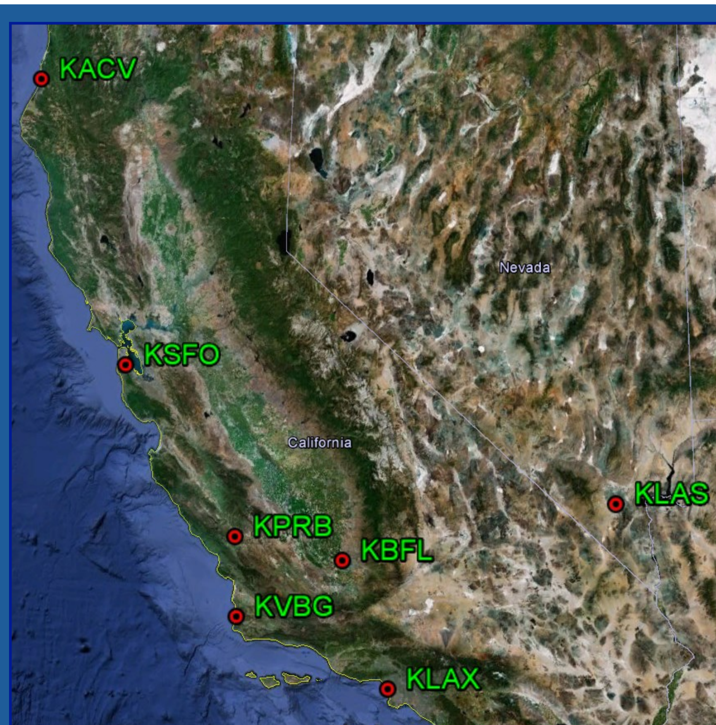


Figure 6. Locations of the seven observing stations in the pressure gradient assessment. KVBG is VAFB.

Table 2. List of the 30 OSS-identified station pairs and distance (km) between them used in the PG calculations. The station pairs below the green line were added by the AMU.

Station Pair	Distance (km)
KVBG – KBFL	159.0
KBFL – KLAS	359.6
KVBG – KLAS	514.4
KACV – KSFO	402.1
KSFO – KPRB	266.7
KPRB – KVBG	104.1
KVBG – KLAX	218.5
KACV – KPRB	663.3
KPRB – KLAX	279.4
KACV – KVBG	759.6
KSFO – KVBG	358.5
KACV – KLAX	929.6
KPRB – KLAS	495.3
KLAX – KLAS	380.0

Pressure Gradient (PG) formula:

$$PG = \left(\frac{dP}{D}\right) * 100$$

Where: dP = Pressure difference (mb) between two stations
D = Distance (km) between two stations

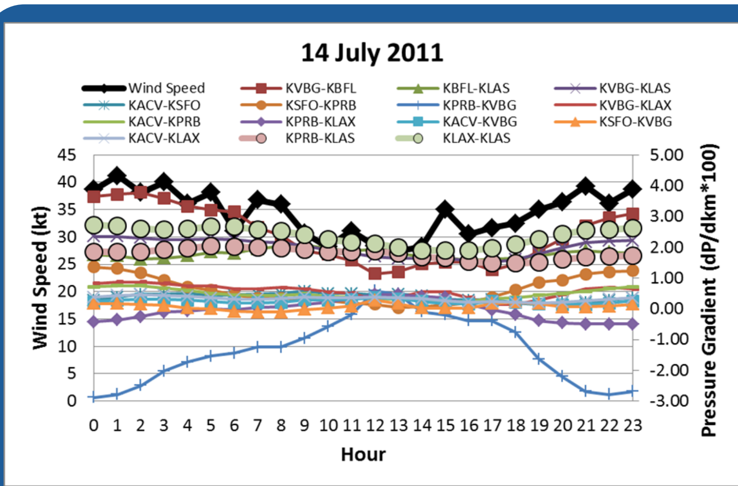


Figure 7. Example PG/MPW versus time graph with a California High flow regime.

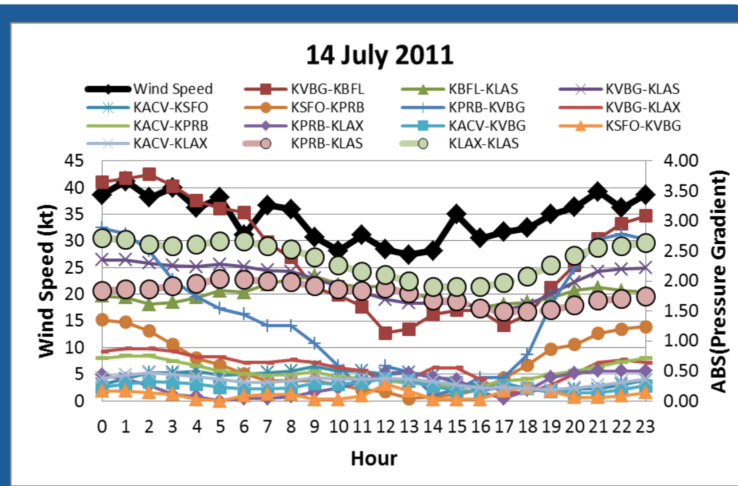


Figure 8. Example ABS(PG)/MPW versus time graph with a California High flow regime.

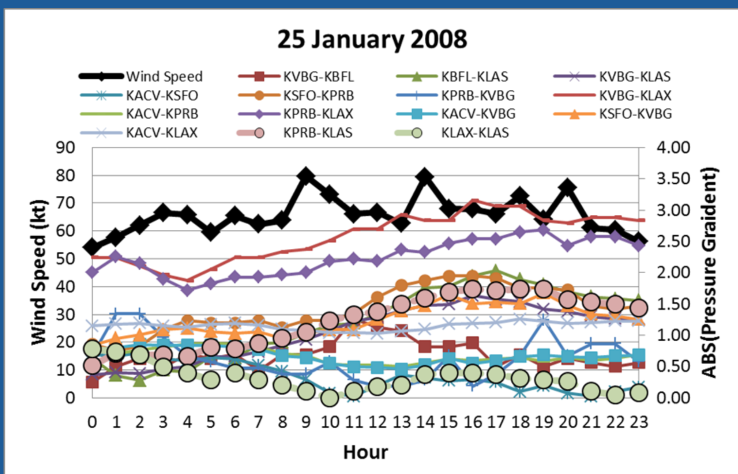


Figure 9. ABS(PG)/MPW versus time graph with an Upper Trough flow regime.

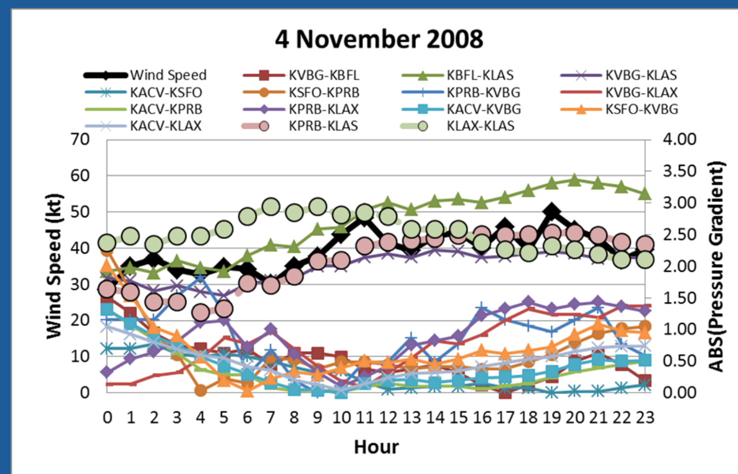


Figure 10. ABS(PG)/MPW versus time graph with a North Pacific Low flow regime

ABS(PG)/MPW versus time graph for 25 January 2008 with an Upper Trough (UT) synoptic regime. When comparing the ABS(PG)s for each station pair, the KVBG-KLAX and KPRB-KLAX ABS(PG)s, with a NS orientation, followed the MPW trend and had greater magnitudes than the other pairs at the same times. Another example, Figure 10, is from 4 November 2008 with a North Pacific Low (NPL) synoptic regime. After comparing these ABS(PG)s, there were four with higher magnitudes; KBFL-KLAS, KVBG-KLAS, KPRB-KLAS and KLAX-KLAS (see Figure 6). All of these station pairs had EW oriented PGs on this day.

To further investigate the relationship between PG and MPW at VAFB, the AMU will divide VAFB into two sections: North Base (NB) and South Base (SB). The NB-MPW and SB-MPW will be determined per hour and compared to the PGs. The NB and SB towers are identified by the yellow and light blue diamonds in Figure 11, respectively.

Climatology Database

Ms. Shafer completed processing the tower data for the climatology database at each of the 26 wind towers. The database includes temperature (F), dewpoint (F), relative humidity (%), average 1 minute sustained wind speed (kt) and direction (degrees), and peak wind speed (kt) and direction (degrees) at the 2, 4, and 16 m sensor levels. If time permits, Ms. Shafer will calculate climatology statistics and deliver this information in a Microsoft Access or Excel GUI as discussed at the November 2012 tasking meeting.

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

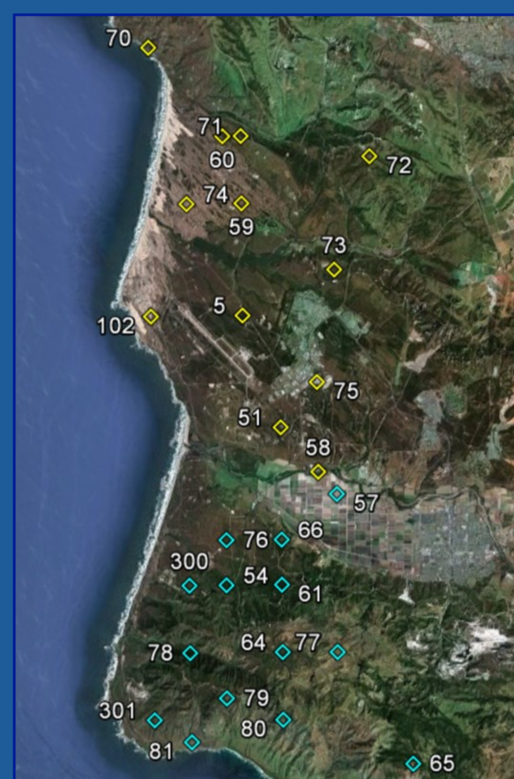


Figure 11. All VAFB wind towers designated as North Base (yellow) and South Base (light blue)

First Cloud-to-Ground Lightning Timing Study (Dr. Huddleston)

The probability of CG lightning occurrence is included in the daily and weekly lightning probability forecasts issued by the 45 WS. These forecasts are important in the warm season months, May-October, when the area is most affected by lightning. Many KSC and CCAFS organizations use this information when planning potentially hazardous outdoor activities, such as working with fuels or rolling a vehicle to a launch pad. These organizations would benefit greatly if the 45 WS could provide more accurate timing of the first CG lightning of the day in addition to the probability of lightning occurrence. The AMU has made significant improvements in forecasting the probability of lightning for the day. However, forecasting the time of the first CG lightning with confidence has remained a challenge. The ultimate goal is to develop a tool that provides the distribution of first CG lightning times in the KSC/CCAFS lightning warning circles to assist the 45 WS customers to plan for activities prone to disruption due to lightning activity. In this task, the AMU will determine if there is a relationship between speed-stratified flow regimes and the time of the first CG strike. This relationship, if it exists, would be used in a final tool to assist forecasters in determining when the first CG lightning will occur on KSC/CCAFS.

Stratification

In the previous quarter, the AMU and 45 WS discussed ways of stratifying the data into sea breeze flow regimes and speed categories. The resulting stratifications, three based on flow regime and two based on wind speed in the surface to 5,000 ft layer, are outlined in Tables 3, 4, and 5. For more details on how the categories were chosen, refer to AMU Quarterly Report, (Q1 FY13). The original intent was to stratify the data by flow regime and speed category. With two, four, and eight flow regime categories, and three and four speed categories, the data could be divided into a minimum of 6 and maximum of 32 stratifications. Dr. Huddleston would then choose the stratification combination that provided enough samples with which to conduct a robust statistical analysis.

Data Analysis

Dr. Huddleston began analysis to determine if there was a relationship between the flow regime/speed combinations and the timing of the first lightning strike of the day. In most cases, her analysis showed that stratification to the requested levels resulted in sample sizes that were too small for meaningful statistical analysis. Accordingly, Dr. Huddleston performed analysis on data that was stratified by either the flow regimes in Tables 3 and 4 or the speed regimes in Table 5, but not combined.

Dr. Huddleston used the chi-square (χ^2) statistical significance test to determine whether there was a significant relationship between the first lightning strike of the day and one of the sea breeze flow regimes or one of the speed regimes. The χ^2 test requires a null hypothesis (H_0). Dr. Huddleston defined H_0 as no significant relationship between the flow regime sectors or speed categories and the first lightning strike of the day. H_0 can either be rejected as being improbable or not rejected. Note that H_0 is never accepted, just not rejected. Not rejecting H_0 means there is not enough evidence to reject it, not that it is valid. The alternative hypothesis (H_1), then, is that there is a significant relationship between the flow regime sectors or speed categories and the first lightning strike of the day.

Table 3. The eight 45 WS sea breeze flow regime sectors for the surface to 5,000-ft layer as outlined in the 45 WS Forecast Reference Notebook (FRN).

Sea Breeze Flow Regime	Direction Sector
E	>66º and ≤110º
SE	>110º and ≤155º
S	>155º and ≤200º
SW	>200º and ≤245º
W	>245º and ≤290º
NW	>290º and ≤335º
N	>335º or ≤20º
NE	>20º and ≤66º

Table 4. The alternate two- and four-sector sea breeze flow regime sectors for the surface to 5,000-ft layer.

Stratification	Sea Breeze Flow Regime	Direction Sector
Two-Sector	Off-Shore	≥135º and <315º
	On-Shore	≥315º or <135º
Four-Sector	Off-Shore SW	≥135º and <225º
	Off-Shore NW	≥225º and <315º
	On-Shore NE	≥315º or <45º
	On-Shore SE	≥45º and <135º

Table 5. The mean surface to 5,000-ft layer four-speed stratifications and alternate three-speed stratifications.

# Speed Stratifications	Stratification Name	Wind Speed Range
Four (FRN)	Low	≤5 kt
	Medium	>5 kt and ≤11 kt
	Medium High	>11 kt and ≤16 kt
	High	>16 kt
Three (alternate)	Low	≤7.7 kt
	Med	>7.7 kt and ≤12.6 kt
	High	>12.6 kt

For the first step in the χ^2 test, Dr. Huddleston determined the observed number of strikes in each hour for each stratification and, from the observed values, calculated an associated expected number of strikes. She calculated the expected number of strikes by multiplying the total number of strikes in each hour, regardless of flow regime or speed, with the total number of strikes in a flow regime sector or speed category regardless of time, then divided that number by the total number of first lightning strikes of the day in the period of record (POR), which is the warm season months in the years 1989-2012. For example, the total number of first strikes in the eight-sector easterly (E in Table 3) flow regime over all hours was 64. The total number of first strikes in the 0700 local hour was 35. She multiplied these two values and then divided by the total number of first strikes of the day over all hours and flow regimes for the POR, which was1,282. The expected number of first strikes for the 0700 local hour in the E flow regime was (64*35)/1,282 = 1.75. While it is not possible to have a fractional number of first strikes, this expected value, 1.75, is what was needed for the χ^2 calculation. The observed number of first strikes for this stratification was 5.

After all expected frequencies were calculated, Dr. Huddleston

$$\chi^2 = \sum \frac{(\#Observed - \#Expected)^2}{\#Expected}$$

computed the χ^2 statistic using the equation (Wilks 2006)

She then compared the calculated χ^2 statistic to a an associated χ^2 critical value in a standard χ^2 distribution table. If the calculated χ^2 statistic was greater than the χ^2 critical value, then she could reject H_0 and assume there was a significant relationship between the first strike of the day and flow regime or speed category. Otherwise, she could not reject H_0 and could conclude with some certainty that there is no statistically significant relationship between the first strike of the day occurrence based on flow regime or speed category.

Table 6 shows the overall results of the analysis. The only statistically significant outcome in which H_0 could be rejected was for the two-sector flow regimes (Table 4). For the χ^2 test to give accurate results, most expected values must be large. Dixon and Massey (1983) define this as no more than 20% of the expected values being < 5. Because of this restriction, the χ^2 test was invalid for the eight- and four-sector flow regime stratifications. All stratifications (either flow regime or speed category) that divided the data into more than two sectors caused the groups of data to be too small for meaningful statistical analysis such that H_0 could not be rejected.

Even though the χ^2 test showed a statistically significant relationship with the two-sector flow regimes, i.e. there are differences in the first lightning strike occurrence between onshore and offshore flow, it did not indicate which times were different. The 45 WS forecasters requested a tool to help them determine the timing of the first strike. In order to test which times were different, Dr. Huddleston used the Marascuilo procedure (NIST/SEMATECH 2013). This procedure enables comparisons between all pairs of groups simultaneously, which can identify the groups likely responsible for rejecting H_0.

To start the Marascuilo procedure, Dr. Huddleston counted the number of hours for which data were available for the onshore and offshore stratifications. There were 17 hours (0700-2300 local time) each of onshore and offshore flow, equaling 34 hours or groups. She then calculated the total number of pairs of data to compare using the formula k*(k-1)/2, where k is the number of groups of data, in this case 34. The total number of data pairs in this test was 34*33/2 = 561. This results in every time period being compared to every other time period. Dr. Huddleston computed the difference in each pair of data, and then computed the corresponding critical ranges for each pair of data. Next, Dr. Huddleston compared the absolute difference of each of the data pairs against its corresponding critical range. If the absolute difference in the data pair was greater than its critical range, then she could conclude that observed values were significantly different from each other (Levine et al. 2007). Unfortunately, the Marascuilo procedure did not find any observed values that were significantly different from one another, mostly likely due to the small group sizes after stratification by hour as needed for the procedure.

Table 6. Results from the χ^2 tests. H_0 is the null hypothesis indicating no significant statistical relationship between the first strike of the day and flow regime or speed category stratifications. H_1 is the alternate hypothesis indicating a significant statistical relationship between the first strike of the day and flow regime or speed category stratifications.

Stratification	Status	Comments
Eight-sector flow regimes (Table 3)	χ^2 test invalid	More than 20% of expected values < 5
Two-sector flow regimes (Table 4)	Reject H_0	Significant relationship with first strike
Four-sector flow regimes (Table 4)	χ^2 test invalid	More than 20% of expected values < 5
Four-speed categories (Table 5)	Fail to reject H_0	No relationship to first strike found
Three-speed categories (Table 5)	Fail to reject H_0	No relationship to first strike found

Graphical User Interface

Although the number of observations in each of the stratifications was too small to allow for valid statistical comparisons, Dr. Huddleston discussed with the 45 WS if providing a GUI displaying the frequencies and percentages of the timing of lightning under the various stratifications would be helpful. The 45 WS agreed that such a GUI would be helpful to the forecasters and launch weather officers (LWOs) in generating their daily forecasts for lightning timing. At the LWOs' request, Dr. Huddleston added a preliminary TI stratification in the GUI to account for stability and moisture.

Dr. Huddleston developed a GUI using the Slicers feature in Excel 2010. Slicers, which are new to Excel 2010, are embedded graphic objects that allow the user to quickly and easily filter data in an Excel PivotTable on multiple criteria. Slicers can also be used to filter data in more than one PivotTable created in the workbook simply by connecting additional tables. Slicers show which filtering criteria are currently selected in the connected PivotTables (Harvey 2010).

Figure 12 shows an example of the GUI using Excel 2010 Slicers for the FRN sea breeze flow regime stratification (Table 3). Note that in this example, although the selection boxes for both the FRN speed category and the alternate speed category (Table 5) are shown, the user is expected to select from one or the other, but not both. Dr. Huddleston will emphasize this in the GUI training for the customer.

Dr. Huddleston showed an initial draft of the GUI without Slicers to Ms. Winters, Mr. McAleenan, and Mr. Roeder of the 45 WS, who approved the design. She then showed a second version of the GUI using Excel Slicers to Mr. McAleenan and Mr. Craft of the 45 WS, who approved the new design.

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

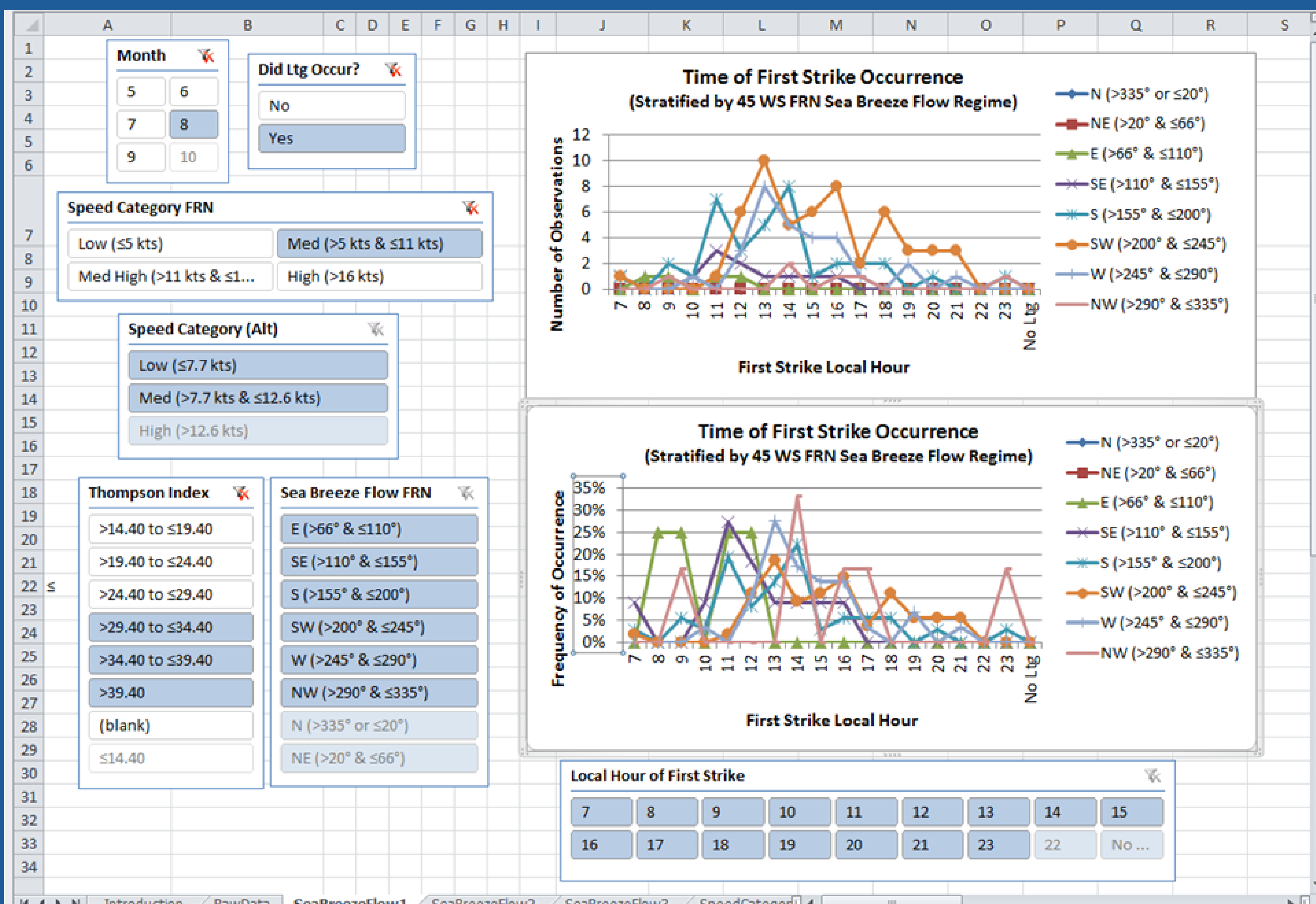


Figure 12. An example of a GUI using Excel 2010 Slicers for the FRN flow regime stratification. In this example, the stratifications were the month of August, days when lightning occurred, medium FRN speed category, and Thompson Index >29.40. The top chart shows the number of times lightning occurred during each hour and the bottom chart shows the frequency of occurrence as a percentage of first lightning strike occurrences in each flow regime. Note that after the user selects the filters from the Slicer menus, the categories that contain no data after filtering are grayed out and moved to the end of each of the Slicer menu.

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

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

Stability Parameters

Dr. Bauman generated the stability parameters to be used as severe weather indices based on the 1500 UTC XMR sounding data for the 24 years of warm season months from 1989-2012. There were a total of 2,842 soundings available out of a possible 3,672 days. Dr. Bauman removed 14 soundings from the database on days when KSC/CCAFS was under the influence of a tropical cyclone, and another 30 that failed QC checks resulting in a total of 2,798 soundings. He generated the following severe weather indices from the soundings:

- Lifted Index (LI)
- K-Index (KI)
- Thompson Index (TI)
- Showalter Stability Index (SSI)
- Total Totals (TT)
- Cross Totals (CT)
- Vertical Totals (VT)
- Severe Weather Threat Index (SWEAT)
- Convective Available Potential Energy (CAPE)
- CAPE based on the maximum equivalent potential temperature (CAPE Max θ_e)
- CAPE based on the forecast maximum temperature (CAPE FMaxT)
- Convective Inhibition (CIN)
- PW
- Temperature at 500 mb
- Average relative humidity in the 850-500 mb layer
- Average relative humidity in the 850-600 mb layer
- Helicity
- Storm Relative Motion Speed and Direction

Stability Thresholds

After generating the indices, Dr. Bauman categorized the occurrence of days with reported severe weather and days without reported severe weather by threshold values for each index, and then developed charts showing the percent of time severe weather was reported based on specific thresholds. The thresholds were the same as those used in the Severe Weather Decision Aid (Bauman et al. 2005). An example using TT is shown in Figure 13. When the TT was in the low category (TT ≤ 45), severe weather was reported 11% of the time. When TT was in the medium category (46 ≤ TT ≤ 48), severe weather was reported 25% of the time. When TT was in the high category (TT > 48), severe weather was reported 45% of the time.

Dr. Bauman used the categorized thresholds from each index to determine if they would be useful predictors of severe weather occurrence. He created a threat score for each index derived from the percent of time severe weather occurred in each threshold category. To scale the threat score between 0 and 10, he divided the percent value by 10. He will use these scaled threat score values as the basis to compute a total threat score from multiple indices.

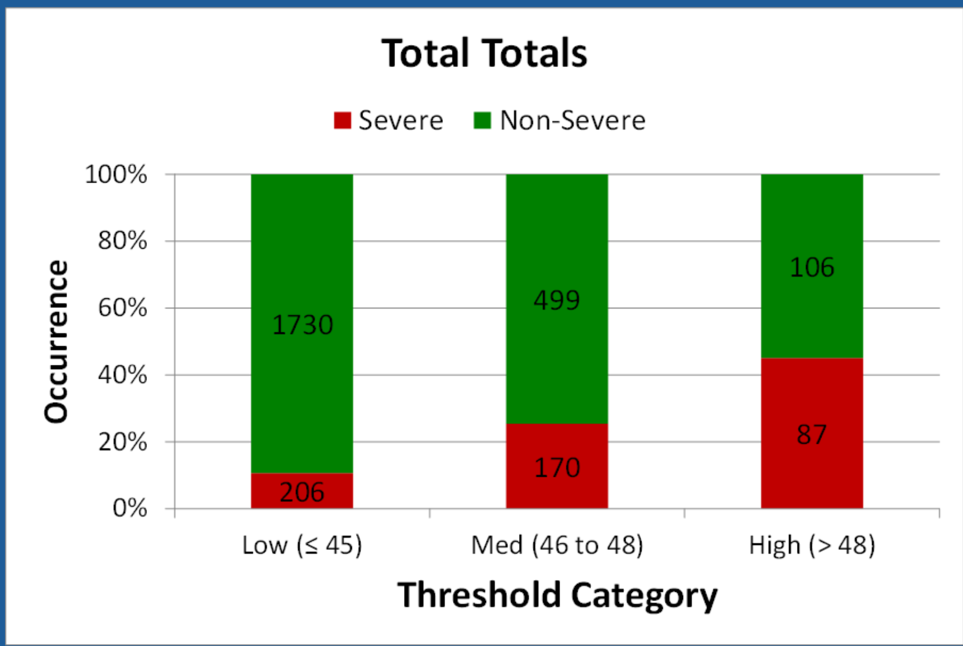


Figure 13. Stacked bar chart of TT for the low, medium and high threshold categories showing percent occurrence of the number of days with reported severe weather (red) and days with no reported severe weather (green).

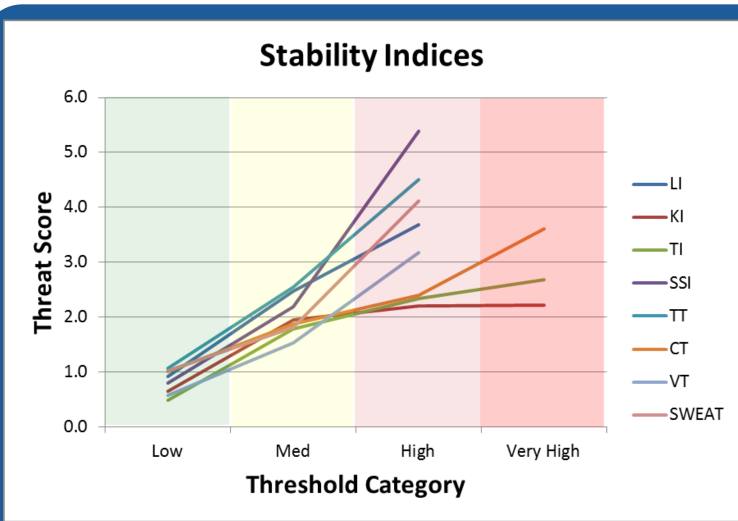


Figure 14. Line chart of stability indices showing the threat score for each index in each threshold category.

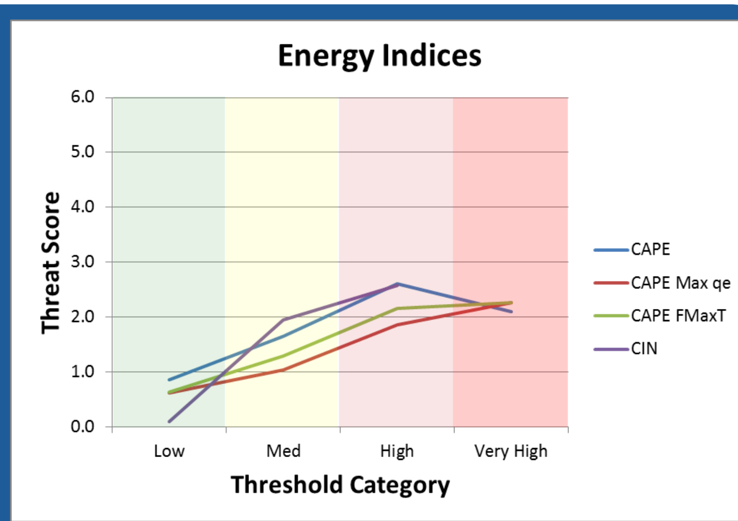


Figure 15. Line chart of energy indices showing the threat score for each index in each threshold category.

Figure 14 compares the threat score for each index in each category. Lines with steeper slopes show a relationship to severe weather by having low threat scores in the Low category increasing to higher threat scores in the High or Very High categories. Based on the slope of each line in Figure 14, the best indicators of severe weather occurrence were SSI, TT, SWEAT, LI and VT as they had the largest increase in severe weather threat score from lowest to highest threshold category. The CT, TI and KI slopes were not as steep, representing a smaller threat score change across the threshold categories and, therefore, they were not as good as the other indices in their forecastability of severe weather between categories. Similarly, the thresholds of energy indices derived from the soundings are shown in Figure 15. The CIN, CAPE Max θ_e and CAPE FMaxT were the best energy index indicators with slopes similar to the CT, TI and KI stability indices.

Flow Regimes and Jet Position

The flow regime for each day and position of the 200 mb jet relative to east central Florida are also indicators of the occurrence of reported severe weather. Figure 16 shows the occurrence of severe weather based on daily flow regime and Figure 17 shows the occurrence of severe weather based on 200 mb jet position. Severe weather is more likely to be reported in the northwest or southwest flow regimes and when upper-level jet dynamics cause divergence aloft. In both figures, the threat scores are as previously described. These values will also be used with the multiple indices to compute a total threat score.

Total Threat Score

A total threat score (TTS) will be output by the tool to provide the forecasters with an objective assessment of the daily threat of severe weather. Dr. Bauman summed the threat scores from the stability indices, energy indices, flow regime and 200 mb jet position for each day with reported severe weather and for each day with no reported severe weather to determine the TTS for each day in the data set. The daily TTS values ranged from 7 to 39. Based on the range of scores, he created seven TTS categories to help the forecasters assess the likelihood of severe weather occurrence. Table 7 shows the occurrence of reported severe weather for each of the seven TTS categories.

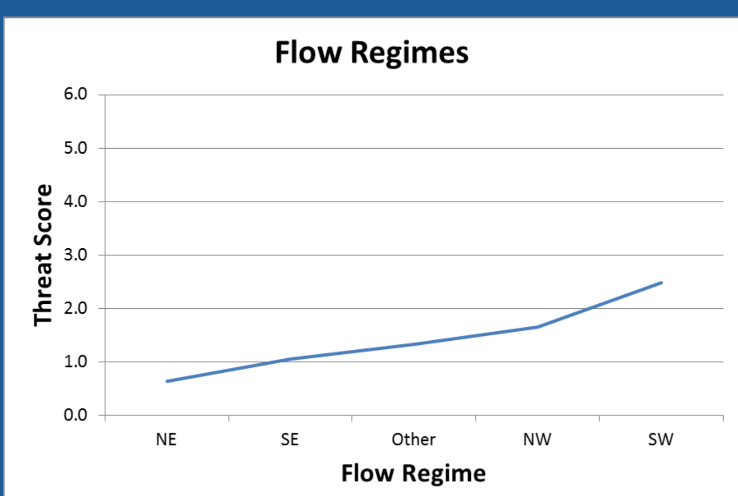


Figure 16. Line chart of daily flow regime showing the threat score for each flow regime.

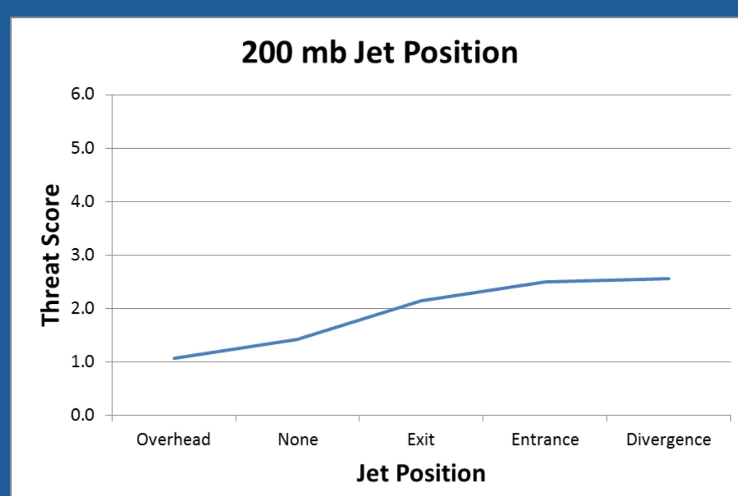


Figure 17. Line chart of 200 mb jet position showing the threat score for each jet position characterization.

The occurrence was determined by dividing the number of severe days in each category by the total number of days in that category. For example, 48% of the time severe weather was reported for days when the TTS was 25-29. In the data set, severe weather was reported on 181 days out of 375 days (181 ÷ 375 = 0.48) when the TTS was 25-29.

Table 7. Occurrence of severe weather based on seven total threat score categories.

TTS	< 10	10-14	15-19	20-24	25-29	30-34	≥ 35
Occurrence	0%	2%	7%	18%	48%	63%	92%
Severe Days	0	11	63	147	181	50	11
Total Days	23	535	937	836	375	80	12

Dr. Bauman will incorporate the stability thresholds and threat score categories into MIDDS to develop the real time severe weather tool based on the 1500 UTC sounding.

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

INSTRUMENTATION AND MEASURMENT

Configuration and Evaluation of a Dual-Doppler 3-D Wind Field System (Ms. Crawford)

Space vehicle ground and launch operations are halted when wind speeds from specific directions exceed defined thresholds and when lightning is a threat. Strong winds and lightning are difficult parameters for the 45 WS to forecast, yet are important in the protection of customer vehicle operations and the personnel that conduct them. A display of the low-level horizontal wind field to reveal areas of high winds or convergence would be a valuable tool for forecasters in assessing the timing of high winds impacting operations, or convection initiation (CI) and subsequent lightning occurrence. This is especially important for areas where no weather observation platforms exist. Developing a weather radar dual-Doppler capability would provide such a display to assist forecasters in predicting high winds and CI. The wind fields can also be used to initialize a local mesoscale numerical weather prediction model to help improve the model forecast winds, CI, and other phenomena. Finally, data combined from multiple radars will lessen radar geometry problems such as the cone of silence and beam blockage. This display will aid in using ground processing and space launch resources more efficiently by stopping or starting work in a timelier manner. The AMU was tasked by the 45 WS and NWS MLB to develop a dual-Doppler display using data from the 45 WS Doppler Radar, NWS MLB Weather Surveillance Radar 1988-Doppler (WSR-88D), and the Federal Aviation Administration Terminal Doppler Weather Radar at Orlando International Airport as input, and available software to derive the wind field over east-central Florida, especially over KSC/CCAFS to support the safety of ground and launch operations.

Software and Hardware

Ms. Crawford began the task by determining the appropriate software and hardware for the task. She consulted with Dr. Huddleston, who conducted the AMU study determining the feasibility of a dual-Doppler capability with the local radars (Huddleston 2012). She provided Ms. Crawford with reference material describing multi-Doppler radar analyses to assist in determining the available software packages and the necessary computing resources.

Huddleston (2012) identifies three software packages that can be used to create a dual-Doppler analysis. First, the 45 SW Radtec 43/250 dual-polarization/Doppler radar uses the Interactive Radar Information System (IRIS™) software package by Vaisala to display the data. The IRIS software has an add-on product called NDOP that provides the capability to create dual-Doppler wind fields. The cost for NDOP at the time of the study was $16,000. Secondly, the National Center for Atmospheric Research (NCAR) has a set of radar processing software programs that can be downloaded and used free of charge (http://www.mmm. ucar.edu/pdas/pdas.html). This software was used in Dolan and Rutledge (2007) to create multi-Doppler analyses in real time. Finally, the National Severe Storm Laboratory's (NSSL) Warning Decision Support System Integrated Information (WDSS-II) system can create dual-Doppler analyses in a research mode, with the possibility of real-time operation (http://www.cimms.ou.edu/~lakshman/WDSS2/index.shtml).

The KSC Weather Office budget does not allow for a $16,000 software purchase, so Ms. Crawford will use either the NCAR or WDSS-II software. Through the websites given in the previous paragraph, she learned that any PC with a current Linux operating system is sufficient to run either package. Dr. Bauman determined that the AMU has a PC that can be used for this purpose. It has dual 2.4 GHz processors, 6 GB RAM and 1 TB of hard drive space. This is a more powerful system than that used for real-time dual-Doppler analysis in Dolan and Rutledge (2007).

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

Wind Pairs Database for Persistence Modeling (Mr. Decker)

NASA LSP space launch teams include a UL wind assessment in their vehicle commit-to-launch decisions. Their assessments are based on wind measurements obtained earlier in the launch count, which may not represent the environment the vehicle will ascend through. Uncertainty in the UL winds over the time period between the assessment and launch can be mitigated by a statistical analysis of wind change over time periods of interest using historical data from the launch range. Without historical data, theoretical wind models must be used, which can result in inaccurate wind placards that misrepresent launch availability. This can result in over conservatism in vehicle wind placards and may reduce launch availability. Conversely, if the model is under-conservative it could result in launching into winds that might damage the vehicle. LSP tasked the AMU to calculate wind change statistics over specific time periods, also known as wind pairs, for each month from historical UL wind observations at the ER, WR and WFF. The wind pairs of interest are over the time periods of 45 and 90 minutes, and 2, 3 and 4 hours. The intent of these databases is to help LSP improve the accuracy of launch commit decisions based on UL wind assessments. Because of their experience in working with UL wind pair databases and statistical analysis of UL wind change, the Natural Environments (NE) group at Marshall Space Flight Center (MSFC) is working on this task under the AMU's direction.

Data Acquisition and Processing

Upper level wind measurements can be made from a variety of instrumentation. The most common is a balloon-lofted instrument package known as a rawinsonde that measures the wind directly and transmits the data back to a ground-based receiving system. Rawinsondes are released at the ER, WR, and WFF. Another balloon-based system used at the ER and WR is a specially designed balloon known as a Jimsphere, which were tracked by ground-based radars. Software at the ground station uses the radar data to determine wind speed and direction. The ER has multiple vertically pointing 50-MHz and 915-MHz Doppler Radar Wind Profiler (DRWP) systems that, when their measurements are spliced together, can generate a wind profile in the region of interest for launch vehicles. An advantage of the DRWPs over balloon-based systems is that they take measurements at much higher temporal frequencies than balloons. This yields orders of magnitude more profiles compared to balloon profiles. The WR also has a duplicate DRWP system to the ER but due to limited sample size and time to process the data it will not be available for this task.

The only source of UL wind data available at WFF is from rawinsondes. Mr. Decker obtained two databases of rawinsonde profiles from WFF for this task. The first was from the National Climatic Data Center (NCDC) Integrated Global Radiosonde Archive (IGRA) data from January 1965 through December 1999. The other database of rawinsondes was obtained directly from WFF and has a POR of January 2000 through January 2013. He first processed these data through QC algorithms to remove unacceptable profiles and then combined the data into a single comprehensive database.

Archived data from rawinsondes and Jimspheres were available for the WR wind pair assessment. Mr. Decker obtained three sources of data: IGRA rawinsondes from January 1965 through January 2013, WR rawinsonde profiles from January 2007 to December 2012, and a WR Jimsphere database with a POR from January 1965-December 2007. There is a time overlap with the 3 data sources as some of the WR rawinsondes and none of the WR Jimsphere data were included in the IGRA database. He processed the data from the rawinsonde archives through QC algorithms to remove unacceptable profiles and then combined into a single comprehensive database. Mr. Decker obtained the Jimsphere database in late March, so it was not included in the initial analyses. He will QC these data and include them in the comprehensive database.

Because of the aforementioned advantages of DRWP data over rawinsonde and Jimshphere data, Mr. Decker will only evaluate the DRWP data for the ER. Data from the ER DRWP systems are currently being processed at MSFC NE to generate databases of wind pairs. Once processed, this database will have a POR of January 2000 through December 2009. Details of the QC processes are documented in Barbre (2012). Once the processing is complete, Mr. Decker will create wind pairs with these data for the ER.

Preliminary Data Analysis

Mr. Decker's initial analysis consisted of counting the number of wind pairs for the five time intervals (45 and 90 minutes, 2, 3, and 4 hours) contained in the generated WR and WFF databases over their PORs. His experience with generating temporal wind pair databases from balloon systems indicated that there were not enough profile pairs per month to have a statistical sample that captures the full range of wind change variability. Therefore, he expanded the time periods by +/- 15 minutes to capture more pairs for each period. For example, profile pairs that were spaced between 2:45 to 3:15-hours were included in the count of 3-hour pairs. The number of temporal pairs for all five intervals over the POR in the WR database is 1835 temporal pairs. Given this count, Mr. Decker decided to separate the pairs into three wind climatology seasons: Summer, Winter and Transition. He stratified the WR data based on worst and best months to launch a vehicle. The worst period is the winter months of January through March, and the best period is the summer months of May through September. The other months, April and October through December, constitute the transition period. Table 8 lists the number of wind pairs for each of the five time interval and three seasonal periods. Note that these totals are expected to increase when the Jimsphere profile database is incorporated.

The WFF database pair count over the POR for all five time interval periods resulted in 590 pairs (Table 9). Even though there were over 30,000 profiles in the WFF database, unless there were special situations requiring high frequency of balloon launches, the vast majority of profiles in the WFF database are separated by 12 hours or greater. The small annual sample size for each time interval may not capture the range of temporal variability in the winds and also increases the uncertainty in characterizing wind change extremes. Mr. Decker will perform further analysis to determine if this database is acceptable for the intended use.

Continuing Work

The WR and WFF balloon databases contain data that are spaced at inconsistent vertical intervals. Therefore, Mr. Decker will either interpolate the data to fill in missing points, or filter the data to remove smaller wavelength features in order to produce equally spaced altitude profiles that contain the same energy content. At the same time, he will perform a power spectrum analysis on the different balloon systems to determine the effective vertical resolution to apply when filtering the wind data. In addition, Mr. Decker will perform a pair count of the ER DRWP database to determine the number of pairs. He will deliver three sets of wind pair databases, one for each range, upon completion of task.

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

Table 8. Seasonal count of wind pairs in the WR POR for the five time periods.

Time Interval	Winter	Summer	Transition	TOTAL
45 minutes	151	196	178	525
90 minutes	53	90	66	209
2 hours	125	181	128	434
3 hours	114	165	92	371
4 hours	76	139	81	296
TOTAL	519	771	545	1835

Table 9. Seasonal count of wind pairs in the WFF POR for the five time periods

Time Interval	Winter	Summer	Transition	TOTAL
45 minutes	26	91	42	159
90 minutes	9	61	16	86
2 hours	12	74	16	102
3 hours	68	61	17	146
4 hours	19	58	20	97
TOTAL	134	345	111	590

MESOSCALE MODELING

Range-Specific High-Resolution Mesoscale Model Setup: Data Assimilation (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 high resolution model would provide that capability. This is a continuation of a previously customer-approved task that began in FY12 in which the Weather Research and Forecasting (WRF) model was tuned for the ER and WFF. This task will provide a recommended local data assimilation (DA) and numerical forecast model design optimized for the ER and WFF to support space launch activities. The model will be optimized for local weather challenges at both ranges.

Configuration of New Modeling Clusters

The two new AMU modeling clusters were turned on in January 2013. Under KSC direction, Mr. Magnuson from ENSCO, Inc., began initial setup on the clusters for AMU personnel to use. His work was halted by KSC in February 2013 and will resume when KSC IT Security provides an “Authority to Operate” certification for both clusters.

Installation and Configuration of Data Assimilation Software

Dr. Watson acquired the GSI software to use for the data assimilation portion of the task. GSI is a variational data assimilation system that was originally developed by the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Prediction (NCEP) and is freely available for community use. The system has been used in various operational systems since its development.

Dr. Watson installed the software on the existing AMU modeling cluster with the help of Mr. Magnuson. GSI could not be compiled on the existing cluster since it required a newer version of the compiler software. Therefore, Dr. Watson configured and compiled GSI on an ENSCO cluster that had the updated compiler software and ported it over to the AMU cluster. Dr. Watson then tested the installation by running GSI test cases from the Developmental Testbed Center website (http://www.dtcenter.org/com-GSI/users/).

Dr. Watson began acquiring initialization data for GSI, including conventional observations from platforms such as METAR and sounding, and various satellite data such as brightness temperatures, satellite winds, precipitation rates, etc. The data is available in Binary Universal Form for the Representation of meteorological data (BUFR) and is freely available from NCEP. She will continue to acquire data as needed as the task progresses.

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

AMU ACTIVITIES

AMU Operations

Mission Immediate

Dr. Huddleston and Dr. Bauman completed a Mission Immediate task to assess the accuracy of the NCEP North American Mesoscale (NAM) model low-level wind speed and direction forecasts and compare them to XMR Skid Strip observations. The 45 WS was concerned the model was not performing properly due to a model change in October 2012. They wanted to quantify any degradation as soon as possible because Range Safety uses the data in their toxic, debris and Blast Assessment prediction models, and range forecasters use the data in their forecasts. Dr. Bauman wrote a script to download and process the NAM files created before the model change (15 October 2011-15 January 2012) and after the model change (15 October 2012-15 January 2013) and saved them as Excel formatted files for Dr. Huddleston. She computed bias, standard deviation and mean error of the NAM forecasts against the XMR observations provided by Mr. McAleenan of the 45 WS. The NAM model appeared to perform very well when compared to the XMR observations. There were no statistical differences in the wind speed before and after the model changed. The wind direction, however, did appear to deviate more from observations after the model changed. Overall the model, before and after the changes, matched the observations well.

IT

The AMU file server containing over 21 years' worth of AMU work failed on 3 January. No data was lost because the AMU routinely backed up the server to local external disk drives. On 14 January, Mr. Robert Brown, NASA GP-G, provided the AMU with a shared folder on a GP server at KSC to replace the AMU's failed server. Dr. Bauman completed moving 855 GB of AMU files to the new shared folder on 31 January. The AMU staff also received new NASA Agency Consolidated End-user Services workstations to replace their old PC's.

Conferences and Training

Dr. Bauman, Ms. Crawford and Ms. Shafer attended the 93rd Annual American Meteorological Meeting in Austin, Texas, 7-11 January. Dr. Bauman and Ms. Shafer presented AMU work at the 16th Aviation, Range and Aerospace Meteorology (ARAM) conference at the AMS meeting. Dr. Bauman also chaired the opening session of the ARAM conference.

Dr. Bauman, Ms. Crawford, and Ms. Shafer attended the Day Of Launch Working Group meeting at KSC; the AMU staff attended annual security training at ENSCO's Cocoa Beach office; and Dr. Watson presented the results from the Range-specific High-resolution Mesoscale Model Setup task to the 45 WS. Dr. Bauman and Dr. Huddleston provided first drafts of their input for a feature article on "Research to Operations" for the journal *Space Weather* to Dr. Merceret.

Operations Support

Mr. McAleenan of the 45 WS asked the AMU for assistance assessing if the heavy rainfall on 24 February impacted the Falcon 9 Dragon capsule while exposed on the launch pad. Dr. Bauman downloaded the NWS MLB WSR-88D radar data and used the AMU GR2Analyst software to display only reflectivities ≥ 45 dBZ. The data indicated heavy rainfall did not occur at the launch pad and therefore did not impact the Dragon capsule.

Visitors

Dr. Bauman and Dr. Huddleston provided an overview of the AMU to Mr. Marc Siebert of the Ka-Band Objects Observation and Monitoring (KaBOOM) project. The AMU staff presented an overview briefing of the AMU to the new 45 WS Range Weather Operations Flight Commander, Capt. Sweat, and discussed the AMU's current tasks. They also presented an overview briefing of the AMU to personnel from the KSC Procurement Directorate and discussed the AMU's current tasks.

AMU Chief's Technical Activities (Dr. Huddleston)

Dr. Huddleston reviewed the KSC 50 MHz DRWP replacement program development review (PDR) packets. The PDR occurred at KSC on 17-18 January. She also worked on several action items, including the verification and validation plan, for the 50-MHz DRWP procurement. She attended a technical interchange meeting to discuss software development for the DRWP Median Filter First Guess algorithm and its interface with MIDDS. She also attended the Lightning Advisory Panel meeting at KSC on 26-28 Feb 2013.

Dr. Huddleston attended an introduction to and a tour of the new KaBOOM test site at KSC. Dr. Huddleston, KSC Weather Office, and the 45 WS have been working with the KaBOOM project to provide weather support for their operations.

The KSC Weather Office worked with ENSCO and Space Florida to establish an agreement between Space Florida and NASA through a Space Act Agreement (SAA) to allow Space Florida to provide additional funding to the AMU contract in support of weather technology transition to develop a local high-resolution numerical model to help improve weather hazard forecasts for new commercial spaceflight activities at KSC. Ultimately, NASA could not complete the SAA before Space Florida needed to obligate their funds and decided to contract directly with ENSCO for support.

Dr. Huddleston reviewed a draft journal article on KSC/CCAFS rainfall patterns for John Drese of Ino-Medic Health Applications, and completed a 12-week Duke University online Coursera.org course called "Think Again: How to Reason and Argue".

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LIST OF ACRONYMS

14 WS	14th Weather Squadron
30 SW	30th Space Wing
30 OSS	30th Operational Support Squadron
45 RMS	45th Range Management Squadron
45 OG	45th Operations Group
45 SW	45th Space Wing
45 SW/SE	45th Space Wing/Range Safety
45 WS	45th Weather Squadron
ABS	Absolute Value
AFSPC	Air Force Space Command
AFWA	Air Force Weather Agency
AMPS	Automated Meteorological Profiling System
AMU	Applied Meteorology Unit
ARW	Advanced Research WRF
AUC	Area Under the Curve
AWIPS	Advanced Weather Information Processing System
BUFR	Binary Universal Form for the Representation of meteorological data
CAPE	Convective Available Potential Energy
CAPE Max θ_e	CAPE based on the Maximum Equivalent Potential Temperature
CAPE FMaxT	CAPE based on the forecast maximum temperature
CCAFS	Cape Canaveral Air Force Station
CI	Convection Initiation
CIN	Convective Inhibition
CG	Cloud-to-Ground
CH	California High
CSR	Computer Sciences Raytheon
CT	Cross Totals
DA	Data Assimilation
DRWP	Doppler Radar Wind Profiler
ER	Eastern Range
ESRL	Earth System Research Laboratory
EW	East-West orientation
FRN	Forecast Reference Notebook
FSU	Florida State University
GSI	Gridpoint Statistical Interpolation
GUI	Graphical User Interface
H_0	Null Hypothesis
H_1	Alternative Hypothesis
IGRA	Integrated Global Radiosonde Archive
IRIS	Interactive Radar Information System
JSC	Johnson Space Center
KaBOOM	Ka-Band Objects Observation and Monitoring
KI	K Index
KSC	Kennedy Space Center
LI	Lifted Index
LSP	Launch Services Program
LWO	Launch Weather Officer
MCO	Orlando International Airport
MIDDS	Meteorological Interactive Data Display System
MPW	Maximum Peak Wind
MSFC	Marshall Space Flight Center
MSLP	Mean Sea Level Pressure
NAM	North American Mesoscale model
NB	North Base (at VAFB)
NCAR	National Center for Atmospheric Research
NCDC	National Climatic Data Center
NCEP	National Centers for Environmental Prediction
NE	Natural Environments
NLDN	National Lightning Detection Network
NOAA	National Oceanic and Atmospheric Administration
NPL	North Pacific Low
NS	North-South orientation
NSSL	National Severe Storms Laboratory
NWS MLB	National Weather Service in Melbourne, FL
PDR	Program Development Review
PG	Pressure Gradient
POR	Period of Record
PW	Precipitable Water
QC	Quality Control
SB	South Base (at VAFB)
SMC	Space and Missile Center
SSI	Showalter Stability Index
SWEAT	Severe Weather Threat Index
TI	Thompson Index
TT	Total Totals
TTS	Total Threat Score
UL	Upper Level
URL	Uniform Resource Locator
USAF	United States Air Force
UT	Upper Trough
VAFB	Vandenberg Air Force Base
VT	Vertical Totals
WDSS-II	Warning Decision Support System Integrated Information
WFF	Wallops Flight Facility
WR	Western Range
WRF	Weather Research and Forecasting Model
WSR-88D	Weather Surveillance Radar 1988-Doppler
XMR	CCAFS 3-letter identifier

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

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