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Upgrade Summer Severe Weather Tool in MIDDS

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May 2010

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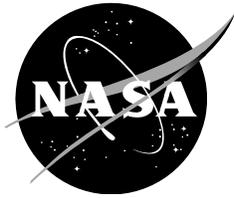
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Space Administration

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Executive Summary

The 45th Weather Squadron (45 WS) Commander's morning weather briefing includes an assessment of the likelihood of local convective severe weather for the day in order to enhance protection of personnel and material assets of the 45th Space Wing, Cape Canaveral Air Force Station (CCAFS), and Kennedy Space Center (KSC). The severe weather elements produced by thunderstorms include tornadoes, convective surface winds ≥ 50 knots, and/or hail with a diameter $\geq 3/4$ inches. Forecasting the occurrence and timing of these phenomena is challenging for 45 WS operational personnel.

In previous work the Applied Meteorology Unit (AMU) analyzed stability parameters and synoptic patterns from east-central Florida severe weather days during the warm season months of May-September in the years 1989-2003 in order to determine which parameters were important in severe weather forecasting. The stability parameters and synoptic patterns that showed potential were assigned weights based on their threat value. A Meteorological Interactive Data Display System (MIDDS) based Graphical User Interface (GUI) was developed in a follow-on task that retrieves stability parameters and other information from MIDDS automatically and computes a severe weather Total Threat Score (TTS), minimizing the forecaster's interaction with the tool.

For this task, the 45 WS requested the AMU to upgrade the severe weather database from the previous phase by adding weather observations from the years 2004 – 2009 to the previous 1989-2003 study period, re-analyze the data to determine the important parameters, make adjustments to the index weights depending on the analysis results, and update the MIDDS GUI. The added data increased the period of record from 15 to 21 years. Data sources included local forecast rules, archived sounding data, surface and upper air maps, and two severe weather event databases covering east-central Florida.

Four of the stability indices showed increased severe weather predication. The results were presented in stacked column graphs that depicted the percent occurrence of severe/non-severe days with respect to a severe weather threat index for each stability parameter. The Total Threat Score (TTS) of the previous work was verified for the warm season of 2009 with very good skill. The TTS Probability of Detection (POD) was 88% and the False alarm rate (FAR) of 8%.

Based on the results of the analyses, the MIDDS Severe Weather Worksheet GUI was updated to assist the duty forecaster by providing a level of objective guidance based on the analysis of the stability parameters and synoptic-scale dynamics. The tool retrieves needed values from MIDDS automatically, and requires the forecaster to answer a few subjective questions. This improved GUI with mouse-over help allows the forecaster to quickly compute and analyze the daily TTS. Making this tool more automatic reduces the possibility of human error and increases efficiency, allowing forecasters to do other duties.

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1. Introduction

The 45th Weather Squadron (45 WS) Commander's morning weather briefing includes an assessment of the likelihood of local convective severe weather for the day. This forecast is provided in order to enhance protection of personnel and material assets of the 45th Space Wing, Cape Canaveral Air Force Station (CCAFS), and Kennedy Space Center (KSC). The severe weather elements produced by thunderstorms include tornadoes, convective surface winds ≥ 50 knots, and/or hail with a diameter $\geq 3/4$ inches. Forecasting the occurrence and timing of these phenomena fairly easy during the cool season (Oct-Apr), being associated with strong fronts that are usually predicted very well by numerical models. However, forecasting severe weather is very challenging during the warm season (May-Sep).

In previous tasks, the Applied Meteorology Unit (AMU) analyzed stability parameters and synoptic patterns from central Florida severe weather days during the warm season in the years 1989-2003 in order to determine which were important to severe weather development and forecasting. An objective HyperText Markup Language (HTML) worksheet was developed that used important parameters and patterns to assist forecasters in determining the probability of issuing severe weather watches and warnings for the day.

The AMU also did a follow-on task that resulted in a Meteorological Interactive Data Display System (MIDDS) based Graphical User Interface (GUI) to replace the HTML worksheet. This GUI retrieved stability parameters and other information from MIDDS automatically, minimizing the forecaster's interaction with the tool. The result was a reduction in the possibility of human error and increased efficiency, giving forecasters more confidence in the tool output and allowing them more time to do other duties.

For this task, the 45 WS requested the AMU upgrade the severe weather database by adding weather observations from the years 2004-2009 to the previous 1989-2003 study period, re-analyzing the data to determine the important parameters, make appropriate adjustments to the index weights depending on the results of the analysis, and update the MIDDS GUI with any new values. The AMU accomplished this goal and delivered the new GUI to the 45 WS for operational use.

2. Previous Work

In the Severe Weather Forecast Decision Aid task final report (Bauman et al. 2005), the AMU presented a 15-year climatological study of severe weather events and related severe weather atmospheric parameters. The period of record (POR) for the analysis was May – September, 1989 – 2003. The data sources included local forecast rules, archived soundings, Cloud-to-Ground Lightning Surveillance System (CGLSS) data, surface and upper air maps, and two severe weather event databases covering east-central Florida. The AMU used the local forecast rules to set threat-assessment thresholds for stability parameters that were derived from the sounding data. The severe event databases were used to identify days with reported severe weather and the CGLSS data were used to differentiate between lightning and non-lightning days. These data sets provided the foundation for analyzing stability parameters and synoptic patterns with the goal of developing an objective tool to aid in forecasting severe weather events.

An interactive web-based HTML Severe Weather Forecast Decision Aid was developed to assist the duty forecaster by providing a level of objective guidance based on the stability parameters from the CCAFS sounding, CGLSS data, and synoptic-scale dynamics. In the follow-on study (Wheeler 2009), the HTML tool was converted into a MIDDS GUI worksheet using Tool Command Language and its associated Tool Kit (Tcl/Tk). When opened, the GUI retrieves and calculates most of the daily sounding stability indices needed by the worksheet. The forecaster would answer a few subjective questions and the Total Threat Score (TTS), the index representing the level of severe weather threat, would be calculated and displayed.

3. Database

For this work, the AMU updated the severe weather database with data from the warm seasons in 2004 – 2009, increasing from a 15- to a 21-year climatological study of atmospheric stability indices and severe events from 1989-2009. To be consistent with previous work, the AMU collected the same data types and parameters used in the previous work to update the severe weather database. Severe weather reports during 2004-2009 were collected from the Storm Prediction Center (SPC) and data from severe weather days in that period from the National Climatic Data Center (NCDC) database. The CCAFS 1000 UTC sounding stability parameters were provided from the ongoing Objective Lightning Probability Tool task being conducted by the AMU. Also, the 200mb charts were analyzed to identify the placement and characteristics of the upper-level jet. With this update, the data sets included severe

weather events, synoptic weather patterns, upper jet pattern, and sounding stability parameters. Each data type proved to have some relevance to forecasting the threat of convection in east-central Florida and at KSC/CCAFS.

3.1 Sounding Parameters

A thorough analysis of atmospheric stability based on a local upper air sounding is needed for any convective forecast. The 15 indices listed in Table 1 are in the severe weather database and were analyzed for their utility in forecasting severe weather. These six stability indices (bold) and eight other sounding parameters are readily available in MIDDS from the CCAFS rawinsonde. A listing of each of the sounding stability indices and additional calculated parameters from MIDDS used in the TTS calculation is shown in Table 1.

| Table 1. The six stability (in bold font) and nine other sounding parameters in the severe weather database and the equations used in their calculation. | |
|--|--|
| Index Acronym | Definition |
| LI | Lifted Index = $(T_{500} - T^*)$ T* = Temperature of a parcel characterized by the mean T_d in the lowest 3000ft and the forecast maximum surface temperature if it were lifted dry adiabatically to saturation and then moist adiabatically to 500 mb. |
| KI | K Index = $(T_{850} - T_{500}) + T_{d850} - (T_{700} - T_{d700})$ |
| TT | Total Totals = $(T_{850} - T_{500}) + (T_{d850} - T_{500})$ |
| SSI | Showalter Stability = Index $(T_{500} - T^*)$ T* = Temperature a parcel characterized by the T_{850} and T_{d850} would have if it were lifted dry-adiabatically to the LCL and then moist-adiabatically to 500 mb. |
| CT | Cross Totals = $(T_{d850} - T_{500})$ |
| TI | Thompson Index = $KI - LI$ |
| PW | Precipitable water in mm in the layer from the surface to 500 mb |
| 10070RH | Average Relative Humidity in percent (%) from 1000-700 mb |
| CFMaxT | CAPE calculated using the forecast maximum temperature for the day instead of the surface temperature in the morning |
| LLJ | Low Level Jet below 5000 ft (Wind direction and speed) |
| INV | Height of Inversion below 8000 ft |
| T850 | The sounding temperature at 850 mb |
| TDif | The difference between forecast maximum and convective temperatures |
| MDPI | Microburst Day Potential Index |

3.2 Synoptic Weather Patterns

The synoptic weather patterns investigated included the position of the upper level jet streak if one existed and the position of the surface high pressure ridge axis over east central Florida. It is commonly known that upper level divergence and/or the left-exit and to a lesser degree right-entrance quadrant of a jet streak in the vicinity of convective systems can help produce severe weather. The 45 WS forecasters often analyze the position of the surface high pressure ridge axis protruding westward from the Bermuda high pressure center as an indicator for convection occurrence. It is generally known that if the surface ridge is south of the KSC/CCAFS area the probability for convection is increased.

4. Data Analysis Results

The AMU gathered severe weather reports for the years 2004 – 2009 from SPC and data for those severe weather days from NCDC. The 200mb charts were analyzed to identify placement and characteristics of any jet streaks overhead. The Florida flow regime patterns were also added to the severe weather database. The data sets

were integrated and compared to the severe weather reports of hail, high wind and tornadoes to determine what the parameter values were on each of the severe weather event days.

Analysis of the Total Totals, Lifted Index, Thompson Index and Showalter Stability Index stability parameters from the soundings revealed increased severe weather forecast potential in the 2004 – 2009 data and in all 21 years (1989-2009) combined. This increased the tool’s overall severe weather predicting capability. The AMU determined the severe weather threat thresholds of Low, Medium and High for each stability parameter from the new dataset and compared them with the thresholds from the previous work. The relationship between each stability parameter and threshold criteria for the severe weather threat was calculated for severe and non-severe days based on the 1000 UTC CCAFS sounding. The results of each of these four parameters are detailed below.

4.1 Total Totals (TT)

The TT thresholds specifies that there is a low threat for severe weather for CCAFS/KSC during the warm season when $TT \leq 45$, a medium threat when $46 \leq TT \leq 48$, and a high threat when $TT > 48$. When $TT > 48$, a severe weather event was reported in 45% of the 2004–2009 days. This increased the overall 21-year value to 34% from 28% for the 15 years in the previous work. Figure 1 displays the threat levels of Low, Medium and High with the occurrence/non-occurrence of severe weather for the full 21 years.

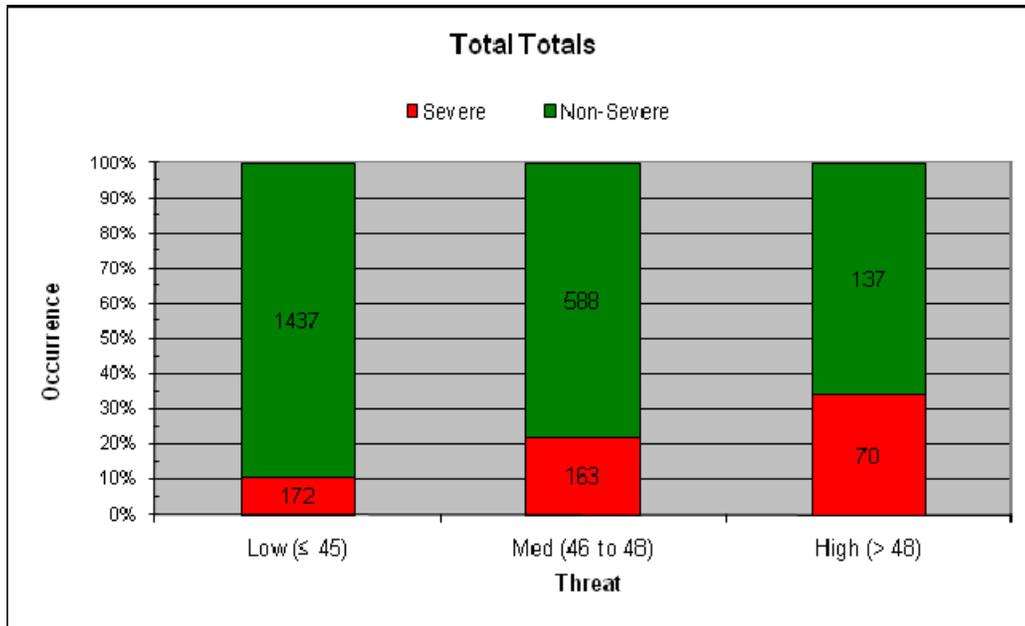


Figure 1. Stacked column graph of TT value thresholds. The number of severe/non-severe occurrences for the Low, Medium and High threat thresholds for all 21 years in the severe weather database.

4.2 Lifted Index (LI)

The LI thresholds values indicate that there is a low threat for severe weather when $LI \geq -2$, a medium threat when $-3 \geq LI \geq -5$, and a high threat when $LI < -5$. When the LI was < -5 , severe weather was reported 50% of the time in the new 6-year data set. Figure 2 shows the LI Low, Medium and High threat distribution for all years in the severe weather database.

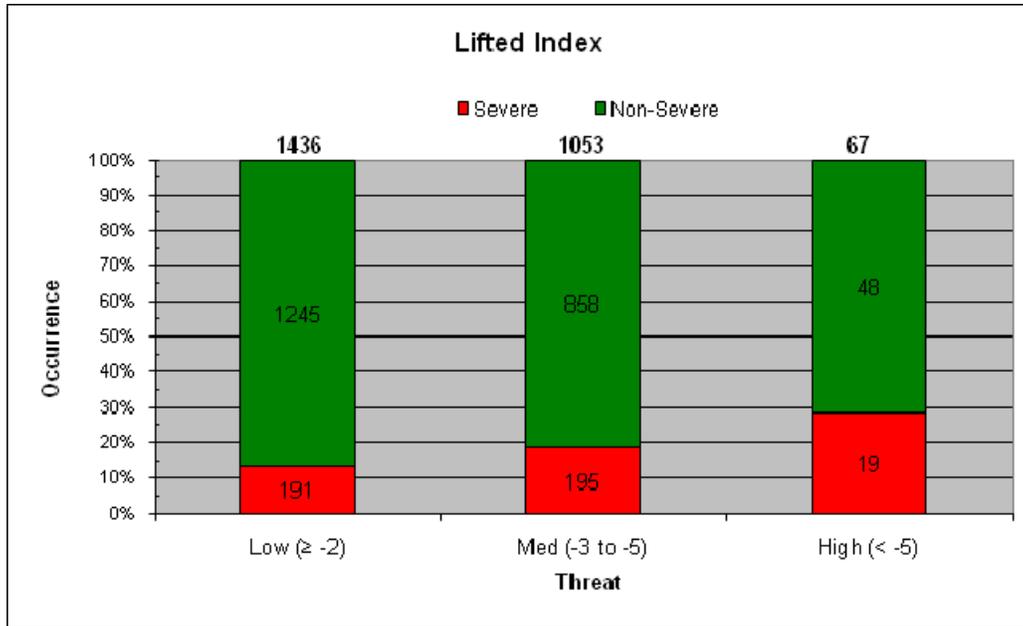


Figure 2. Same as Figure 1 except for LI.

4.3 Thompson Index (TI)

The TI specifies low threat when $TI < 25$, medium threat when $25 \leq TI \leq 34$, high threat when $35 \leq TI \leq 39$, and very high threat when $TI \geq 40$. The TI continued to be a valuable high threat predictor for severe weather as it was in the previous work. When the TI value was > 40 , severe weather was reported 94% of the time in the new 6-year data set. It increased to 91% occurrence for the 21-year POR over the previous work value of 88%. Figure 3 shows the severe weather threat distribution for all years in the severe weather database.

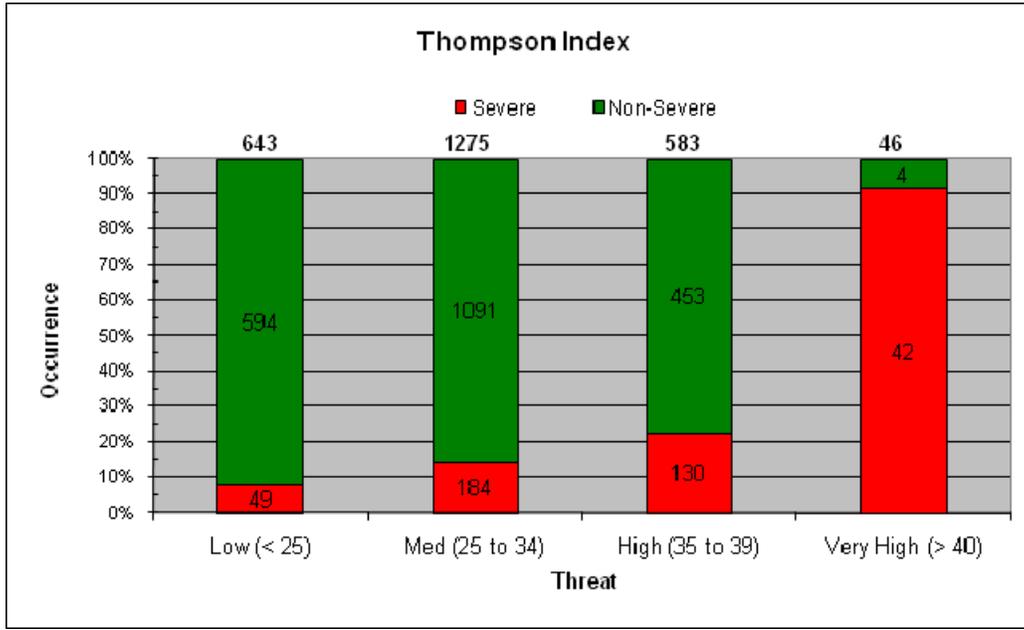


Figure 3. Same as Figure 1 except for TI and the fourth threat category Very High.

4.4 Showalter Stability Index (SSI)

The SSI thresholds indicate that there is a low threat when $SSI \geq 3$, a medium threat when $2 \geq SSI \geq -2$, and a high threat when $SSI < -2$. The 2004-2009 severe weather databases confirmed that SSI is a good severe weather predictor. When the $SSI < -2$, severe weather was reported in central Florida 37% of the time, an increase over 31% from the previous work. Figure 4 shows SSI threshold distribution for all years.

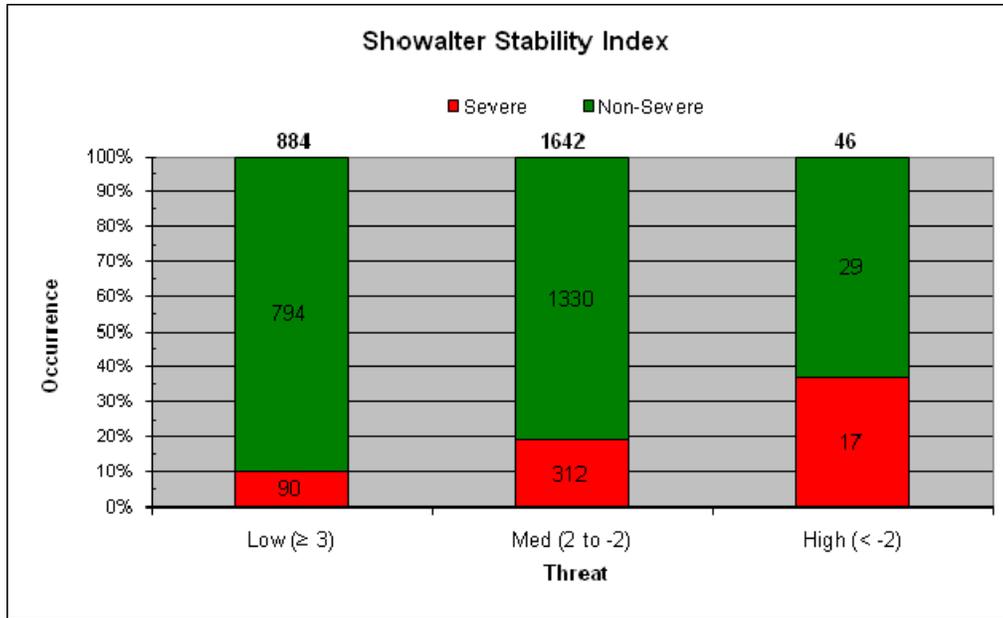


Figure 4. Same as Figure 1 except for SSI.

5. Severe Weather Worksheet GUI

The AMU updated the Severe Weather Worksheet GUI in MIDDs with the results from the data analysis. The GUI was developed in Wheeler (2009). Several features were added to the GUI to help the 45 WS forecaster understand the worksheet and to be able to make a hard copy print of the daily TTS.

Figure 5 shows the updated Severe Weather Worksheet GUI. The worksheet is a Tcl/Tk-based tool that the forecaster can access from their MIDDs workstation. The GUI retrieves and calculates most of the severe weather parameters from the CCAFS 1000 UTC morning sounding. It calculates values and weights for 14 out of the 26 questions in the worksheet. The other 12 questions are subjective and need to be answered by the forecaster. These questions were handled by displaying the question for the forecaster, having mouse-over help to display descriptive text, and a View Graphic button. The forecaster checks Yes or No for each question. The response to each question is assigned a value that was drawn from discussions with experienced forecasters and/or the occurrence of severe weather related to the stability parameters. The View Graphic button displays a MIDDs graphic image of the parameter to help the forecaster answer the question. The GUI calculates an index value based on the forecaster response. When the forecaster selects the button marked "Calculate Total Threat Score (TTS)", the GUI adds all the index values and displays the total to the forecaster. The magnitude of the total, which is the TTS, represents the severe weather threat for the day. All of the calculated values and parameters are written and stored in a text file that can be viewed later. The forecaster has the option to make a hard copy print of the TTS along with the stability parameters for that day. They can also print the previous day's values if the worksheet was filled out.

[Help](#)

SEVERE WEATHER WORKSHEET
CALCULATES the TOTAL THREAT SCORE (TTS),
Valid May - Sep

TODAY: Answers

| | | | | |
|--|---|--------------------------|--|---|
| Is SEVERE WX mentioned in FXUS62 bulletin? | <input checked="" type="radio"/> YES | <input type="radio"/> NO | View MLB Fcst Discussion | N |
| Was SEVERE WX mentioned in previous bulletin? | <input checked="" type="radio"/> YES | <input type="radio"/> NO | View Previous MLB Discussion | N |
| Was severe wx reported by TPA or MLB? | <input checked="" type="radio"/> YES | <input type="radio"/> NO | View MLB/TPA SVR Reports | N |
| Was severe wx reported by TLH or JAX? | <input checked="" type="radio"/> YES | <input type="radio"/> NO | View TLH/JAX SVR Reports | N |
| Is there a FNT/SQ Ln in NW FL, moving SE? | <input checked="" type="radio"/> YES | <input type="radio"/> NO | Develops 4-Phi Front Anal 00-09z | N |
| Is there a distinct moist/dry bndry across C FL? | <input checked="" type="radio"/> YES | <input type="radio"/> NO | View WV Loop | N |
| Do the Sounding winds veer with height, Sfc - 10Kft? | <input checked="" type="radio"/> YES | <input type="radio"/> NO | See XMR Skew-T | N |
| Is there a 200mb spd max, right entrance region, left exit region or div near? | <input checked="" type="radio"/> YES | <input type="radio"/> NO | Display 200mb Wind Plot | N |
| What is the Flow Regime? | <input type="radio"/> SW1 <input type="radio"/> SW2 <input type="radio"/> SE1 <input type="radio"/> SE2 <input type="radio"/> NW <input type="radio"/> NE | | | N |
| If a Sea Breeze forms, will it stay east of I-95? | <input checked="" type="radio"/> YES | <input type="radio"/> NO | See east-central FL Analysis | N |
| Are you forecasting a late developing Sea Breeze? | <input checked="" type="radio"/> YES | <input type="radio"/> NO | | N |
| Are you forecasting or observing multiple boundary collisions? | <input checked="" type="radio"/> YES | <input type="radio"/> NO | | N |

When an upper level speed max entrance/exit region or upper level divergence is present over KSC/CCAFS, severe weather occurs 19% of the time. These conditions account for 29% of all warm season days. Weighted values: Yes = 2, No = 0.

Figure 5. Example of the 45 WS Severe Weather Worksheet GUI. Forecasters will answer each item by checking the appropriate boxes. The TTS will be automatically calculated, displayed and shown on the MIDDS text screen.

6. 2009 Verification Results

The TTS score used for verification was developed from the 2005 earlier severe weather study (Bauman et al., 2005). The AMU calculated verification statistics for the TTS as an independent data set determined by the 45 WS forecasters in the 2009 warm season. When the forecasters completed the Severe Weather Worksheet GUI and computed the daily TTS, a text file was saved that contained their answers to the subjective questions and the sounding stability parameters for the day. This allowed a comparison of the daily TTS with reported severe weather events in 2009. The standard 2x2 contingency table shown in Table 2 was used to calculate the statistics and scores shown in the last row of Table 2.

Table 3 shows the contingency table statistics for the 2009 warm season. The 45 WS forecasters completed the severe weather worksheet and calculated a TTS for 94 of the 153 days. The TTS forecast threshold value for the contingency table was 5: if < 5 it was a No forecast and if ≥ 5 it was a Yes forecast. The central Florida severe weather verification area included three coastal counties (Brevard, Volusia, Indian River) and three inland counties (Seminole, Orange, Osceola), all of which are typically in the same large-scale air mass as KSC/CCAFS on most warm season days. If severe weather was reported across these Florida counties, that was classified as observed Yes. The Severe Weather Worksheet TTS verified well in the 2009 warm season, with a low FAR and high values for POD, CSI and HSS.

| | | | |
|---|-----|--|----|
| Table 2. The standard contingency table used for forecast verification. | | Observed Event | |
| | | Yes | No |
| Forecast Event | Yes | a | b |
| | No | c | d |
| N = a + b + c + d | | Critical Success Index (CSI) = a/(a+b+c) | |
| False Alarm Rate (FAR) = b/(a+b) | | Heidke Skill Score (HSS) = [(a+d) - E]/(N-E) | |
| Probability of Detection (POD) = a/(a+c) | | E = [(a+c)(a+b)+(b+d)(c+d)]/N | |
| | | True Skill Statistic (TSS) = a/a+c - b/b+d | |

| | | | | |
|---|-----|------------------------|-----------|------------|
| Table 3. Warm season 2009 TTS Verification Statistics | | Observed Severe | | FAR = 0.08 |
| | | Yes | No | POD = 0.88 |
| Forecast Severe | Yes | 23 | 2 | CSI = 0.82 |
| | No | 3 | 66 | HSS = 0.94 |
| | | | | TSS = 0.86 |

7. Summary

This report presented a severe weather forecasting tool developed from a 21-year climatological study of severe weather events and related severe weather atmospheric parameters. Data sources included local forecast rules, archived sounding data, surface and upper air maps, and two severe weather event databases covering east-central Florida. The severe weather events databases were used to identify days with reported severe weather. These data sets provided the foundation for analyzing the stability parameters and synoptic patterns that were used to develop the objective tool to aid in forecasting severe weather events. The period of record for the analysis was May – September, 1989 – 2009.

Several of the stability indices showed a higher rate of severe weather predication in the added years of 2004-2009 as compared to the previous study (1989-2003). The results were presented in stacked column graphs that depicted the percent occurrence of severe/non-severe days with respect to a severe weather threat index for each stability parameter. By displaying the data in this format, it was evident some stability parameters provided objective guidance for the frequency of occurrence of severe weather.

Based on the results of the analyses, the MIDDS Severe Weather Worksheet GUI was updated to assist the duty forecaster by providing a level of objective guidance based on the analysis of the stability parameters and synoptic-scale dynamics. The tool retrieves needed values from MIDDS automatically, and requires the forecaster to answer a few subjective questions. This improved GUI with mouse-over help allows the forecaster to quickly compute and analyze the daily TTS. Making this tool more automatic reduces the possibility of human error and increases efficiency, allowing forecasters to do other duties.

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List of Abbreviations and Acronyms

| Term | Description |
|------------------|---|
| 10070RH | 1000 to 700 mb average Relative Humidity |
| 45 WS | 45th Weather Squadron |
| AMU | Applied Meteorology Unit |
| CAPE | Convective Available Potential Energy |
| CCAFS | Cape Canaveral Air Force Station |
| CFMaxT | Cape using Maximum forecast Temperature |
| CT | Cross Totals |
| HTML | HyperText Markup Language |
| GUI | Graphical User Interface |
| KSC | Kennedy Space Center |
| INV | Height of Inversion |
| KI | K-Index |
| LI | Lifted Index |
| LLJ | Low Level Jet |
| MDPI | Microburst Day Potential Index |
| MIDDS | Meteorological Interactive Data Display System |
| NCDC | National Climatic Data Center |
| PW | Precipitable Water |
| SPC | Storm Prediction Center |
| SSI | Showalter Stability Index |
| T ₈₅₀ | Temperature at 850 mb |
| TDif | Forecast maximum temperature – convective temperature |
| TI | Thompson Index |
| TT | Total Totals Index |
| UTC | Coordinated Universal Time |

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