A Sounding-based Severe Weather Tool to Support Daily Operations at Kennedy Space Center and Cape Canaveral Air Force Station

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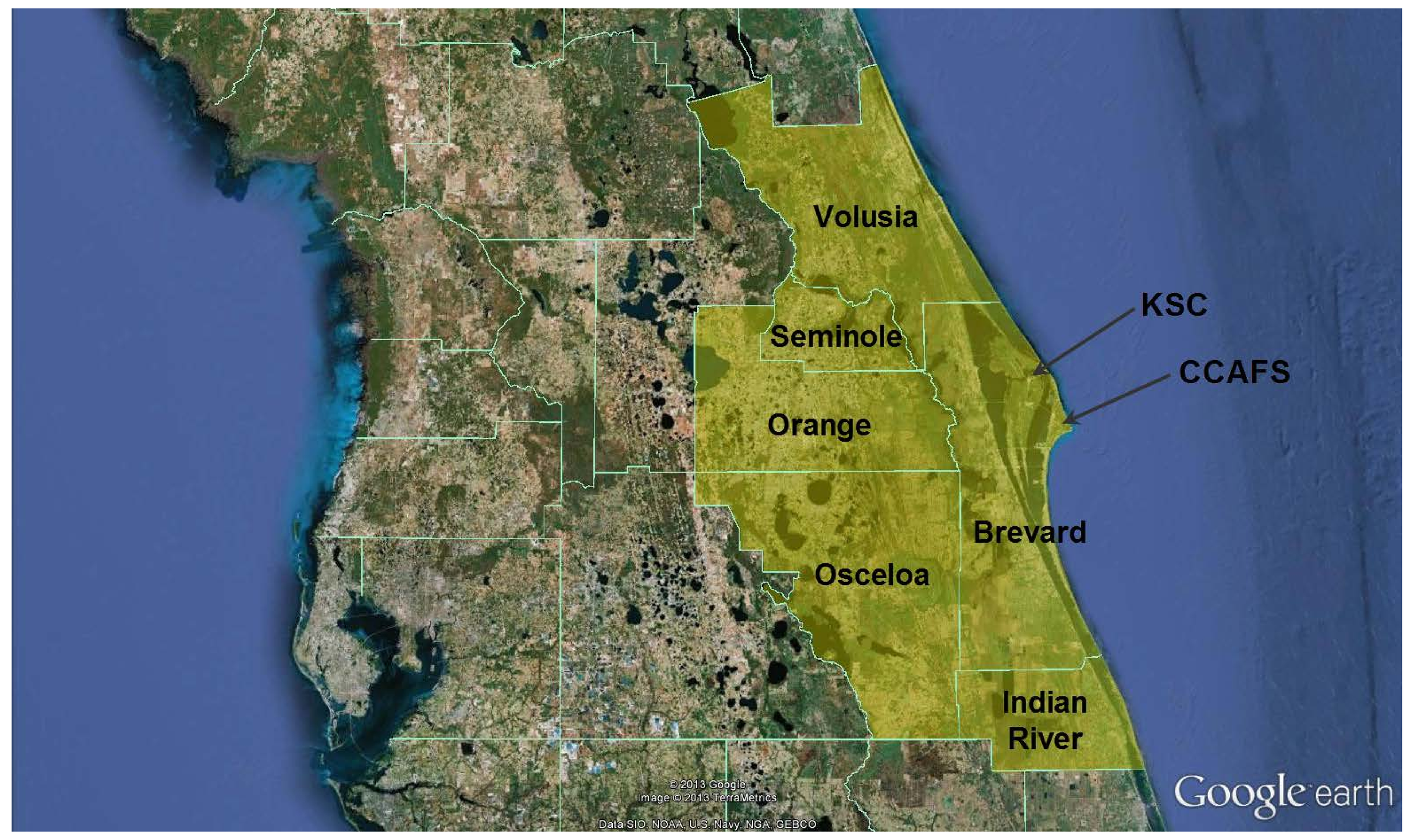
P758

OBJECTIVE: Update existing Severe Weather Tool

- Use the 1500 UTC sounding instead of the 1000 UTC sounding
- Make the tool more objective and user friendly
- Add two years of data to the period of record

BACKGROUND

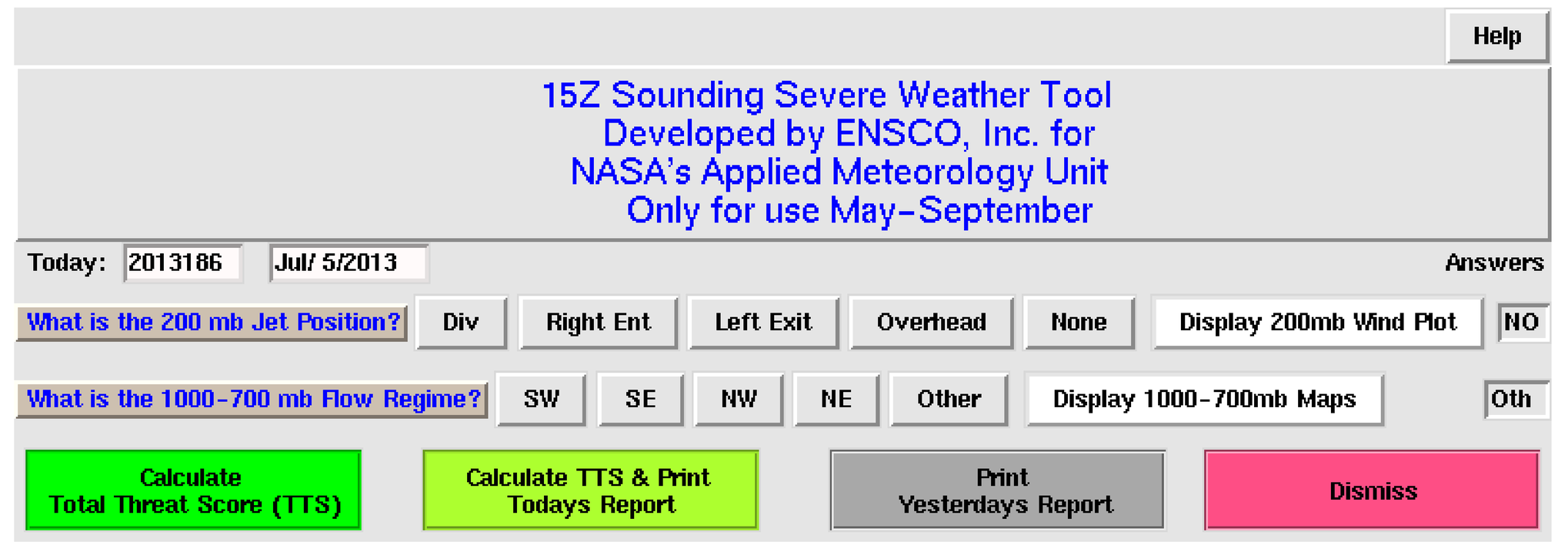
- People and property at Kennedy Space Center (KSC) and Cape Canaveral Air Force Station (CCAFS) are at risk when severe weather occurs
- Strong winds, hail and tornadoes can injure individuals and cause costly damage to structures if not properly protected
- Operations at KSC and CCAFS use the daily and weekly severe weather forecasts issued by the 45th Weather Squadron (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 launch pad
- Missed lead-times and false alarm statistics show that severe weather in east-central Florida is difficult to forecast during the warm season (May-September)
- The 45 WS requested the Applied Meteorology Unit (AMU) develop a warm season severe weather tool for use in the Meteorological Interactive Data Display System (MIDDS) based on the late morning, 1500 UTC (1100 local time), CCAFS (XMR) atmospheric balloon 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



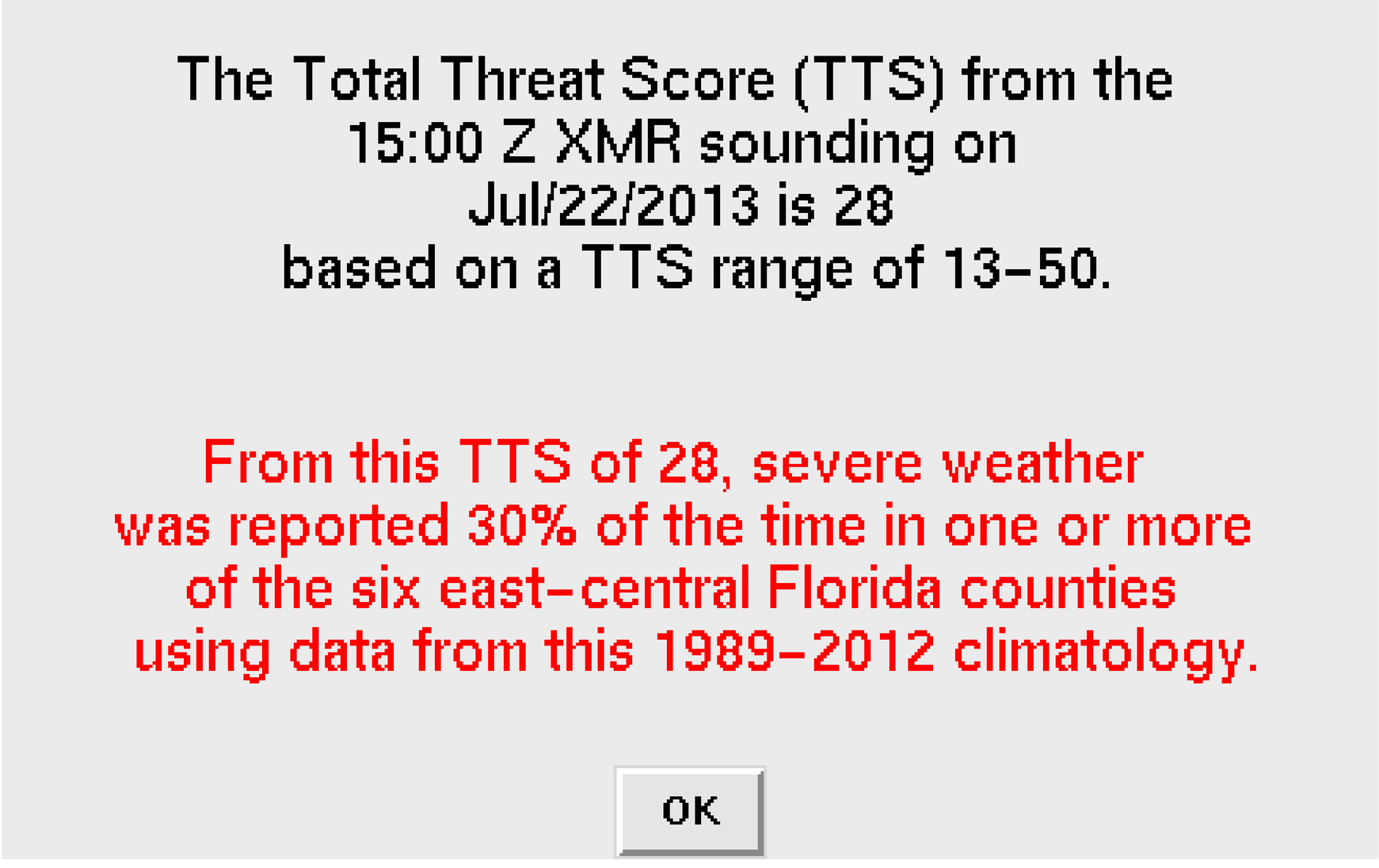
Map of central Florida showing the six counties (shaded in yellow) included in the severe weather events database. The location of KSC and CCAFS are shown on the map; both reside in northern Brevard County.

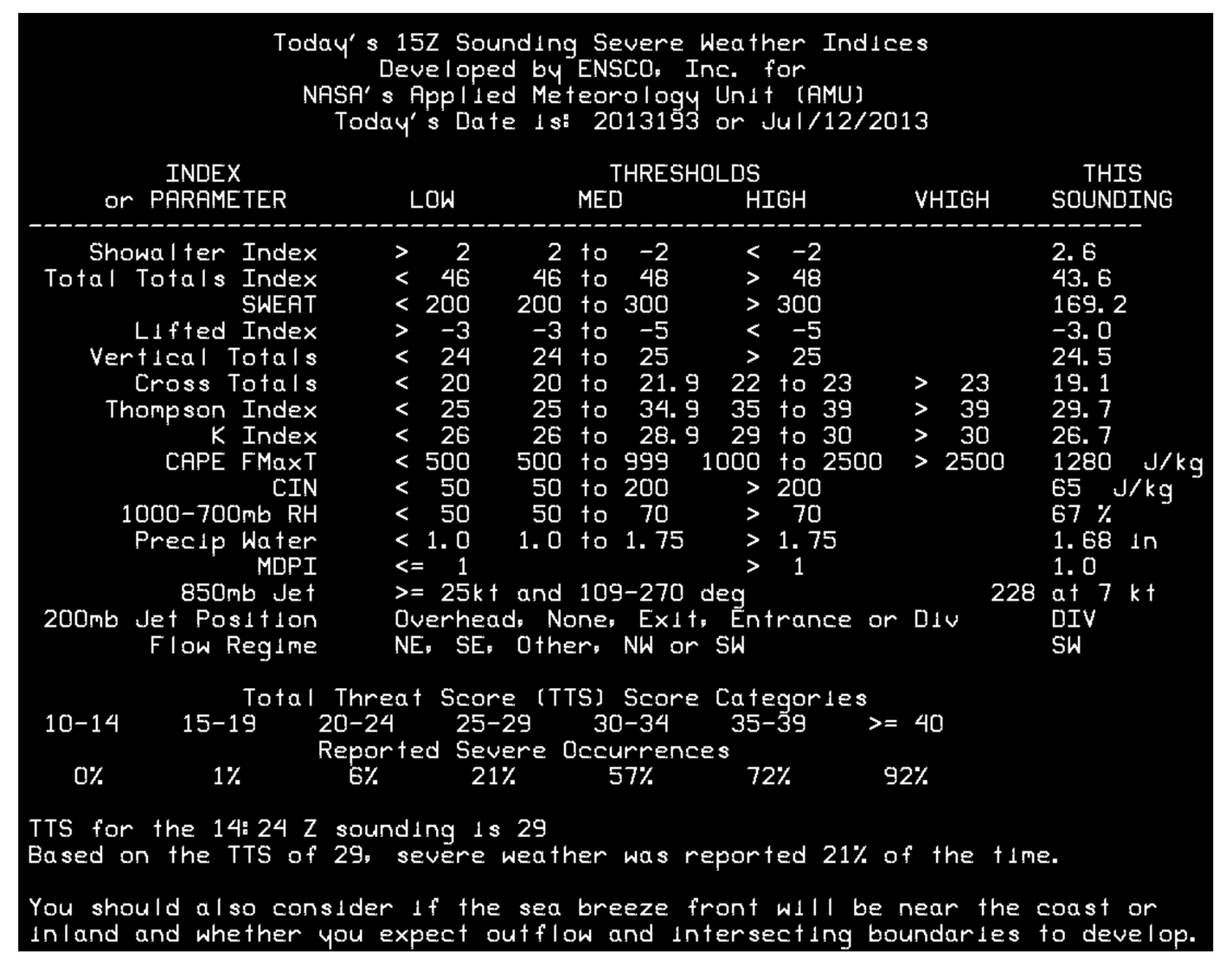
GRAPHICAL USER INTERFACE

- Developed in MIDDS
- Written in Tool Command Language and its associated Tool Kit (Tcl/Tk)
  - Computes and retrieves sounding parameters and then presents the user with the GUI for manual input
  - New GUI reduced number of subjective questions by 83%



Input window for the GUI.





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              Today's 15Z Sounding Severe Weather Indices
                    Developed by ENSCO, Inc. for
               NASA's Applied Meteorology Unit (AMU)
                Today's Date is: 2013193 or Jul/12/2013

       INDEX                         THRESHOLDS                         THIS
    or PARAMETER        LOW        MED         HIGH        VHIGH      SOUNDING
----------------------------------------------------------------------------
   Showalter Index      >   2     2 to  -2    <  -2                    2.6
 Total Totals Index     <  46    46 to  48    >  48                    43.6
              SWEAT     < 200   200 to 300    > 300                    169.2
       Lifted Index     >  -3    -3 to  -5    <  -5                    -3.0
    Vertical Totals     <  24    24 to  25    >  25                    24.5
       Cross Totals     <  20    20 to  21.9  22 to 23    >  23        19.1
    Thompson Index      <  25    25 to  34.9  35 to 39    >  39        29.7
           K Index      <  26    26 to  28.9  29 to 30    >  30        26.7
        CAPE FMaxT      < 500   500 to 999  1000 to 2500  > 2500       1280  J/kg
               CIN      <  50    50 to 200    > 200                    65  J/kg
     1000-700mb RH      <  50    50 to  70    >  70                    67 %
      Precip Water      < 1.0   1.0 to 1.75   > 1.75                   1.68 in
              MDPI      <=  1                 >  1                     1.0
        850mb Jet       >= 25kt and 109-270 deg                  228 at 7 kt
 200mb Jet Position     Overhead, None, Exit, Entrance or Div         DIV
       Flow Regime      NE, SE, Other, NW or SW                       SW

                 Total Threat Score (TTS) Score Categories
 10-14    15-19    20-24    25-29    30-34    35-39    >= 40
                    Reported Severe Occurrences
   0%       1%       6%      21%      57%      72%      92%

TTS for the 14:24 Z sounding is 29
Based on the TTS of 29, severe weather was reported 21% of the time.

You should also consider if the sea breeze front will be near the coast or
inland and whether you expect outflow and intersecting boundaries to develop.
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GUI output windows show TTS and frequency of reported severe weather (left) plus summary of all parameters (right).

DATA

- Existing data sets
  - Upper-level (200 mb) jet stream analyses
  - Severe storm reports
    - o National Climatic Data Center Storm Events Database
  - Daily flow regimes
    - o Mean wind direction in the 1000–700 mb layer from the Jacksonville (JAX), Tampa (TBW), and Miami (MFL) 1200 UTC soundings. Based on Lambert (2007), the 1000 UTC or 1500 UTC CCAFS (XMR) sounding was used to determine the flow regime when it could not be classified by using the combined wind directions from the other three 1200 UTC soundings.

This table contains the names of each flow regime as reclassified in Lambert (2007) from Lericos et al. (2002), a brief definition of each flow regime, and the number of days in each regime during the warm seasons in 1989–2012

AMU Naming Convention	Flow Regime Definition	# Days in the Regime
SW-1	Subtropical ridge south of MFL, Southwest flow over KSC/CCAFS.	502
SW-2	Subtropical ridge north of MFL, south of TBW. Southwest flow over KSC/CCAFS.	882
SE-1	Subtropical ridge north of TBW, south of JAX. Southeast flow over KSC/CCAFS.	655
SE-2	Subtropical ridge north of JAX. Southeast flow over KSC/CCAFS.	343
NE	Northeast flow over Florida, likely from a stronger-than-average subtropical ridge north of JAX extending into southeast U.S., at times forming a closed high pressure center.	542
NW	Northwest flow over Florida, likely from a stronger-than-average subtropical ridge south of MFL extending into Gulf of Mexico.	471
Other	When the layer-averaged wind directions at the three stations did not fit in defined flow regime.	251
Missing	Not enough soundings available to determine a flow regime	25

- New data sets
  - 1500 UTC XMR soundings
  - Stability parameters derived from those soundings
- Period of Record
  - Warm season months of May–September in the 24-year period 1989-2012

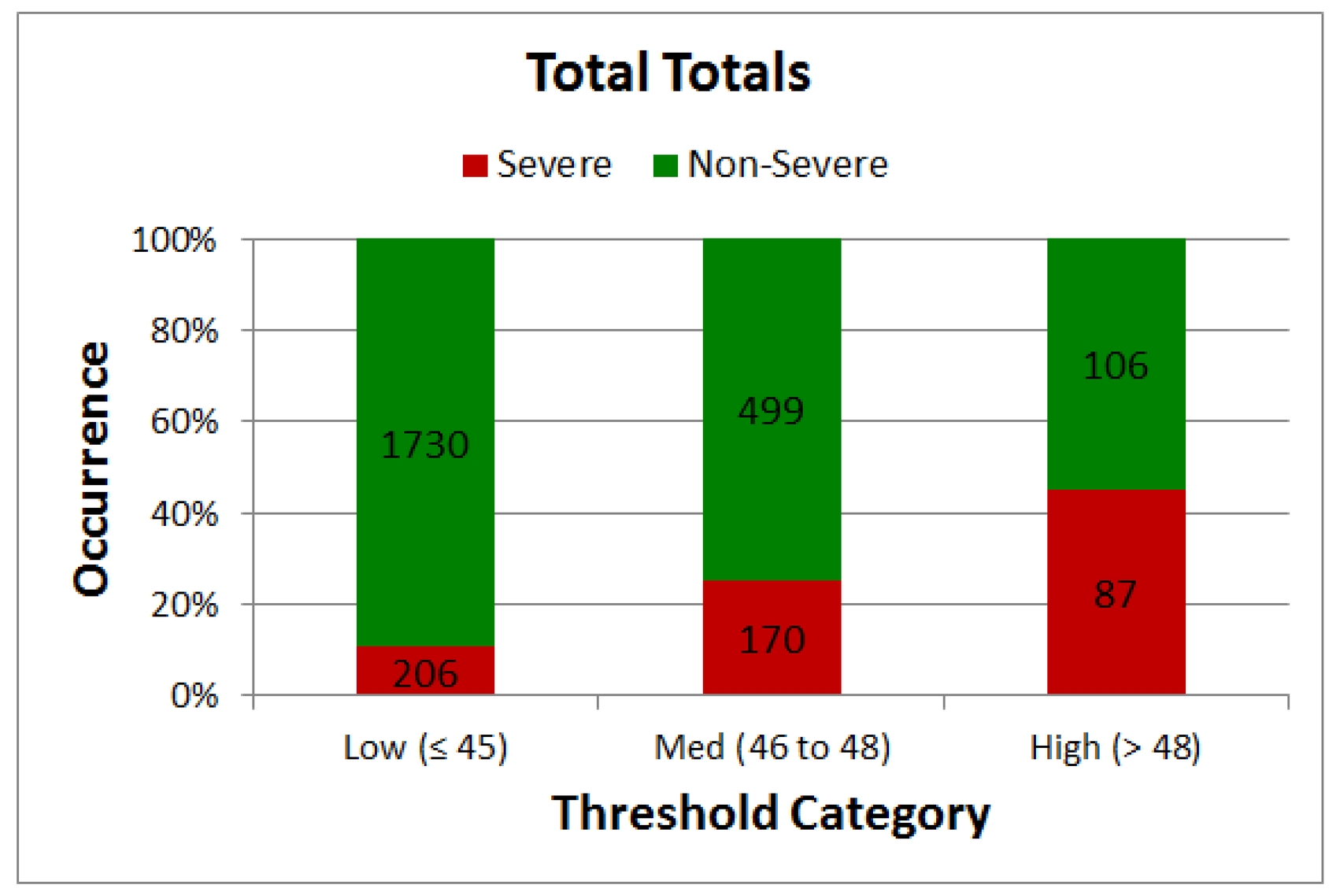
Sounding locations used to determine the flow regimes

SEVERE INDICES and PARAMETERS

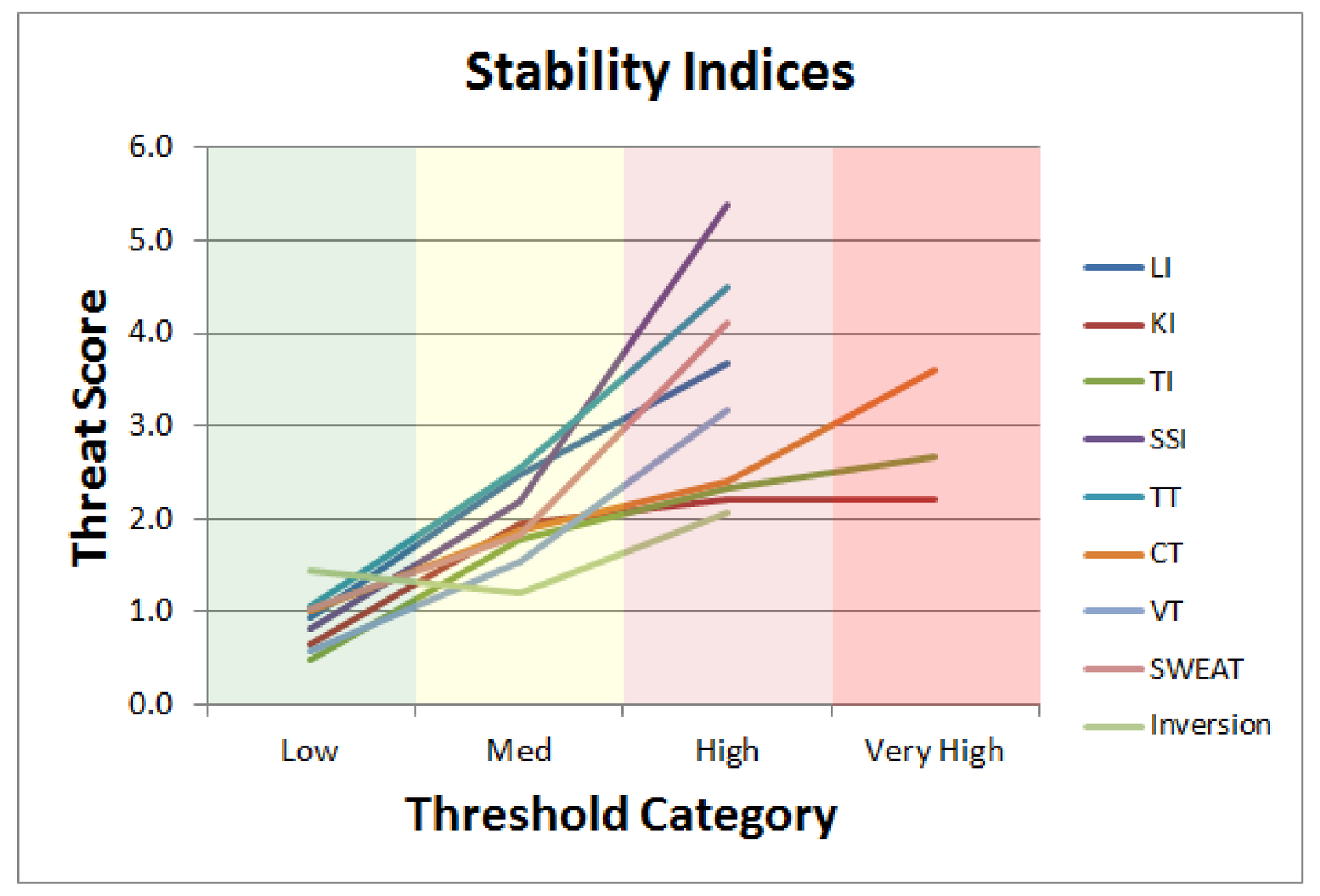
- Lifted Index (LI)
- K-Index (KI)
- Thompson Index (TI)
- Showalter Stability Index (SSI)
- Total Totals (TT)
- Cross Totals (CT)
- Vertical Totals (VT)
- Severe Weather Threat Index (SWEAT)
- Convective Available Potential Energy (CAPE)
- CAPE based on the maximum equivalent potential temperature (CAPE Max θ_e)
- CAPE based on the forecast maximum temperature (CAPE FMaxT)
- Convective Inhibition (CIN)
- Precipitable Water (PW)
- Temperature at 850 mb (T_{850})
- Temperature at 500 mb (T_{500})
- Average relative humidity in the 1000-700 mb layer
- Average relative humidity in the 850-500 mb layer
- Average relative humidity in the 850-600 mb layer
- Microburst Day Potential Index (MDPI) (Wheeler 1996)
- Inversion height below 8 kft
- Wind speed ≥ 25 kt and wind direction ≥ 109° and ≤ 270° at 850 mb (850 Jet)
- Veering winds from surface to 10 kft (WarmAdv)
- Helicity
- Storm Relative Motion Speed and Direction

STABILITY THRESHOLDS AND THREAT SCORES

- After generating stability indices and parameters
  - Categorized days with reported severe weather and days without reported severe weather by threshold values for each index
  - Developed charts showing the percent of time severe weather was reported based on specific thresholds
- Used categorized thresholds from each index to determine if they would be useful predictors of severe weather occurrence
- Created a threat score for each index derived from the percent of time severe weather occurred in each threshold category

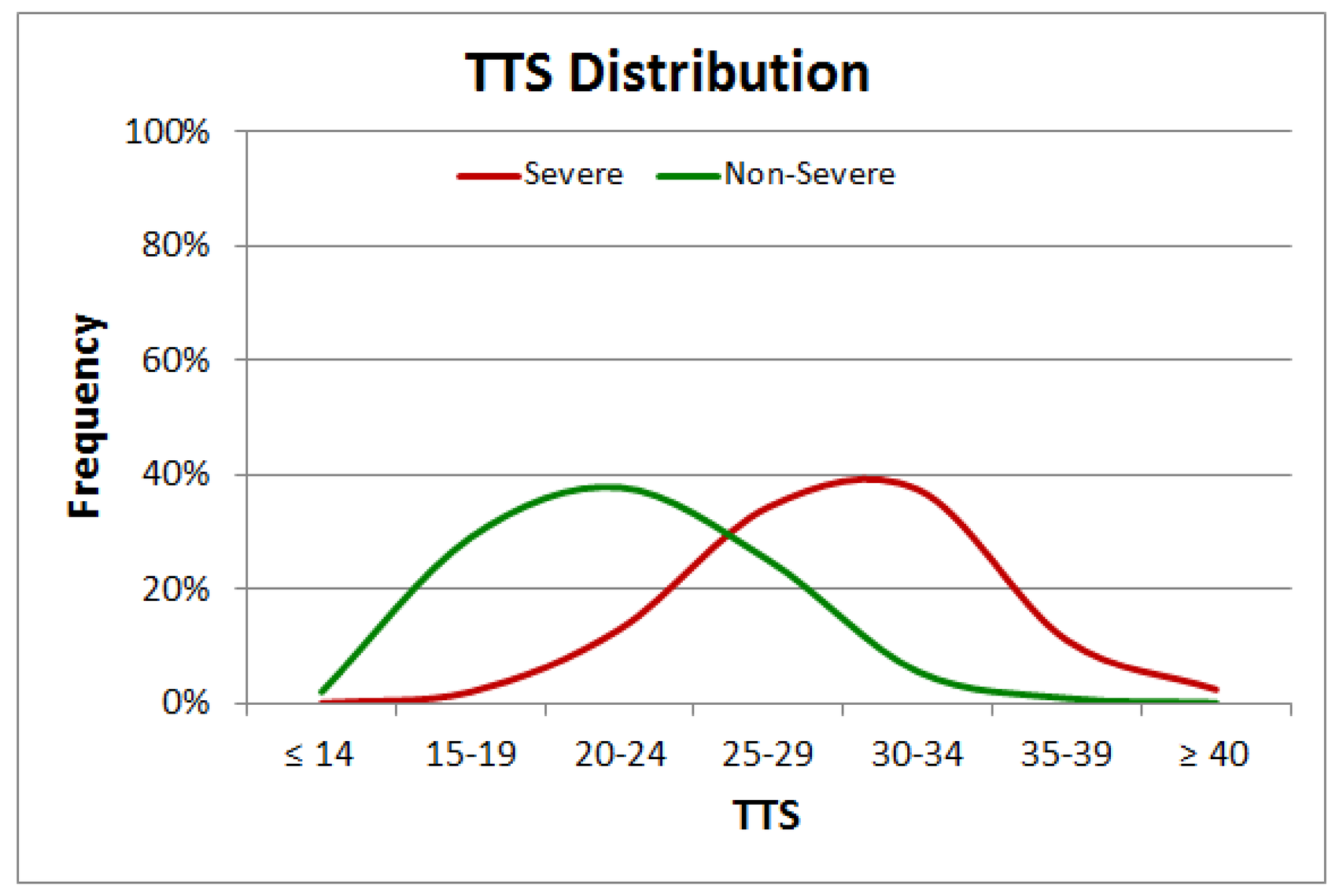


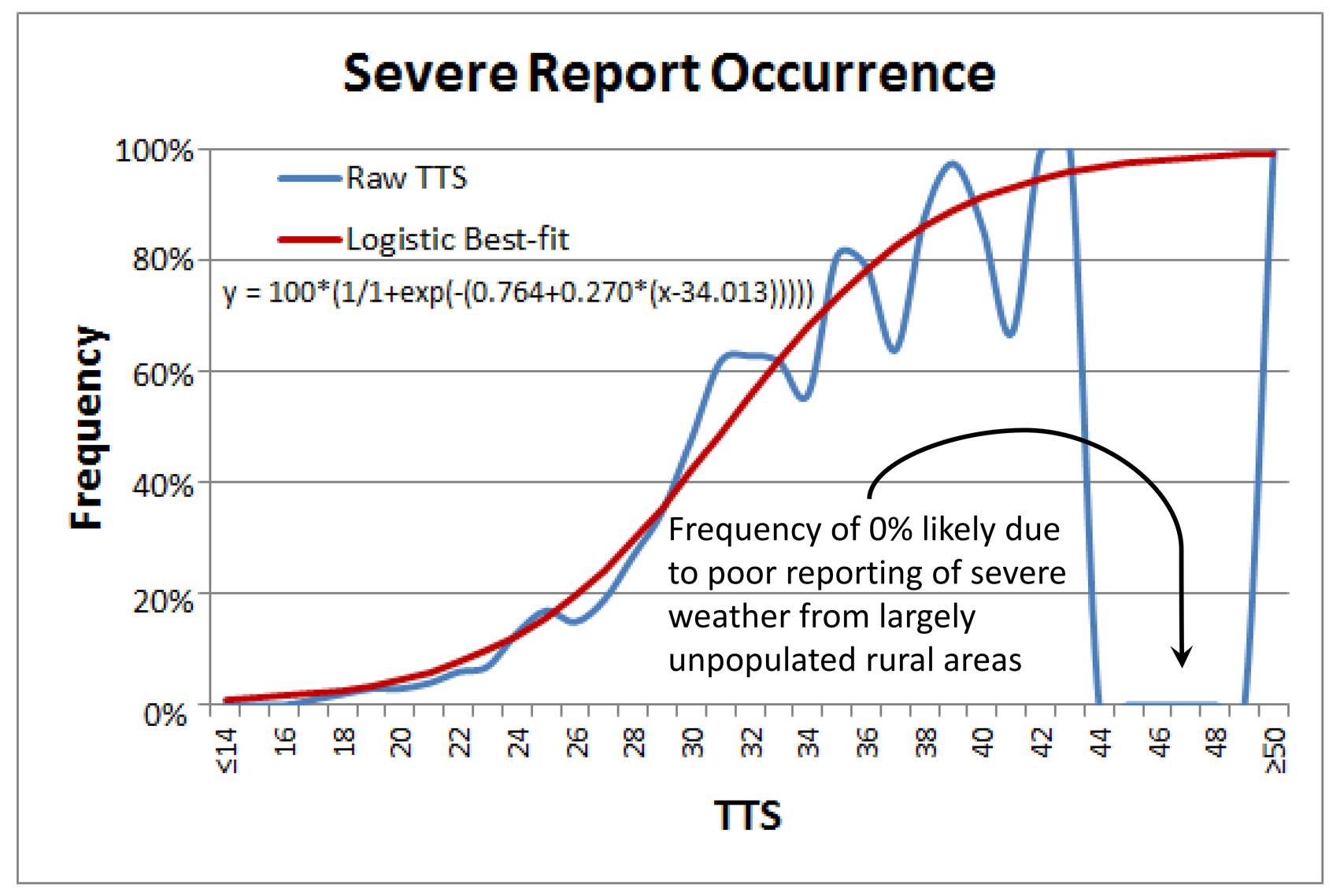
Stacked bar chart of TT for the low, medium and high threshold categories showing percent occurrence of the number of days with reported severe weather (red) and days with no reported severe weather (green).



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

- The Total Threat Score (TTS) distribution for days with reported severe weather and for days with no reported severe weather should demonstrate the ability of the TTS to indicate the severe weather potential
  - Maxima of the distributions are distinct, indicating the TTS distribution provides insight into the severe weather potential
- Produced occurrence of reported severe weather based on TTS category
  - Created best-fit logistic curve since the logistic curve is constrained to be within 0% to 100% and is often used in probabilistic regression





CONCLUSIONS

- Because people and property at KSC and CCAFS are at risk when severe weather occurs, the AMU developed an updated warm season severe weather tool for use in MIDDS based on the late morning, 1500 UTC, XMR sounding
- Built upon work in previous tasks developing severe weather decision aids
  - Used three existing data sets that were compiled during those tasks and updating them with 2011 and 2012 data including 200 hPa jet stream analyses, severe storm reports, and daily flow regimes
  - Developed two new data sets that included the 1500 UTC XMR soundings and stability parameters derived from those soundings
- Determined a threat score based on individual sounding stability indices and parameter thresholds and, from those, calculated a TTS for every 1500 UTC sounding in the 24-year database and compared the TTS to reported severe weather occurrences on each day with a sounding
- Determined a frequency of reported severe weather for each TTS and incorporated the values in an operational tool in MIDDS

References are available in the extended abstract or the AMU final report at http://science.ksc.nasa.gov/amu