MEASURED SEVERE CONVECTIVE WIND GUST CLIMATOLOGY OF THUNDERSTORMS FOR THE CONTIGUOUS UNITED STATES, 2003-2009

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ABSTRACT

A severe convective wind gust climatology spanning 2003-2009 for the contiguous United States is developed using measured Automated Surface Observing System (ASOS), Automated Weather Observing System (AWOS), and Oklahoma Mesonet wind observations. National Lightning Detection Network and Radar Mosaic/Level II data are used amongst other quality control checks to identify and remove erroneous observational data. The filtered observations are then time matched with a number of diagnostic mesoanalysis fields from the Storm Prediction Center (SPC) for assessment of the severe convective wind gust environments. These data are then binned based on season and geographic region in order to identify atmospheric regimes characteristic to different parts of the country. The filtered observations are compared to storm reports archived by the SPC. Finally, a relatively denser surface observing network in Oklahoma is utilized to determine how consistently severe convective wind gusts are recorded by differing networks (i.e. ASOS/AWOS and Oklahoma Mesonet).

This study characterizes and contextualizes observations associated with southeast weak shear environments and contiguous U.S. strong deep layer shear, higher CAPE atmospheric regimes. Additionally, results exemplify the usefulness and necessity of a dense observing system network and demonstrate that the highest frequency of measured wind gusts occur throughout the southern and central High Plains and in a corridor from South Dakota across the southern Great Lakes region.

1. INTRODUCTION

Climatological information, when analyzed in conjunction with meteorological parameters and current synoptic patterns, is an essential part of operational forecasting. Such knowledge allows forecasters a greater understanding of atmospheric processes, gives a general idea of how the atmosphere tends to behave in certain temporal, spatial, and environmental situations, leads to greater forecasting proficiency, and provides a cornerstone for scientific advances. However, central to an effective climatology are quality controlled observations and reliable data acquisition methods that lend considerable credibility to the subsequent dataset (Weiss et al. 2002). Reporting inconsistencies within the SPC severe thunderstorm database (Schaefer and Edwards, 1999) have made constructing a severe convective wind gust climatology problematic. Many of these inconsistencies can be alleviated if data are drawn specifically from a network of surface observing stations and a dataset of severe convective wind gusts is assimilated using only measured observations.

Many studies thus far have focused largely upon convective modes responsible for generating severe convective wind gusts or environmental characteristics in which these events occur. Moreover, past studies have not made a distinction between measured gusts and wind damage reports and have not differentiated between the two different types of winds. For example Johns and Hirt (1987) analyzed the

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frequency of derecho cases over a period from 1980-1983 which commonly occur in a northwest flow pattern from South Dakota, across the southern Great Lakes, and into the Ohio Valley. Additionally, Wakimoto (1985) discussed the ability to forecast dry microburst activity across the High Plains and associates various environmental parameters with the evolution of this phenomenon. Finally, Burke and Schultz (2004) examined cold season bow echoes throughout the contiguous United States. While generally not focused on severe convective wind gusts, these studies provide important insight into the frequency and patterns of severe thunderstorms historically responsible for producing severe wind reports.

Inconsistent wind reporting methods within the SPC severe thunderstorm database (hereafter, SPC wind database) (see Section 2.2 for details) have motivated this study which constructs a climatology of measured severe convective wind gusts through the use of solely ASOS (Automated Surface Observing System), AWOS (Automated Weather Observing System), and Oklahoma Mesonet measured wind gusts from 2003-2009. Through this approach, measured wind gusts can be compared (where and when applicable) to estimated gusts and wind damage reports in hopes of developing a more credible SPC wind database. Yet, a rigorous quality control process is required to eliminate erroneous reports and determine the presence of convection.

The goal of this work is to establish a measured severe wind gust climatology over the contiguous United States, from which spatial and temporal frequency distributions and atmospheric variables can be analyzed with respect to different atmospheric regimes. Additionally, Oklahoma Mesonet observations are compared to Oklahoma ASOS/AWOS instrumentation to determine the frequency with which each instrument observes and records severe events.

2. METHODOLOGY

2.1 *Definitions and Background*

A thunderstorm is considered severe by the occurrence of one or more of the following: (a) convective wind gust ≥ 25 m s^{-1} (50 kt), (b) an unmeasured gust that produces damage, or (c) hail with a diameter ≥ 2.54 cm (1 in.). Processes producing a severe wind gust caused by a thunderstorm can include but are not limited to the following: (a) downward momentum transfer of high velocity air to the surface, (b) downdraft enhancement through evaporative cooling. These downdraft enhancing processes can occur in all types of convective modes. For example, supercells, or a storms with strong or persistent mesocyclone signatures (Browning, 1977), squall lines that can include Quasi Linear Convective Systems (QLCS), as defined by Trapp et al. (2005a), single thunderstorm cells, and multicell thunderstorm clusters, to name a few. It is important to note that the dataset for this study does not include severe convective wind gusts associated with land falling tropical cyclones, despite them being convective in nature.

2.2 *Limitations to the Wind Database*

Several inconsistencies within the SPC wind database have discouraged efforts to create a measured convective wind gust climatology from archived wind reports. Weiss et al. (2002) outline five major issues affecting the quality of reports within the SPC wind database: (a) population biases affecting the likelihood of an event being observed, (b) diurnal cycles, allowing daytime events being easier to observe, (c) procedural guidelines and protocols for determining if an event qualifies as severe, (d) the scientific training and understanding of the observer, both spotter and storm surveyor, and (e) the ability to conduct accurate storm surveys. A host of other factors also play a role, such as the number of damaging targets and variability in logging reports, which can partially be based on guidelines used by persons documenting phenomena, to name a few of many variables that undoubtedly influence the make up of the wind report database.

Additionally, with recent NWS verification initiatives for warning products, growing populations, and greater public awareness, the number of severe wind reports observed towards the end of the millennium was strikingly larger than that observed 30 years earlier (Weiss et al. 2002). However, it is important to note that most of the additional reports received largely fall just above severe threshold criteria (Weiss and Vescio, 1998). This demonstrates that despite a greater number of wind reports being relayed by local forecast offices, the amount of reported “significant” (33.4 m s^{-1}, 65 kt) events remains relatively unchanged (Hales, 1988; Weiss and Vescio, 1998).

Another issue with the SPC wind database is the reliability of a public observer’s estimated wind speed. As Doswell et al. (2005) stated, the public tends to grossly overestimate the speed of the winds they encounter. This can lead to an inflation of reports within the database and raises flags about the reliability of using estimated gusts in a climatological study. Weiss et al. (2002) also demonstrate that weather forecast offices (WFO) tend to differ on reporting procedures for estimated wind gusts. Lacking consistent criteria for reporting such gusts, the database contains differences with how WFO's investigate, complete a storm assessment, and ultimately report the occurrence or nonoccurrence of severe convective wind gusts/damage. Compounding the issue, until 2007 there was no differentiation within the SPC wind database between gusts that were estimated by observers and those that were directly measured by instrumentation.

Aside from a measured gust, it seems the best way to assuredly know the reliability of a severe event estimated by a spotter or the public is to perform a damage survey after the conclusion of the storm, if instrumentation did not measure the phenomenon (Trapp et al. 2006). However, the amount of manpower it would take to verify all reports of wind damage in the United States would be exceptionally difficult if not impossible, especially with long duration or high impact events like derechos or severe weather outbreaks associated with large numbers of severe wind reports.

Through the consideration of measured wind gusts, this study is afforded the consistency and reliability of an automated sensor versus the limitations listed above that, at times, plague severe wind reports. With surface observing stations, error tolerances are known and their reporting methods are similar. However, there are still important limitations to these observations. For example, it's important to acknowledge that instrumentation fails at times for various reasons. Additionally, many ASOS and AWOS stations are located at airports on the peripheries of the cities in which they are stationed. This results in an uneven distribution of observing stations which is shown in Fig. 1 For example, one may expect that a higher density of ASOS/AWOS stations should result in a greater number of storm reports in the upper Midwest than in the West. Additionally, according to the ASOS User's Guide (See NOAA, cited 1998, p. 14), instrumentation records the raw wind speed every second in order to create a two minute average wind speed that displays in the text observation. This wind algorithm stores the highest two second wind speed and records it as a gust only if it is 10 knots or greater than the two minute average speed. This gust is then stored for 10 minutes potentially causing it to show up in multiple special observations sent out over the duration of an extreme weather event. As a result, an extensive quality control process is needed to filter the data for multiple reports and to assure that the gusts recorded were indeed convective and the result of a severe thunderstorm rather than from instrumentation malfunction, a non-convective high wind event, or winter weather.

2.3 *Assessing Convection*

A surface observation database at the SPC was used to acquire all archived ASOS/AWOS and Oklahoma Mesonet observations that recorded a gust or wind speed 50 kt (25 m s^{-1}) or greater from 2003 to 2009. Observations that met this criteria, hereafter termed the "measured dataset" were formatted, organized chronologically, and matched up with their position coordinates and station identification. Archived National Lightning Detection Network (NLDN) data over the same time period were used to check each observation for lightning nearby and eliminate any observations that were obviously not associated with convection. To accomplish this, each candidate observation was placed within a 40 km-by-40 km grid over the contiguous United States. A three-by-three grid array was then centered on the 40 km grid that contained the observation. The measured dataset was tested and returned a binary "hit" or "miss" depending on whether lightning was observed in the gridded array at the time of the observation. All observations reporting a "miss" were eliminated from the measured dataset and those with a "hit" were extracted before continuing with the quality control process.

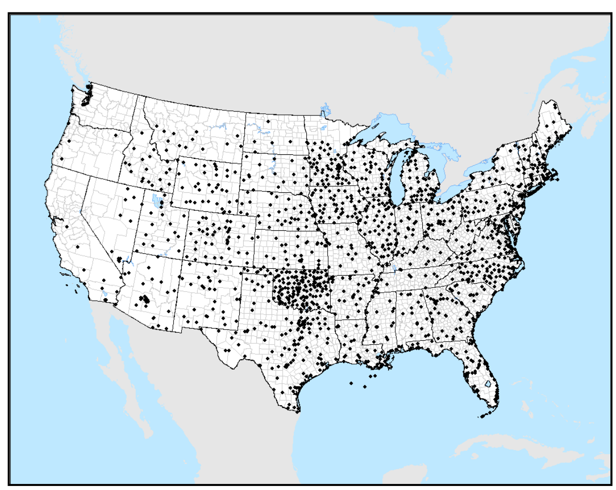

FIG 1. Locations of all ASOS/AWOS and Oklahoma Mesonet stations for which data were archived across the contiguous United States.

2.4 ***Duplicate Reports and Questionable Observations***

Remaining observations in the measured dataset needed to be manually filtered to remove any duplicate reports originating from an instrument during a single severe weather event. For any given ASOS/AWOS station with multiple reports, the highest measured gust was selected and any additional observed gusts from the same station that were less than the maximum gust or equal to and later than the first recorded maximum gust within 59 minutes were discarded. Gust magnitude and time were determined from examining the “PK WND” portion of the observation, if available. Otherwise, magnitude and timestamp were determined from the specifically reported gust magnitude (G) and timestamp on the observation. In a similar fashion, Oklahoma Mesonet data were filtered with respect to gust magnitude and time to record the highest gust and remove any extraneous reports from a severe event.

Subsequently, all observations were checked individually to determine their validity. Any observations with a wind magnitude greater than or equal to 115 kt (59.2 m s^{-1}) were instantly eliminated and determined to be in error. Observations from KMWN (Mount Washington, NH) and KMYP (Monarch Pass, CO) were commonly found to be in error due to their high elevation, non-convective, strong wind gusts. For these specific observations, they were instantly eliminated unless there was strong supporting evidence within the observation text of a thunderstorm in the area. All observations in which doubt remained concerning their validity and all remaining KMWN and KMYP reports were specifically highlighted to undergo much closer scrutiny during the next stage of the quality control process.

2.5 ***Radar Mosaic/Level II***

Each observation in the measured dataset was then manually examined against archived University Corporation of Atmospheric Research (UCAR) national radar mosaic data (See UCAR, cited 2010) to validate the gust listed in the report. A threshold of 35 dbZ was arbitrarily selected to help determine if the convection present was substantial enough to produce a severe convective wind gust. Every observation was examined on an individual basis, taking into account wake lows, distance from reflectivity, geographic locations (i.e. elevation), and low top convective squall lines with or without lightning, among other situational characteristics. If it was clear that there was no evidence of convection nearby at the time of the observation, the measured gust was removed. Highlighted observations from the previous quality control stage were examined more closely to determine the presence of convection. If any doubt persisted with respect to a particular observation, then it was highlighted to be examined more closely with archived WSR-88D Level II data. A few notable limitations contributed to an observation being selected for closer analysis with Level II data. These included missing mosaic data on a few days during the seven year period and the lack of regional mosaic radar for the eastern and western United States up until late 2008. Observations checked against WSR-88D Level II data were evaluated with the same criteria as above and a decision was made whether to remove them from the measured dataset.

2.6 ***SPC Wind Database Examination***

The refined measured dataset was then checked against the SPC wind database to determine the number of matching reports. A MATLAB script was written to check each one of the observations in the measured dataset against every entry in the SPC wind database. Observations were matched by EPOCH time (seconds since 1 January 1970), latitude, longitude, and gust magnitude. Comparison of the two datasets revealed that several entries in the SPC wind database had latitudes and longitudes that were inaccurately reported, reported times that were off by a few minutes, and gust speeds that differed by a couple of knots than what was listed in the actual observation. As a result, tolerances were introduced into the program to help offset some of these inaccuracies. These tolerances were ± 3 kt for wind magnitude, ± .1º (9.0 km) for latitude and longitude and ± 5 minutes on the report time. A binary “hit” or “miss” output was used to display which measured observations matched up with reports in the SPC wind database. Subsequently, each observation was checked manually against the SPC rough log of wind reports archived on the SPC website and “misses” were additionally reexamined against radar data a second time and severe report data, if necessary. This process helped to identify observations that were missed in the script and filter out more erroneous reports. There were instances in which a measured observation did not appear in the SPC wind database but was not subsequently removed from the measured dataset. These observations showed strong evidence of convection on radar, obviously displayed thunderstorm information in the text observation, and/or had multiple unrelated severe reports in the vicinity and at the time of the measured observation. Additionally, it was noted that the SPC rough log in reexamination provided a small filter for observations in which close proximity reports in time/space sometimes canceled out the listed measured severe reports. At the conclusion of this stage of quality control, there is considerable trust in the validity of the observations from the measured dataset.

2.7 *Mesoanalysis*

Observations from the finalized measured dataset were then paired temporally and spatially with corresponding archived SPC hourly mesoanalysis data (Bothwell et al. 2002; Dean et al. 2006). Severe weather ingredient-based parameters such as MLCAPE, 0-6 km shear, etc were assigned to each distinct observation in the measured dataset. Data were then organized and entered into a Geographic Information System (GIS) to begin an examination of the environmental parameters associated with the measured gusts. Three different environmental analyses were performed to showcase the robust and versatile nature of the observations in the measured dataset.

2.7.1 Southeast Weak Shear Environment

All measured dataset observations from the southeast U.S. (AR ,LA, AL, TN, KY, MS, GA, FL, SC, NC, VA) during June, July, and August and characterized by weak deep layer shear (0-6 km shear ≤ 20 kt (10 m s^{-1}); as specified by A. Cook 2007, (personal communication) as a threshold for southeast pulse thunderstorms) were extracted and compared to observations similarly binned from the SPC wind database. The two datasets were compared with respect to MLCAPE, 0-3 km lapse rates, 0-6 km deep layer shear, and precipitable water, amongst a dataset that includes 25 variables for temperature, moisture, instability, and shear.

2.7.2 Contiguous US Organized Severe Storm Environment

Measured dataset observations across the contiguous United States are binned by MLCAPE ≥ 1000 J kg^{-1} and 0-6 km shear ≥ 40 kt (20 m s^{-1}). These criteria are selected to correspond to a Craven/Brooks SigSvr parameter of 20,000, a threshold that indicates an increased likelihood of significant severe weather.(Craven et al. 2002) Binned observations are analyzed with respect to MLCAPE, 0-3 km lapse rates, 0-6 km deep layer shear, precipitable water, and measured gust magnitude.

2.7.3 SPC Reported Observations Within the Measured Dataset.

Observations from the measured dataset are binned based upon whether there is a matching report in the SPC wind database. Data from the two bins are then compared against one another with respect to MLCAPE, 0-3 km lapse rates, precipitable water, and measured gust magnitude to observe any differences.

2.8 *Instrument Performance*

2.8.1 ASOS/AWOS and Oklahoma Mesonet Performance

Measured dataset observations are binned based on whether they were observed by Oklahoma ASOS/AWOS or Oklahoma Mesonet instrumentation. Bins are analyzed to determine the number of severe convective days (SCD, (12Z-12Z), day when system recorded a severe convective gust), the number of days one instrumentation observed a severe gust but the other did not ("unique" severe convective days, USCD), the number of convective days both instruments recorded a gust ("shared" severe convective days, SSCD), and the overall average number of measured gusts observed per SCD for each observing system.

2.8.2 Measured Gust Observation Frequency

Measured dataset observations are plotted to represent the frequency that each station recorded a severe convective wind gust over the seven year period of the study. Additionally, for each state in the contiguous United States, the ratio of ASOS/AWOS stations that recorded a measured severe convective wind gust to the total number of archived ASOS stations in each state is calculated to quantify the relative coverage of measured severe convective wind gusts. Each state is considered separately to account for varying coverage densities across the country. Stations may have been added or subtracted during the study and influence the results slightly.

3. RESULTS

In total, the measured dataset contains 2,612 observations of severe convective wind gusts from 2003-2009. 2,336 observations came from ASOS/AWOS instrumentation, while the other 276 were observed by the Oklahoma Mesonet system. This puts the average number of measured reports per year from the measured dataset at 373. This accounts for only about three percent of the annual wind report average in the SPC database for the same seven year period and quantifies the fact that measured gusts only make up a small fraction of reports logged in the SPC wind database.

3.1 *Southeast Weak Shear Environment*

Filtering the measured dataset for observations from the southeast United States that occurred in a weak deep layer shear environment yielded 87 valid reports. Using the same method for the SPC wind database produced 8,930 observations over the domain of the study. Fig 2a demonstrates that MLCAPE is slightly larger for the measured dataset when compared to the SPC wind database. Specifically, the measured dataset gives a median value of 1987 J kg^{-1} while the SPC wind database a median of 1626 J kg^{-1}. However, there is considerable interquartile overlap between the two datasets.

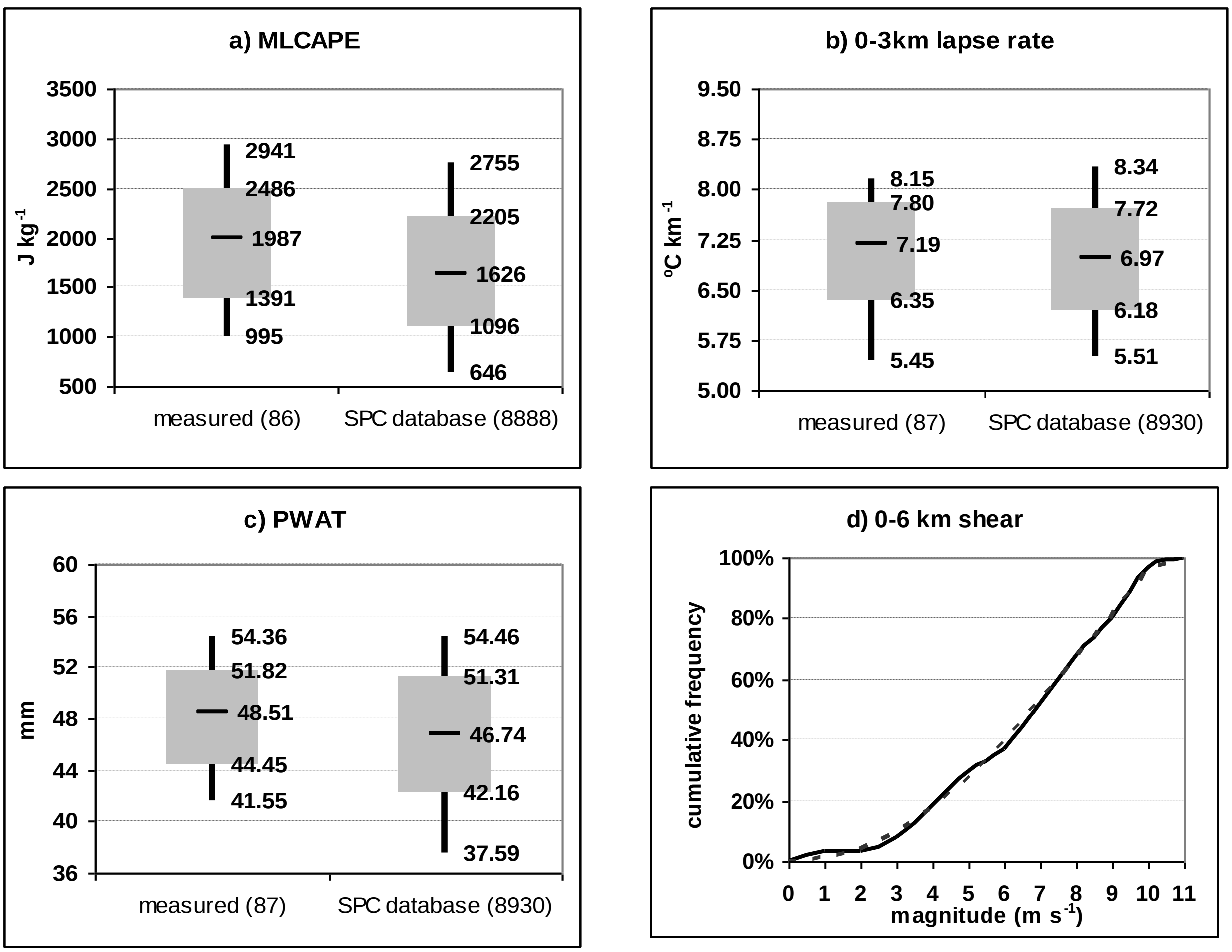

FIG 2. Box and Whisker plots of (a) 100 mb mean layer CAPE (J kg^{-1}), (b) 0-3km lapse rates (^{o}C km^{-1}), (c) Precipitable water (mm), and (d) ogive plot of cumulative frequency (%) for 0-6km deep layer shear (m s^{-1}) in weak shear environments during the warm season in the southeast U.S. for the measured (solid line) and SPC database (dashed line). The shaded region covers the 25th and 75th percentiles; the whiskers extend to the 10th and 90th percentiles. Median values are marked by the heavy horizontal line in the shaded region. Number in parentheses represents the observations in each bin.

Nevertheless, in summer, southeastern U.S., weak shear regimes, it appears that the moderate instability is potentially a necessary ingredient for severe convective wind gusts. Fig 2b,2c show little to no difference between the two datasets when analyzing 0-3 km lapse rates, and precipitable water. Fig 2d notes that most observations in both datasets tend to be skewed towards the threshold of 10 m s^{-1} used to filter the observations. Ultimately, observations tend to agree with A. Cook 2007, (personal communication) and their noted parameters associated with pulse thunderstorm activity. High values of precipitable water due to the warm influx of tropical air from the Gulf of Mexico are evident from a measured dataset median value of 48.5 mm (1.91 in.). Additionally, modest low level lapse rates and weak shear values characterize an environment unlikely to support organized severe weather.

3.2 *Contiguous U.S. Organized Severe Storm Environment*

393 measured dataset observations were determined to have MLCAPE values greater than or equal to 1000 J kg^{-1} and 0-6 km shear values greater than or equal to 20 m s^{-1} (40 kt), most of which (86%) of which occurred from the beginning of April through the end of July. Their locations are shown in Fig 3. Fig 4a shows that the median value of MLCAPE for these observations is 1753 J kg^{-1}, with the interquartile range characterized by moderate amounts of CAPE. Fig 4b demonstrates that 0-3 km lapse rates are not particularly steep, with the median value greater than a moist adiabatic profile. Fig 4c, 4d show the presence of a fairly moist environment with a median precipitable water of 36.8 mm (1.45 in.). Moreover, vertical bulk shear through the lowest 6 km is rather strong with the median value of almost 25 m s^{-1} (49 kt) and with observations skewed close to the filtering threshold of 20 m s^{-1} (40 kt), similar to Fig 2d. The results of Fig. 4 indicate an environment supportive of organized, severe storms, including supercells and long-lived

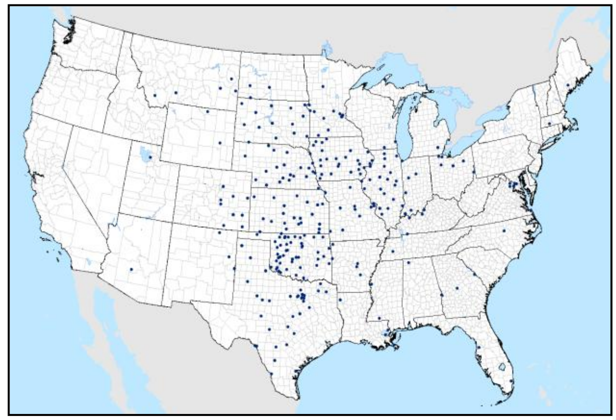

FIG 3. ASOS/AWOS and Oklahoma Mesonet measured severe convective gusts associated with the contiguous U.S., organized severe storm environment.

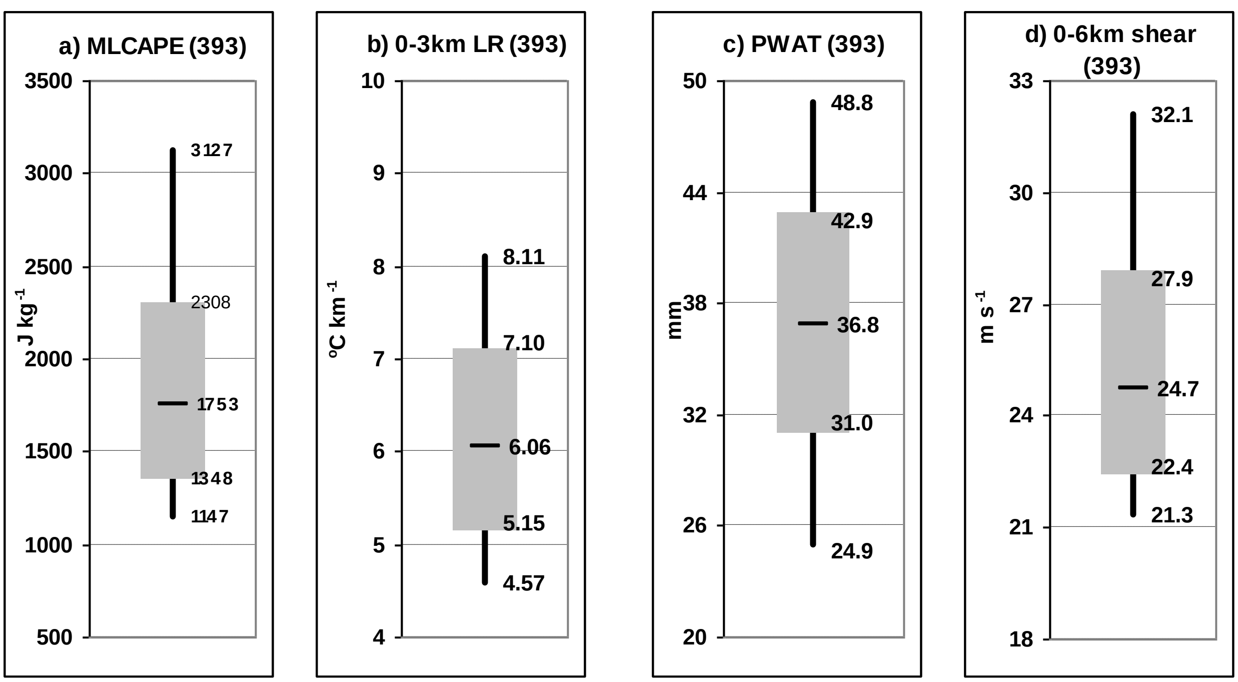

FIG 4. Box and Whiskers plots (same conventions as in FIG 2.) for observations with MLCAPE > 1000 J kg^{-1} and 0-6km shear >20 m s^{-1} for (a) 100 mb mean layer CAPE (J kg^{-1}), (b) 0-3km lapse rates (^{o}C km^{-1}), (c) Precipitable water (mm), and (d) 0-6km deep layer shear (m s^{-1}).

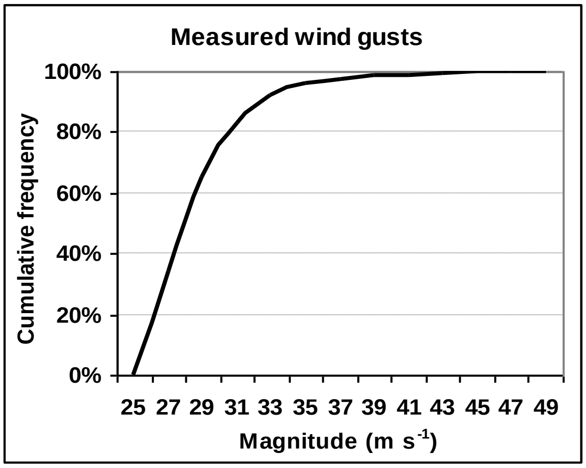

FIG 5. Ogive plot of cumulative frequency (%) for wind magnitudes associated with the contiguous U.S., organized severe storm environment observations from the measured dataset.

MCSs. This is a stark contrast to the southeast pulse thunderstorm regime characterized by a weak deep layer shear environment, shown in Fig 2. Additionally, with observations filtered for a high end severe atmospheric regime, observations do contain a greater fraction of more "significant" gusts. Fig 5 demonstrates that roughly 10% of the observations in the measured dataset filtered into this environment did record a convective wind gust that the SPC would classify as "significant" (33.4 m s^{-1}, 65 kt) (Hales, 1988), while the less volatile southeast pulse thunderstorm environment only had about 3% of their observations record a "significant" gust, in comparison.

3.3 *Storm reported observations within the measured dataset.*

Comparison of the measured dataset with the SPC wind database yielded 2,217 matches. This is almost 85% of all the wind observations contained in the measured dataset. 1,984 of these associated observations came from ASOS/AWOS instrumentation and 233 came from the Oklahoma

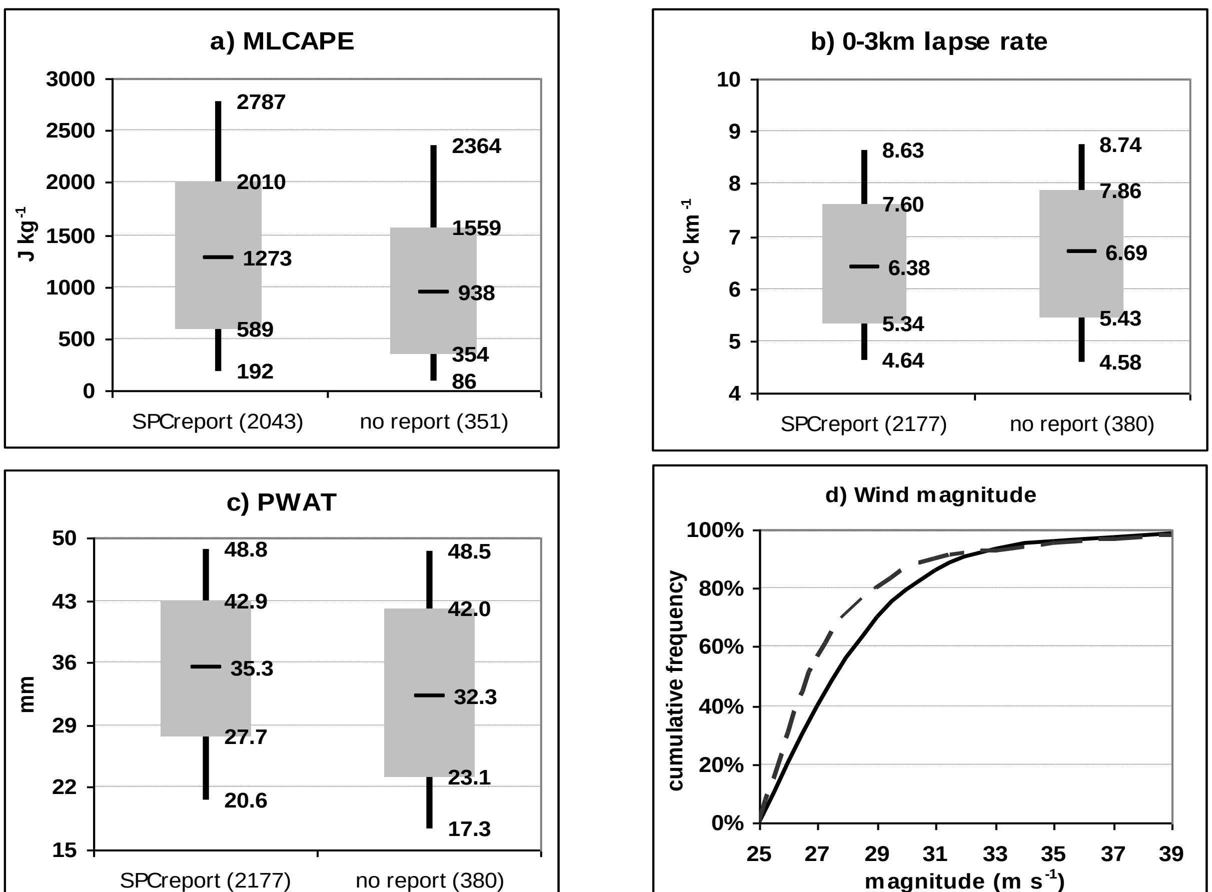

FIG 6. Box and whisker plots (using the same conventions as FIG 2) comparing values of SPC reported and non-reported observations in the measured dataset for (a) 100 mb mean layer CAPE (J kg^{-1}), (b) 0-3km lapse rate (^{o}C km^{-1}), (c) Precipitable water (mm), and (d) ogive plot of cumulative frequency (%) for observed wind magnitude (m s^{-1}) with SPC reported (solid line) and non-reported observations (dashed line).

Mesonet, via the time/space filtering described in Section 2.6. Environments of the matched reports were then compared to the measured dataset reports not found in the SPC wind database (Fig. 6). Specifically examining ASOS/AWOS and Oklahoma Mesonet observations separately, around 85% of observations from each network were also present in the SPC database, reflecting the overall percentage listed earlier. Such a large majority lends credence to the quality control process used herein to compile the dataset and is strongly supportive since most measured gusts are associated with a documented severe weather report. A slight difference in median MLCAPE values can be noticed in Fig 6a. The results of Fig. 6a are somewhat similar to that of Fig. 2a in that there appears to be some discrimination in the MLCAPE between the two environments. However, such a difference may be explained by the quality control process and the methods used to select the observations. Amongst those severe gusts attributed to thunderstorm activity (e.g., wake lows, gust fronts, low topped squall lines) not found documented in the severe wind report database, it is not surprising that these measured observations are often times located in weakly unstable environments or in a seemingly convective overturned airmass. Also, wind magnitudes tend to be bunched down close to the severe wind threshold for these observations (Fig 6d). Fig 6b, 6c show that no appreciable differences were found between 0-3 km lapse rates, precipitable water, and 0-6 km shear (not shown), in addition to a host of other variables.

3.4 *ASOS/AWOS and Oklahoma Mesonet Performance*

Oklahoma has 46 operating ASOS and AWOS stations interspersed throughout the state while the Oklahoma Mesonet system has almost three times as many (120) in the state. The locations of these sites are plotted on the maps in Fig 7a and Fig 7b, respectively. Defining a convective day as 12Z-12Z and using the previously defined severe convective day (SCD), it was determined that ASOS/AWOS instruments registered 89 SCDs over the domain of the study, while Oklahoma Mesonet instrumentation logged 146 SCDs. Of the 89 SCDs counted by ASOS/AWOS, 57 (64.04%) were also logged by the Oklahoma Mesonet, giving a cumulative total of 178 SCDs recorded by both instruments. Examining the 57 "shared" SCDs (SSCDs), there were only four days (7.02%) in which the ASOS/AWOS network reported more severe convective wind gusts than the Oklahoma Mesonet. 24 (42.11%) SSCDs were sampled in equal numbers and there were 29 SSCDs (50.88%) in which the Oklahoma Mesonet reported more severe convective gusts than ASOS/AWOS. Taking into account the fact that the ASOS/AWOS stations in Oklahoma registered a total of 132 measured severe convective wind gusts in the measured dataset and the Oklahoma Mesonet recorded a total of 276 gusts, it is determined that ASOS/AWOS instrumentation recorded a mean of 1.48 gusts per SCD, compared to 2.3 gusts per SCD by the Oklahoma Mesonet. All of these statistics lend evidence to the usefulness and importance of a dense surface observing network in obtaining a more robust sampling of severe weather events. The information shows that not only does a denser network, like the Oklahoma Mesonet, record more SCDs than the ASOS/AWOS network, but they tend to sample more gusts per SCD as well. With an ability to obtain a greater sampling of severe convective wind events, an analysis and climatology using solely measured gusts becomes extremely robust, as evidenced by the Oklahoma Mesonet.

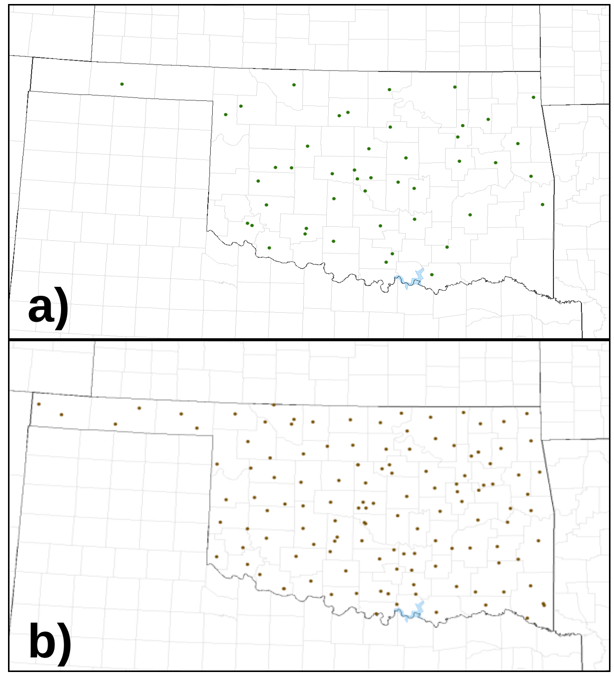

FIG 7. Spatial distribution of (a) Oklahoma ASOS stations (b) Oklahoma Mesonet stations.

3.5 *Measured Gust Observation Frequency*

The frequency distribution of severe convective measured gusts provides some qualitative and quantitative insight into where the greatest

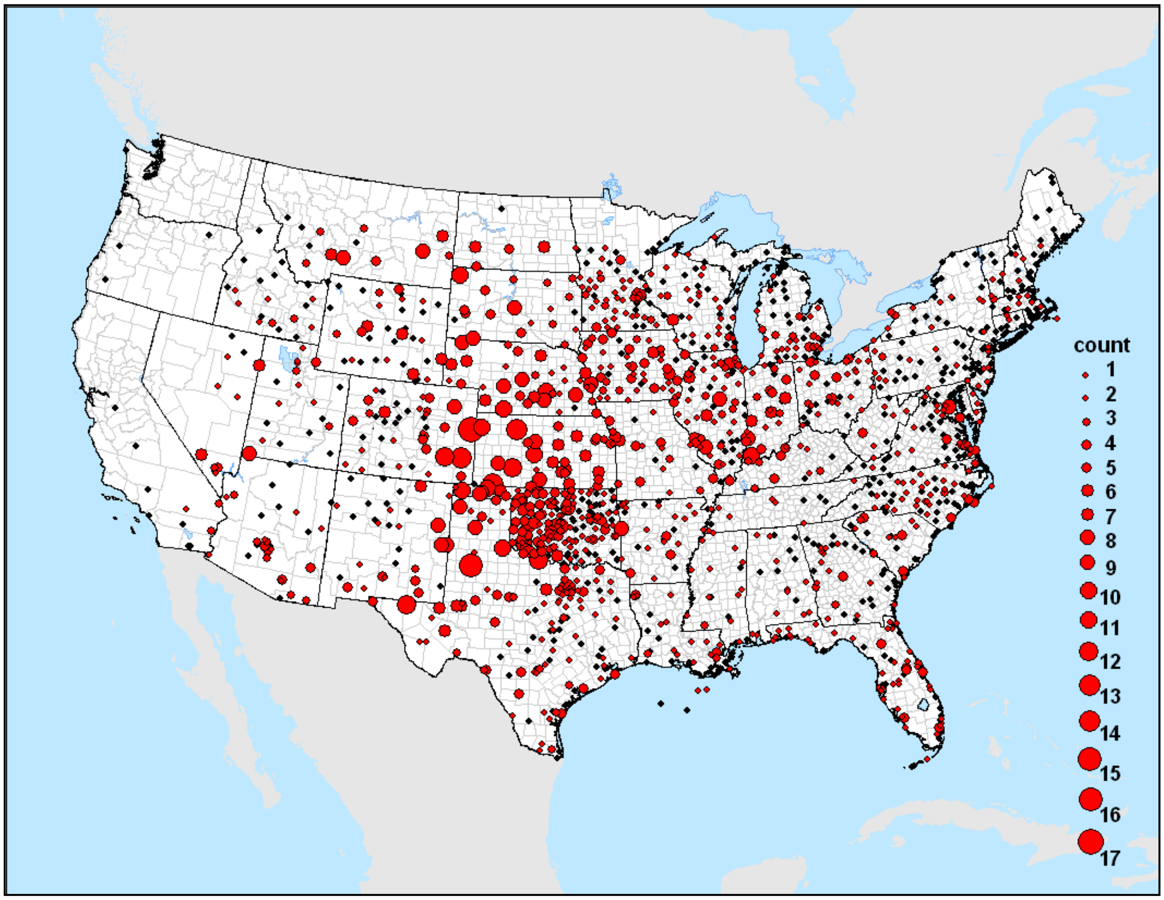

FIG 8. Proportional distribution of stations with recorded severe convective gusts (red) and stations with no measured reports (black). Size of red circles indicates the number of measured severe convective gusts over the seven year period, as denoted in the legend.

probabilities of recording a gust are throughout the nation. Fig 8 shows the proportional distribution of these stations with larger circles representing a greater number of reports, as indicated in the legend. One can easily notice that the stations with the highest numbers of reports are located in the southern and central High Plains region which extends from western portions of Texas and eastern New Mexico northward into western Nebraska and eastern Colorado. Table 1 lists the top ten stations, ASOS/AWOS and Oklahoma Mesonet included, with the most measured severe convective gusts over the domain of the study. A large majority of the measured gusts from the stations in this area take place in the spring to early summer time period of March through July, suggesting that organized convection likely plays a key role in generating these gust reports. Additionally, a secondary corridor of high frequencies is evident and extends from South Dakota and Nebraska east southeastward to the southern Great Lakes states. A large portion of these measured gusts are recorded during the

Rank	Measured Gusts	Station	State
1	17	KITR	CO
2	16	KLBB	TX
3	14	KLBL	KS
4	13	KGDP	TX
	13	KLAA	CO
	13	KHLC	KS
7	12	KDDC	KS
	12	KLHX	CO
	12	KSPS	TX
10	11	K2WX	SD
	11	KGLD	KS
	11	KCDS	TX
	11	KMCK	NE
	11	KGRI	NE

TABLE 1. Most measured gusts per station for ASOS/AWOS and Oklahoma Mesonet, 2003-2009.

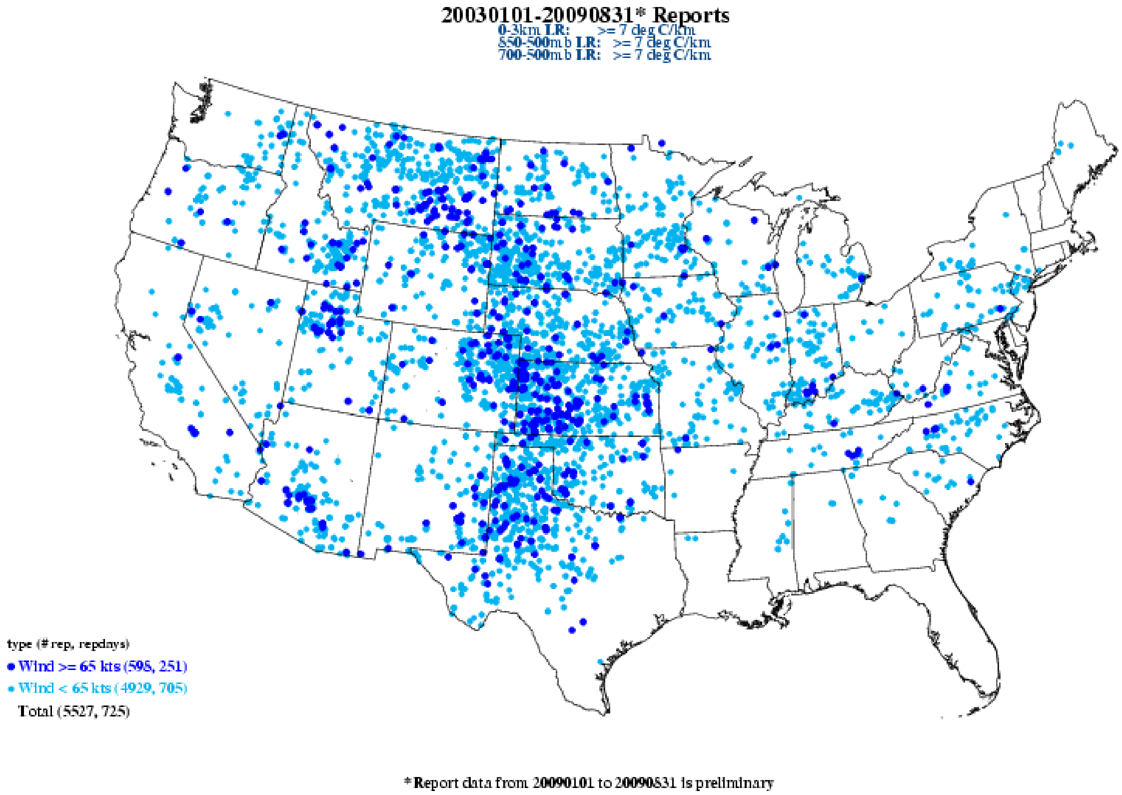

FIG 9. Distribution of all SPC storm reports from 2003 to 31 August 2009 with steep low and mid level lapse rates greater than 7 ^{o}C km^{-1}. Note similarity to distribution in Fig 8.

summer months and seem to show a similar pattern to the Johns and Hirt (1987) northwest flow pattern, suggestive that organized MCS activity is responsible for a number of these reports. Much lower frequencies are observed in the northeast, southeast, and western United States. Low frequencies are additionally observed west of the Rocky Mountains, with locally higher frequency located around southern Arizona, largely attributable to monsoon thunderstorms. Looking at a distribution of SPC wind reports associated with steep (i.e. greater than 7 ^{o}C/km^{-1}) low to mid-level lapse rates in Fig 9 produces a pattern similar to that in Fig 8 and may best explain why the frequencies are higher in the High Plains region.

A more quantitative analysis of these frequencies tends to provide similar information to that observed by Fig 8. The ratios of ASOS stations with measured gust observations to the total number of ASOS stations with archived data in each state are calculated in Table 2, for states with 10 or more valid stations. It is easy to notice that the top percentages generally align with the regions with the higher counts of reported gusts, as previously mentioned. Likewise, areas that have fewer reports for each station tend to have lower percentages, such as in the northeast.

Rank	State	Percentage reporting	Total ASOS
1	Nebraska	0.97	35
2	Kansas	0.93	30
3	S. Dakota	0.90	20
4	Iowa	0.88	51
5	Kentucky	0.87	15
6	Missouri	0.86	22
7	Indiana	0.85	20
8	Oklahoma	0.81	42
9	Texas	0.76	127
10	Arkansas	0.70	30

TABLE 2. Top percentages of ASOS/AWOS stations with measured severe gusts by state (for states with 10+ stations with archived data).

4. DISCUSSION

Ultimately, the measured dataset provides robust and versatile information that can be used in conjunction with other data sources to analyze environmental parameters associated with a host of atmospheric regimes, geographic regions, and seasons. For example, Arizona, largely associated with monsoon activity, was characterized by environments with large temperature-dew point spreads, low values of precipitable water, and extremely steep low level lapse rates. In contrast, southeastern environments are characterized by much higher precipitable water values and higher values of MLCAPE. Central U.S. observations are marked most notably by large values of deep layer shear, but have weaker lapse rates than seen in the southwest and less precipitable water than in the southeast. Additionally, from the analysis, it is evident that the ratio of the number of ASOS/AWOS and Oklahoma Mesonet stations does not correlate to the ratio of the reports from each network. Essentially a denser network does not equate to proportional change in the number of measured severe gusts. Yet, the evidence does show clear benefit to having a denser observing network. Ultimately, this study provides a foundation for further study, most notably in increased frequency distribution analysis and more in-depth environmental analysis.

Although, some caveats do exist with the results of this study. Most notably, it was found that not every ASOS/AWOS site was included in the data archive, the reason for which is currently unknown. Additionally, data were discontinuous for many locations due to equipment failures. For example, the Elkhart, KS (KEHA) station is located in southwest Kansas in the middle of a few stations with high frequencies of reports. Yet, KEHA contains no archived gusts >= 25 m s^{-1} (50 kt) that were not due to instrument malfunction. Further inspection of the site data suggested discontinuous observations due to equipment problems may be a possible cause. Other similar situations were examined and were determined to be either station malfunction or a lack of archived data. These two cases bring into question the amount of operating time that certain stations may have had during the seven year period. However, assuming this is a random occurrence and not more frequent to one part of the domain than another, the overall spatial distribution of measured severe gusts appears valid. Errors were also found in the reported position coordinates of ASOS/AWOS stations in LSR's. For example, some Tyler, TX observations were positioned at the city center when the ASOS station is located at the airport outside of the city. Additionally, some reports in the SPC wind database listed maximum gusts that differed from the actual maximum measured gust from the observation site, by a few knots on occasion. This and similar cases prevented the MATLAB script from finding all reported observations and validated the need for a manual examination of SPC storm reports to find all of the observations that were, in fact, reported to the SPC.

5. SUMMARY AND CONCLUSIONS

The purpose of this study is to establish a measured severe convective wind database and climatology for the contiguous United States from 2003-2009, using archived ASOS, AWOS and Oklahoma Mesonet data. The severe criteria wind observations then went through a quality control process that began with running the data through a lightning filter to check for the presence of convection around the observation. Data were then examined manually, following uniform conventions, to eliminate duplicate reports and questionable observations. Many cases were not specifically clear cut and decisions were made on a case-by-case basis to determine if they should continue on to the next step of quality control. Remaining observations were checked against Radar Mosaic and WSR-88D Level II data to filter out more questionable observations. Lastly, measured observations were checked against the SPC wind database to examine the possibility of a severe wind report at the observation site. A portion of the final dataset includes observations for which there was no severe report, but it was determined to be convectively driven. Such cases likely include gusts produced from convectively induced wake lows, amongst other phenomena. The final measured dataset was then paired with archived SPC mesoanalysis data and binned by a variety of atmospheric regimes and situations.

The summarized results of the analysis are shown as follows:

- 2,612 observations were included in the measured dataset from 2003-2009. 2,336 were from ASOS/AWOS instrumentation and 276 from the Oklahoma Mesonet network.
- The measured dataset would only account for roughly 3% of all severe wind reports to the SPC per year.
- For southeast pulse thunderstorm environments, the measured dataset showed some difference in median

MLCAPE values than those from observations in the SPC wind database.

- Analyzing organized severe storm environments nationally, it was noticed that moderate instability and moderately strong shear was common among measured dataset observations.
- Comparing SPC reported and non-reported observations within the measured dataset showed slight differences in MLCAPE and wind magnitude, with SPC reported observations having higher median values.
- The Oklahoma Mesonet outperforms the ASOS/AWOS network in Oklahoma, averaging almost one more report per SCD. Additionally, out of 57 shared SCDs, only four days did the ASOS/AWOS network record more measured gusts than the Oklahoma Mesonet.
- Analyzing gust frequency shows two primary corridors; one over the central and southern High Plains and the other from the upper Midwest across the southern Great Lakes region.

Through a consideration of solely severe convective wind gusts, many of the biases and inaccuracies within the SPC wind database are mitigated by using a measured wind dataset across similar instrument platforms. ASOS/AWOS and Oklahoma Mesonet equipment follow the exact same method of reporting their wind gusts and such instrumentation is not grossly prone to human error. Analyzing solely quantifiable gusts allows for a more robust and useful climatology to be produced. In the future, the compilation of a measured database can provide forecasters with numerous tools to assess the potential of forthcoming severe weather and recognize the different environmental thresholds necessary for severe weather in a particular region or during a certain season. Additionally, soundings can be linked with these observations to provide background information for forecasters when analyzing current soundings. Such an extensive quality control process ensures great confidence in the data. Such confidence is necessary for building a sound climatology.

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