P10.145 POTENTIAL APPLICATIONS OF A CONUS SOUNDING CLIMATOLOGY DEVELOPED AT THE STORM PREDICTION CENTER

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1. INTRODUCTION

The Storm Prediction Center (SPC) maintains an internal database of observational soundings from the contiguous United States (CONUS), dating back to the 1940s and 1950s for many sites. This database has been the source of extensive development in both research and operational forecasting over the past several decades. Previous studies utilizing this database have primarily focused on individual severe phenomena using proximity soundings (e.g., Evans and Doswell 2001; Thompson et al. 2003).

Attempts have been made to establish sounding climatologies for severe weather events. Rasmussen and Blanchard (1998) analyzed all soundings containing non-zero convective available potential energy (CAPE) from the year 1992 to establish a climatology of supercell and tornado forecast parameters. Craven and Brooks (2004) offered an expanded climatology utilizing three years of sounding data to characterize both convective and non-convective environments.

Perhaps the most extensive work utilizing observed soundings is a resource available on the Rapid City National Weather Service Forecast Office website (http://www.crh.noaa.gov/unr/?n=pw). A CONUS-wide climatology for all routine soundings, with many locations dating back as far as 1948, has been established for precipitable water and 850 hPa temperatures. Available plots include averages for each month, with corresponding percentile rank, maximum, minimum, and standard deviation. The site is frequently referenced by National Weather Service operational meteorologists to provide historical context to ongoing and forecast weather events.

The motivation for this project is to develop a sounding climatology which includes an expanded set of variables and parameters that are commonly referenced in operational forecasting. This information will be displayed via a comprehensive web browser developed at SPC, intended as a reference both for operational and research meteorologists.

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The web browser will be available by the late fall of 2014 on the SPC website (http://www.spc.noaa.gov/exper/soundingclimo). This paper will document the methodology involved in the development of the climatology and accompanying web browser, as well as potential operational and research applications and future work.

2. DEVELOPMENTAL METHODOLOGY

2.1 Sounding Database

The sounding database maintained by SPC includes data from every routine sounding location in the CONUS, with consistent soundings available as far back as 1948 for many locations. A portion of these sounding locations have changed one or more times during the period of record, with the distance between sites typically ranging within 100 km of each other. In these cases, the sounding records were merged into a consolidated dataset for a single site, yielding a total of 74 comprehensive sounding records. Information regarding the period of record for each sounding site is available below each plot on the web page. Routine soundings were launched at 0300 UTC and 1500 UTC between 1948 and 1957, before changing to the current launch times of 1200 and 0000 UTC. The final dataset includes over 2.5 million soundings, which were systematically collected and analyzed.

A wide range of variables (67; Table 1) were collected from the sounding database, including mandatory level temperature, dewpoint, geopotential height, and wind speed. In addition, derived convective parameters (e.g., CAPE, CIN, bulk wind shear, etc.), relevant to convective, winter, and fire weather are included in the sounding climatology. These parameters are computed using routines from the N-SHARP sounding program (Hart and Korotky 1991) available internally to SPC forecasters, and externally on the SPC website (http://www.spc.noaa.gov/exper/soundings/).

2.2 Quality Control

Manual inspection of observational soundings reveals that a small proportion contains errors. Most erroneous soundings that were detected were a result of a single point or small layer within the troposphere with unrealistic values of temperature and/or moisture. In more rare instances, the entire thermodynamic and/or kinematic profile may be erroneous, which can result in excessive values of derived parameters (Fig. 1). Given the volume of soundings included in the climatology, it would be time prohibitive to manually inspect every sounding for errors. Thus, systematic filters were developed to optimally remove a majority of errors, while minimizing the exclusion of legitimate soundings. Two iterations of filters were applied, with the primary goal of removing extreme outlier values.

The first iteration of filters applied to the sounding dataset involves pre-determined unrealistic values for each of the 67 parameters. Statistical methods for determining outliers often use interquartile ranges or standard deviations from the mean to determine outliers. Aggarwal (2013) suggests using a factor of at least three standard deviations away from the mean to filter outliers for most datasets. Given the large sample size and large to occasional extreme variability of the dataset, factors ranging from three to six standard deviations above the mean were used. In order to account for intra-annual variations, unique filter thresholds were calculated for each month to effectively filter out erroneous outliers. A typical number of soundings removed for each parameter can vary greatly, ranging from 30 to 100 soundings, with as many as 1000 soundings removed in extreme cases.

While the first iteration of filters was successful removing a large portion of the errors, more complex filters were applied to situations where an erroneous value is not an outlier. In most situations, this applies to single point or small layer errors where abnormally high temperature and/or dewpoint values result in excessively high values of CAPE when compared to the actual vertical thermodynamic profile. Thus, a cross-check was made with various combinations of surface-to-500 hPa lifted index values to ensure CAPE values were realistic. Other filters comparing the 700-500 hPa lapse rates, mixed-layer and most-unstable parameter calculations, were also used to determine unrealistic combinations (Fig. 2). These filters capture less common occurrences within the sounding record, with a typical number of erroneous soundings ranging from 5-10 per site.

3. WEB APPLICATIONS

A sounding climatology browser was developed to provide an easily accessible, flexible, and intuitive design, available via the SPC website (http://www.spc.noaa.gov/exper/soundingclimo). The browser design allows the user to easily switch between sounding locations and parameters, with a plot of the annual variability of the selected variable prominently displayed (Fig. 3). Included on the plot are the maximum and minimum for each date, the mean for each date, and various percentile ranks (including the median), which are represented as customizable centered moving averages. A readout of each of these values is provided at the bottom of the plot.

The plot display is also highly customizable based on the user's preferences. An option is available to display 1200 UTC, 0000 UTC, or all sounding times (including 0300 and 1500 UTC). Data can be displayed on the plot both in unfiltered or filtered form (using the quality-control methods described in the previous section), although the former is likely to contain outlier errors. Custom plot options include the ability to modify the y-axis attributes, the moving-average length, and a toggle for removing the maximum, mean, and minimum fields to only display the moving average of percentile ranks (Fig. 4). The option to remove values of zero from derived thermodynamic fields (e.g., CAPE, CIN) also exists, in order to eliminate excessive weighting of negligible parameter values.

A unique feature of the sounding climatology page is the diversity and quantity of parameters that are included. The current version of the browser contains a total of 67 parameters available for selection, separated into the following categories: mandatory level data (25); instability parameters (22); kinematic parameters (7); moisture parameters (5); fire weather parameters (4); other derived parameters (4). Several of the parameters are relevant to severe weather forecasting, including low-level SRH and shear (Rasmussen and Blanchard 1998), CAPE and lifted index (Blanchard 1998), fixed-layer significant tornado parameter (STP; Thompson et. al. 2003), and the significant hail parameter (SHIP). Also included are parameters relevant to fire weather forecasting, including the Fosberg index (Fosberg 1978), and surface relative humidity and wind speed.

The option to overlay the latest sounding observation value for each parameter also exists. This allows the user to easily compare current sounding data with historical observations at a selected site. Of particular note, this has been found to be useful in assessing severe weather environments at the SPC, especially in determining where the real-time observed values fall within the historical distribution.

4. OTHER POTENTIAL APPLICATIONS AND FUTURE DEVELOPMENT

The availability of a comprehensive CONUS-wide sounding climatology lends numerous opportunities for future research and development for operational applications. Improvements to the current web display and options are already being considered. The ability to plot historical data beyond the most recent observation, such as year-to-date values, would allow users to observe recent trends. The plotting of forecast model parameters may also benefit operational forecasters.

Other opportunities exist for developing additional data visualization methods. An option for users to select a scatter-plot displaying specific variable combinations is under development. This will allow the user to visualize the parameter space distribution for each sounding site (Fig. 5). Combinations relevant for severe weather forecasting, including CAPE and shear, are expected to be available. Other combinations for winter weather and fire weather forecasting may also be included. Additional development may result in plan-view plots of sounding parameters to better visualize the spatial distribution of values and anomalies.

Future work related to the sounding database is also expected to include linking historical storm reports with observed proximity soundings. This will allow users to visualize the relationship between severe weather events and historical sounding observations, which may prove beneficial in both an operational and research capacity.

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5. REFERENCES

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Parameter	Parcel Level or Layer
Temperature (F)	Surface, 925, 850, 700, 500, 300, 250 hPa
Dewpoint (F)	Surface, 925, 850, 700, 500 hPa
Mixing ratio (g/kg)	925, 850, 700, 500 hPa; 0-1 km, 0-3 km, surface-850 hPa layers;
Wind speed (kt)	Surface (u-component, v-component, absolute magnitude), 925, 850, 700, 500, 300, 250 hPa
Geopotential height (m)	850, 700, 500, 300, 250 hPa
Relative humidity (%)	Surface
CAPE (J/kg)	Mixed-layer, most-unstable, surface-based; Mixed-layer 0-3 km layer
Downdraft CAPE(J/kg)	Surface-based
Convective inhibition (J/kg)	Mixed-layer, most-unstable, surface-based
Lifted condensation level (m)	Mixed-layer, most-unstable, surface-based
Level of free convection (m)	Mixed-layer, most-unstable, surface-based
Lifted index (C)	Mixed-layer, most-unstable, surface-based
Lapse rate (C/km)	700-500 hPa layer, 850-500 hPa layer; 0-3 km layer, 0-6 km layer
Bulk wind shear (kt)	0-1 km, 0-3 km, 0-6 km
Storm-relative helicity (m^2/s^2)	0-1 km layer, 0-3 km layer
Convective temperature (F)	Surface
Precipitable water (in)	
Melting level (ft)	
Wet-bulb zero height (ft)	
Fosberg index	
Fixed-layer significant tornado parameter (STP)	
Significant hail parameter (SCP)	

Table 1. A list of the parameters available for plotting on the SPC sounding climatology page.

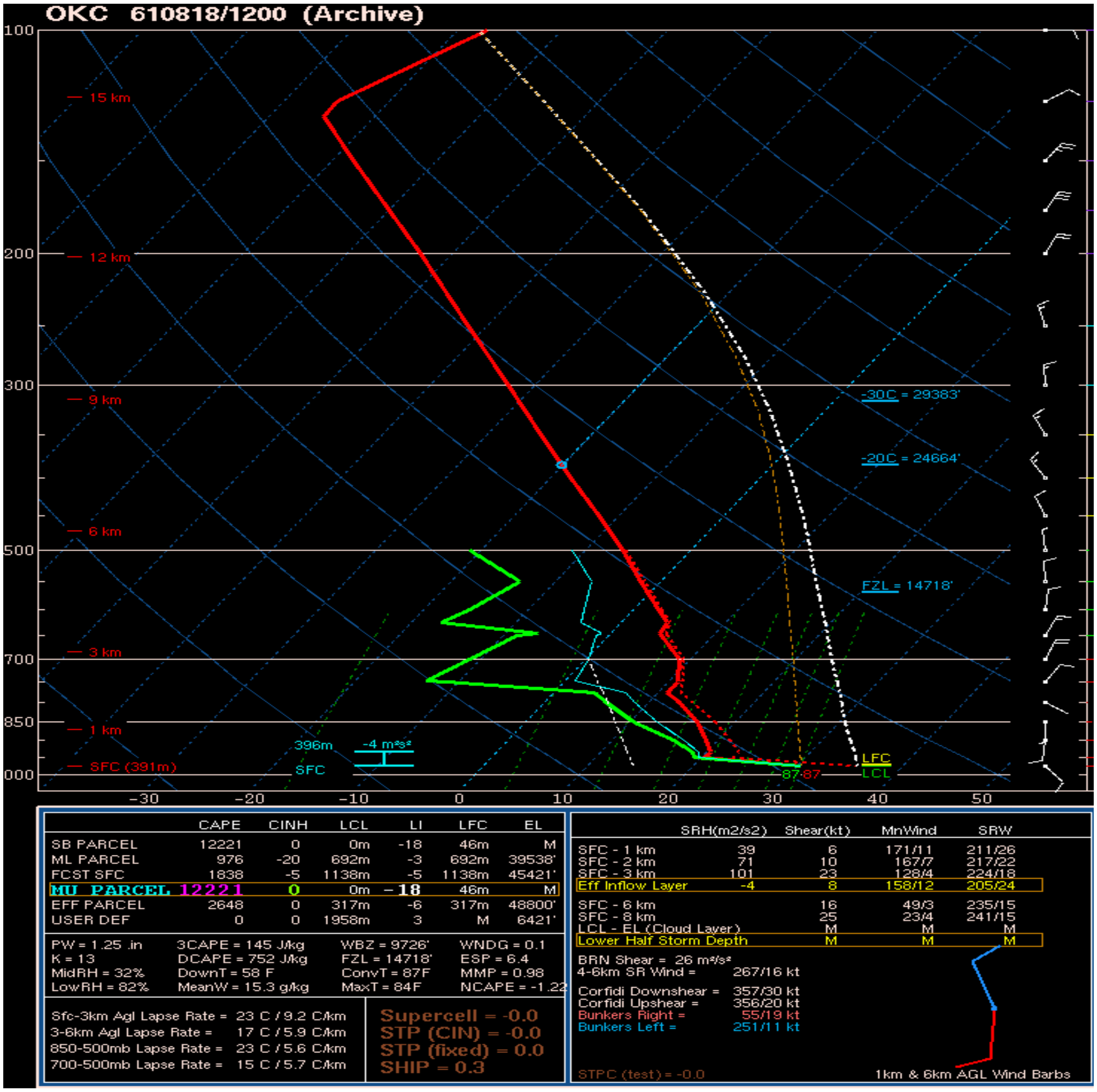

Figure 1. Example of an erroneous thermodynamic profile from a sounding in Oklahoma City, OK, on August 18th, 1961, at 1200 UTC. In this case, the surface dewpoint and low-level lapse rate profile are unrealistic, leading to extremely high values of most unstable and surface-based CAPE and LI.

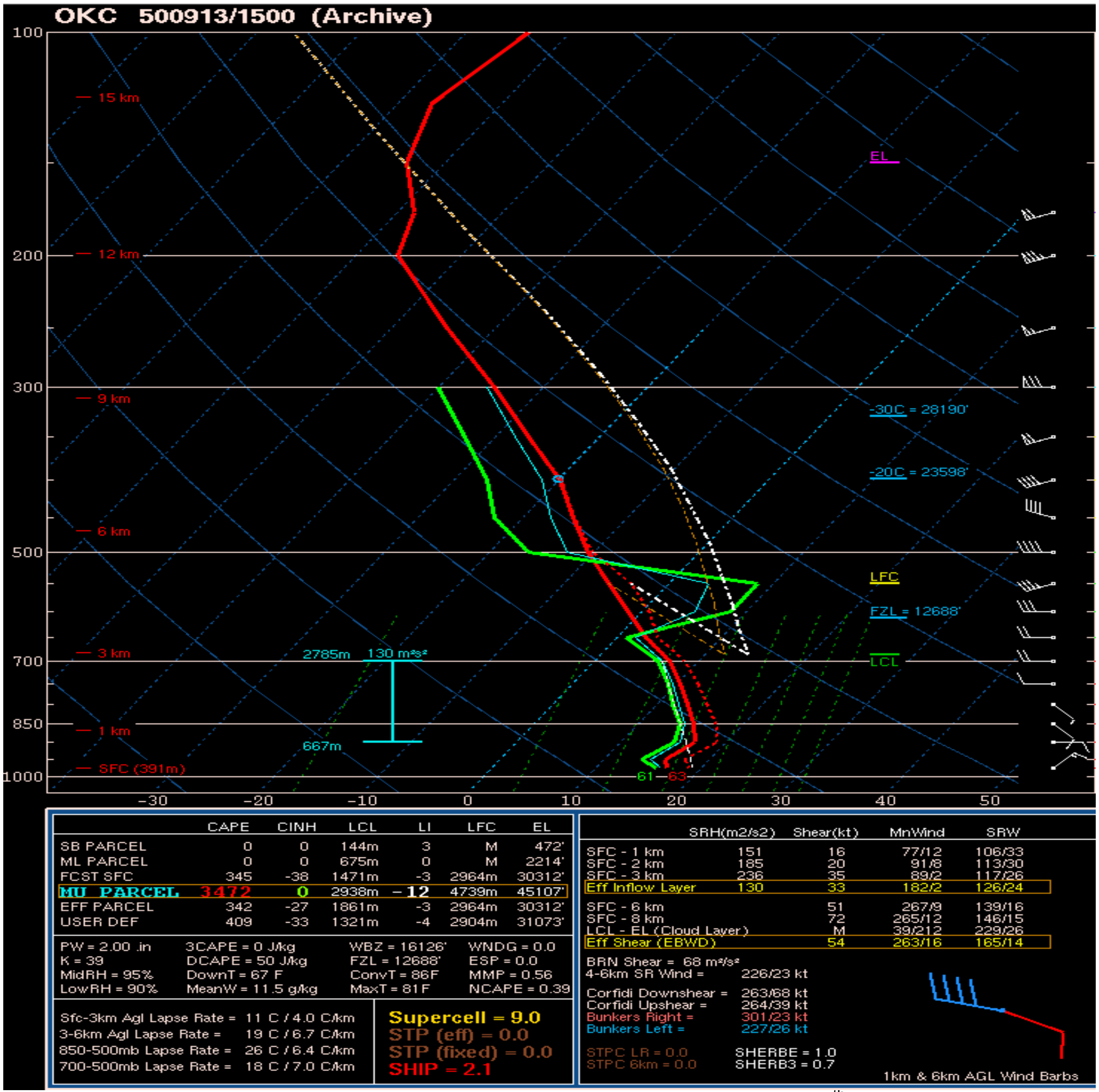

Figure 2. Example of an erroneous sounding in Oklahoma City, OK, on September 13th, 1950, at 1200 UTC. In this case, dewpoint values within the 600-500 hPa layer exceed the temperature, leading to erroneously high values of most-unstable CAPE and LI. The combination filtering method successfully removed this sounding from the database.

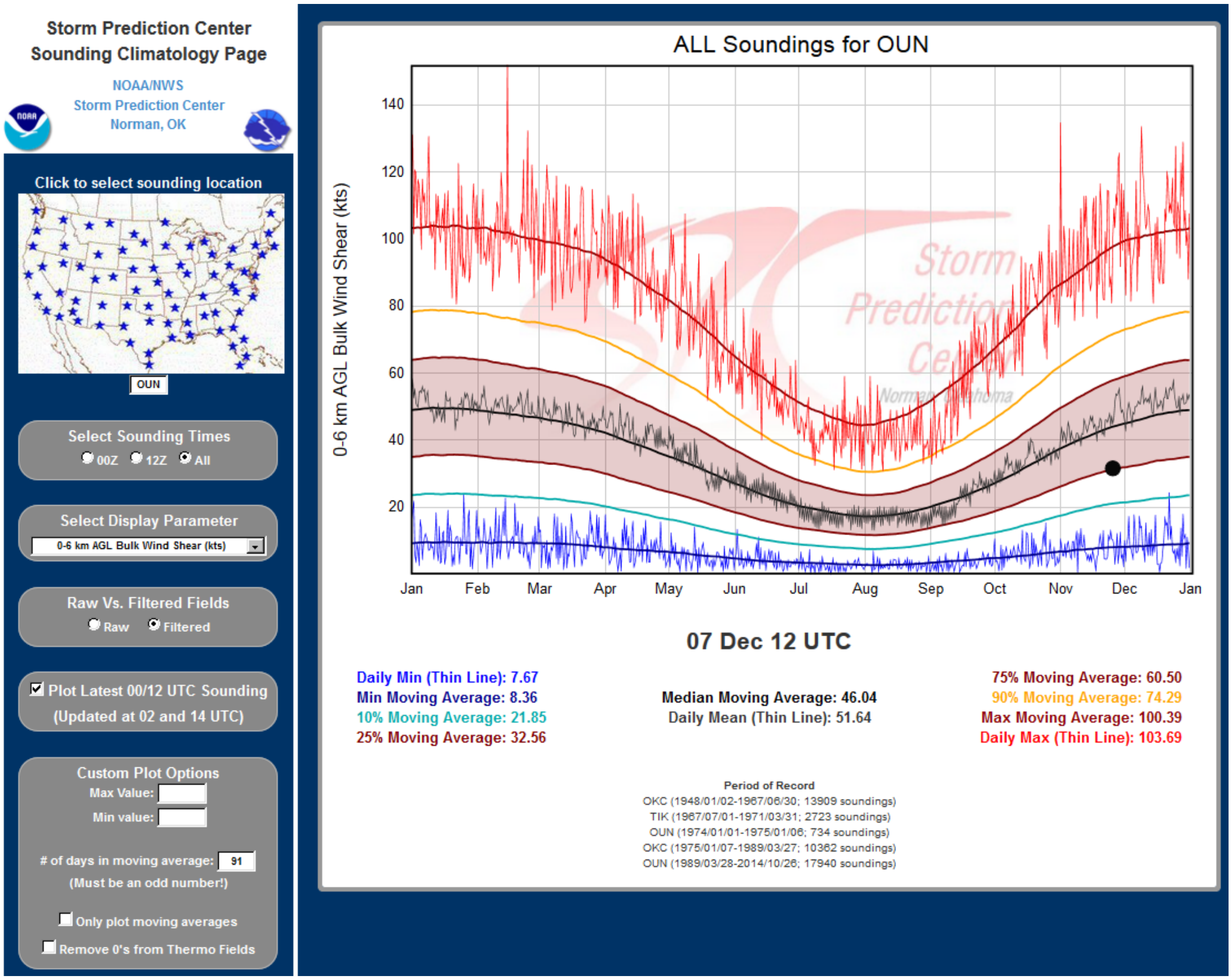

Figure 3. Example image of the sounding climatology web page, available on the SPC website at http://www.spc.noaa.gov. This particular plot shows 0-6 km AGL bulk wind shear for 0000 UTC soundings at Norman, Oklahoma. Customized plot options are shown on the left-side of the page. The black dot overlaying the plot represents the observed value from November 25, 2014.

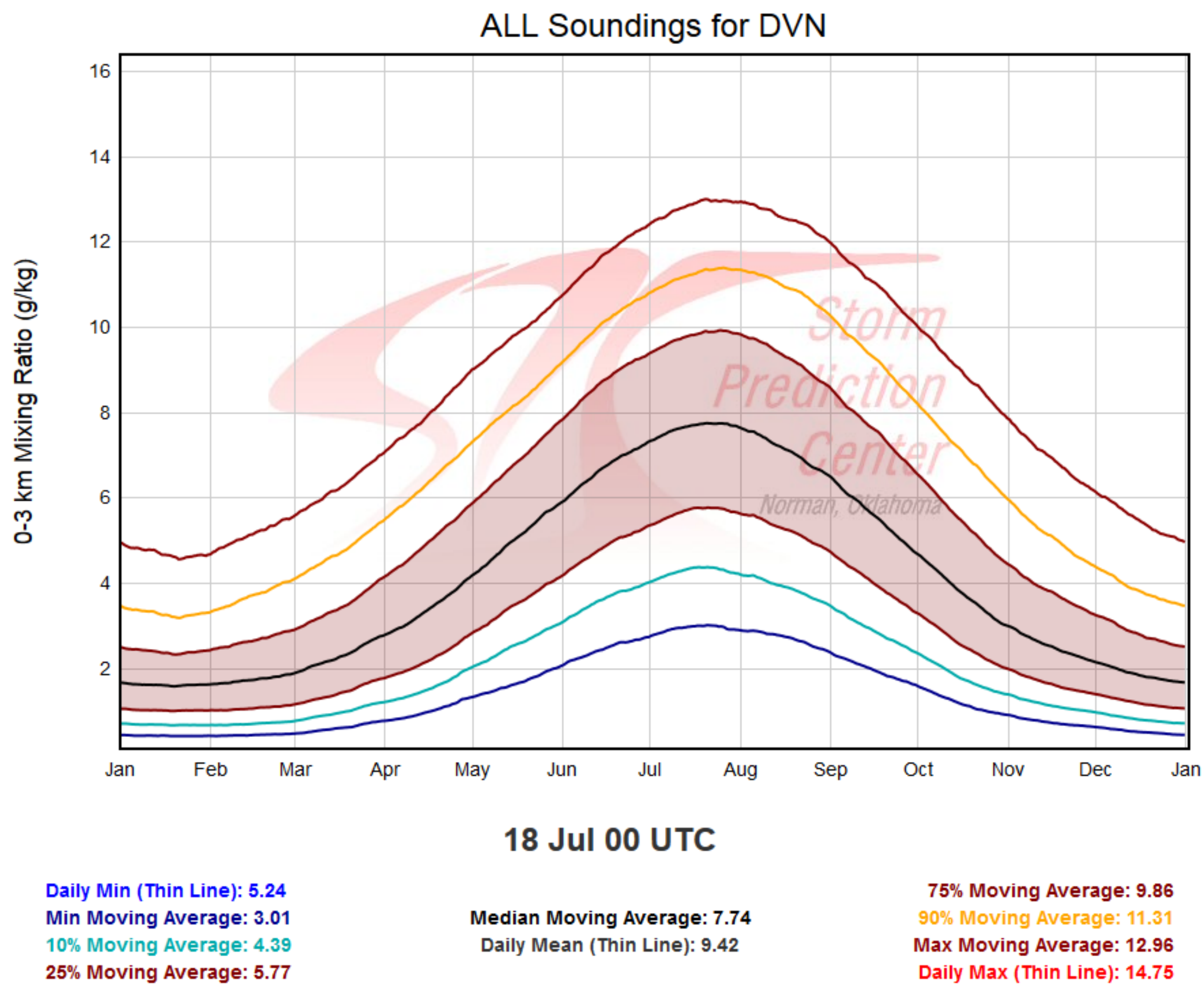

Figure 4. Example image displaying centered 91-day moving averages of various percentile ranks. This particular plot shows 0-3 km AGL mixing ratio for both 1200 and 0000 UTC soundings at Davenport, Iowa.

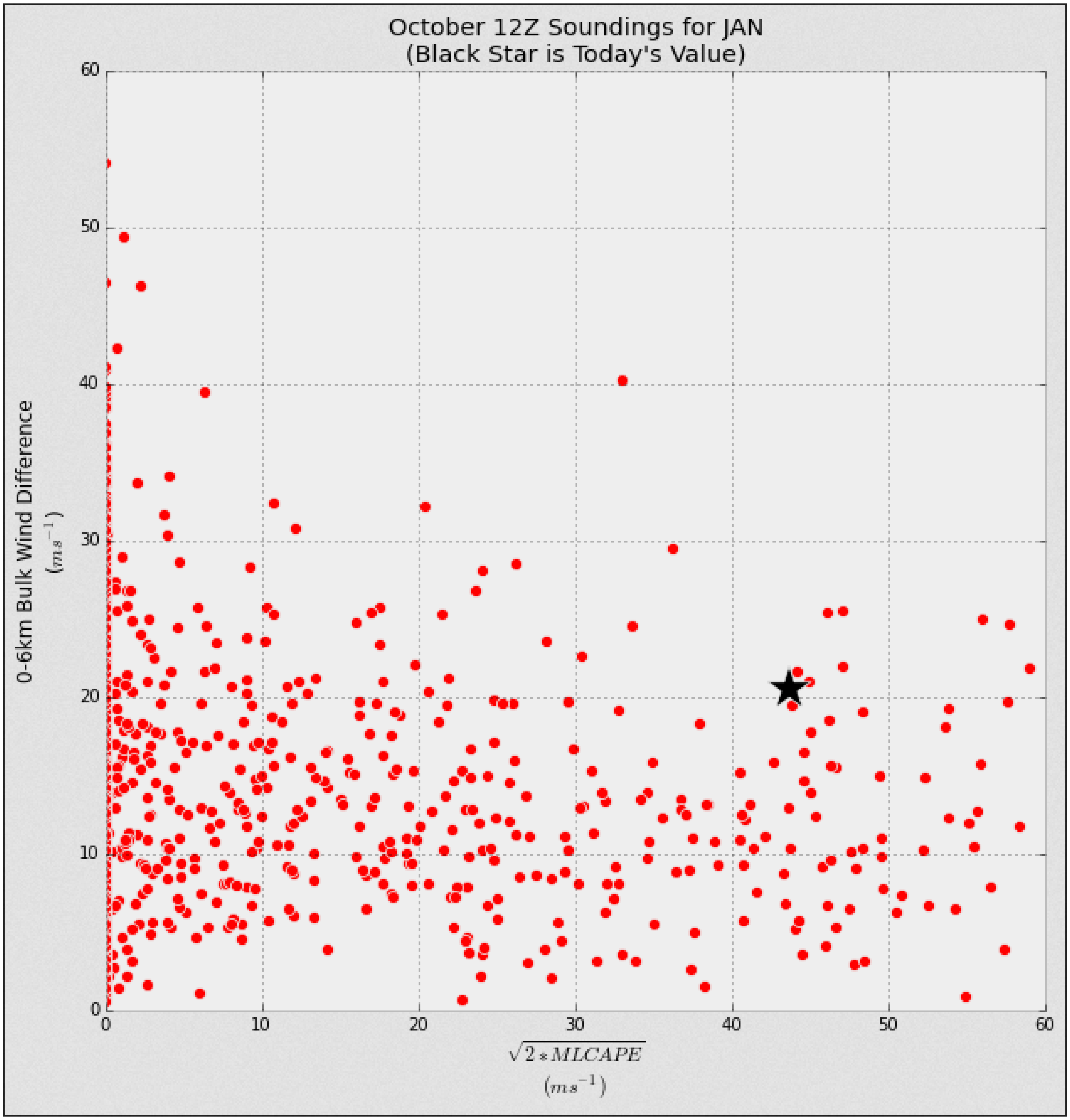

Figure 5. Example of a scatter-plot showing a combination of 0-6 km bulk wind difference and maximum updraft speed (estimated from MLCAPE value). Individual points show soundings during October launched at 1200 UTC at Jackson, MS. The observed value from October 13th, 2014, is denoted by the black star.