P7.4 NON-TORNADIC CONVECTIVE WIND FATALITIES IN THE UNITED STATES

Alan W. Black* and Walker S. Ashley
Meteorology Program, Department of Geography, Northern Illinois University, DeKalb, Illinois

1. INTRODUCTION

While a relatively thorough climatology of tornadoes and tornado casualties exists, information is rather sparse for other types of non-tornadic convective windstorms, especially in terms of their human impacts. Non-tornadic convective winds have the ability to injure and kill; in fact, previous research has suggested that non-tornadic convective winds are responsible for nearly one out of every four wind-related deaths (Ashley and Black 2008). The primary goal of this study is to develop a climatology of non-tornadic convective wind deaths for the period 1977-2007. This initial assessment will provide the foundation for a more detailed analysis of the variety of hazards these events pose.

Climatologies of severe non-tornadic convective winds illustrate that these events are most common in a broad area that includes parts of the Great Plains, Ohio Valley, Southeast, and Gulf Coast and are most frequent in the warm-season months of June, July, and August (Kelly et al. 1985, Doswell et al. 2005). Other studies have addressed specifically the distribution and hazards of widespread, convectively driven windstorms known as derechos (Johns and Hirt 1987, Bentley and Mote 1998, Coniglio and Stensrud 2004, Ashley and Mote 2005). However, the spatial and temporal characteristics of other non-tornadic thunderstorm wind hazards, and their human impacts, remain largely unknown. For this reason, a database of fatalities for the period 1977-2007 was constructed to assess the threat to life in the conterminous United States from non-tornadic convective wind events.

2. DATA AND METHODOLOGY

Information on fatalities caused by non-tornadic convective wind events was gathered from *Storm Data* and NCDC's Online Storm Event Database. Fatality numbers from *Storm Data* must be approached with caution due to the difficulty in the collection of these types of data (Curran et al. 2000, Trapp et al. 2006). Both Curran et al. (2000) and Ashley and Mote (2005) note that hazards such as derecho and lightning fatality events may receive less attention than large-impact events such as floods, tornadoes, or hurricanes. Curran et al. (2000) suggest further that one reason for underreporting may be that most lighting casualty events involve one person. Similarly, about 88% of non-tornadic convective wind fatality events also involve only one person and it is hypothesized that these events may be underreported in *Storm Data* as a result. Despite issues with *Storm Data*, the source is the only consistent database for storm-related casualties (Ashley 2007). Most tornadic and non-tornadic wind events in *Storm Data* include a narrative text description of damage and how casualties occurred. This supplemental information was used to determine the county, parish, and/or town of the death, as well as information relating to the circumstance of death or building structure type where the fatality occurred (e.g., permanent home, mobile home, outdoors, vehicle, etc.). These data were recorded along with basic information such as the date and time of the fatality to complete the fatality dataset assessed in this study.

Due to *Storm Data* fatality undercount concerns, the National Transportation Safety Board's (NTSB) Aviation Accident Database (http://www.ntsb.gov/ntsb/query.asp) was assessed to find additional aircraft fatalities caused by non-tornadic convective wind that were undocumented in *Storm Data*. Aircraft fatalities due to non-tornadic convective wind were identified by reading the accompanying description and using the narrative of the crash to determine if the accident was non-tornadic convective wind related. In many cases, thunderstorms were mentioned as a primary cause, along with microbursts and macrobursts. Cases where it was not clear that the accident was related to non-tornadic convective winds were excluded from this analysis.

A geographic information system (GIS) was used to reveal the spatial patterns of these fatality data. Latitude and longitude information for the location of each fatality was collected, and in cases where only the county (or parish) name was provided, the latitude and longitude of the county seat was used as a surrogate for the fatality location. Fatalities were mapped on an 80km x 80km grid; a grid of this size encloses the same area as a circle with radius 24.6 n mi, which is similar to the area under consideration by SPC forecasts (Doswell et al. 2005). The climatology of non-tornadic convective wind was compared to non-tornadic wind events and to fatalities from non-convective high winds and tornadoes to assess any regional similarities (or differences) that may exist in the spatial distribution of fatalities.

3. RESULTS

3.1 *Characteristics of non-tornadic convective wind fatalities*

There were 1,226 fatalities *recorded* due to non-tornadic convective wind for the 31-yr period of record (Figure 1), 465 of which were aircraft related. Including aircraft fatalities, non-tornadic convective winds account for

* *Corresponding author address/current affiliation:* Alan Black, Midwestern Regional Climate Center, Division of Illinois State Water Survey, Institute of Natural Resource Sustainability, University of Illinois, 2204 Griffith Dr., Champaign, IL 61820-7495; e-mail: awblack@illinois.edu

32.4% of all fatalities caused by wind phenomena during the period. For the same period, 1,713 tornado fatalities and 668 nonconvective wind fatalities were recorded, with an additional 181 fatalities due to hurricane or tropical storm winds. Ashley and Black (2008) suggested that even though non-convective and non-tornadic convective winds present collectively a comparable threat as tornadoes, they receive much less attention in terms of research, media coverage, and public hazard perception. From 1977-2007, non-convective and non-tornadic convective winds, including aircraft fatalities, were responsible for 43.0% of all recorded wind-related fatalities, while tornadoes were responsible for 51.5% of recorded wind fatalities. These results support the hypothesis of Ashley and Black (2008) and highlight the need for further research into *all* types of windstorm casualties. Mass casualties events due to aviation accidents may skew overall results; thus, these fatality events are excluded from the subsequent analysis and are detailed in a later section.

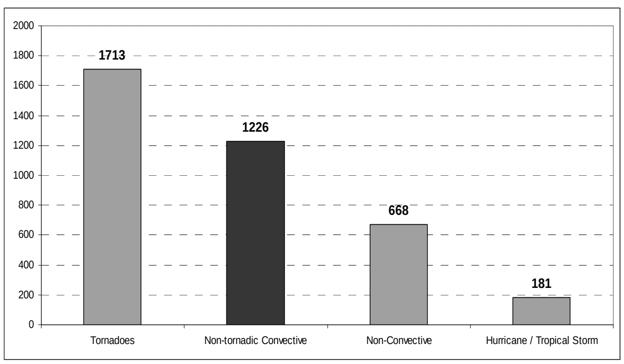

Figure 1. Wind-related fatalities by storm type, 1977-2007.

The number of non-tornadic convective wind fatalities varied from 9 in 1978 to 46 in 1998, with an average of 25.5 per year (Figure 2). There is a large amount of year-to-year variability in the number of non-tornadic convective wind fatalities and no discernable trend in the number of deaths per year. Analysis of the latter period of record suggests a slight decreasing trend in the number of fatalities, but a more extensive period of analysis will be required to see if this is a definitive trend or simply a deviation from the long-term mean.

Ashley and Mote (2005) discovered that derechos were responsible for 38.8% of non-tornadic convective wind fatalities from 1993-2003. Analysis of non-tornado convective wind fatalities for the period 1986-2005 showed that derechos were responsible for an average of 31.7% of fatalities each year. As compared to tornadoes, which are primarily generated from one storm type (i.e., supercells), non-tornadic convective winds may be produced commonly from a multitude of thunderstorm types found on the convective spectrum. This may have implications for the reduction of non-tornadic convective wind fatalities as events that cause these fatalities are more common and may, in turn, lead to greater public complacency and a reduced response to warnings.

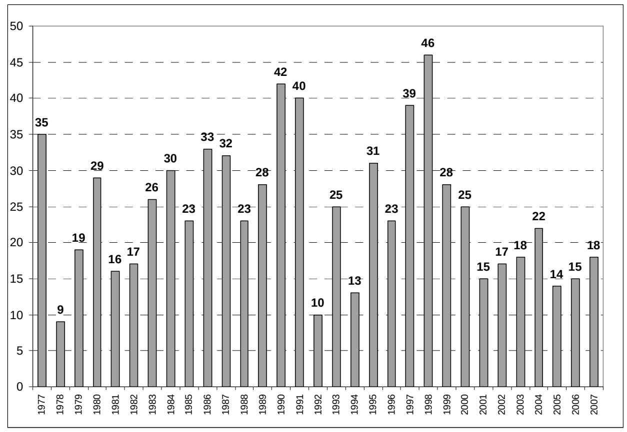

Figure 2. Non-tornadic convective wind fatalities by year, 1977-2007.

Excluding aircraft-related fatalities, non-tornadic convective wind fatalities are most frequent in the late spring and summer months (Figure 3). July had the most fatalities during the period of record, followed by June, May, and August. This temporal frequency in the fatalities coincides well with the warm-season climatological maximum of non-tornadic convective wind occurrences (Kelly et al. 1985, Doswell et al. 2005). Further analysis of fatalities by hour reveals that the number of fatalities remains relatively low overnight, with a drastic increase in counts during the late-morning hours (Figure 4). Fatalities peak between 1500 and 1659 local time, with 27.8% of fatalities occurring during this two-hour time span. The afternoon maximum in fatalities coincides with the afternoon peak of non-tornadic convective wind events illustrated by Kelly et al. (1985). Kelly et al. (1985) note that roughly 20% of non-tornadic convective wind events occur between midnight and noon, nearly identical to the percentage of fatalities occurring during the same hours in this study. While 11% of non-tornadic convective wind events occurred in the overnight period (0000 to 0559 LST), only 7.8% of non-tornadic convective wind fatalities occurred during the same period. A clear contrast exists in the hourly distribution of tornadic and non-tornadic convective wind fatalities. Ashley et al. (2008) found that while only 27.3% of tornadoes occurred at night, those nocturnal events were responsible for 39.3% of fatalities. In addition, overnight (local midnight to sunrise) tornadoes were 2.5 times as likely to cause a fatality as compared to those during the day. Much of this “nocturnal” difference is attributed to difficulty in spotting these tornadoes at night, an increased likelihood that vulnerable housing would be the primary shelter type during the overnight hours, and a breakdown in warning dissemination due to normal sleeping patterns (Ashley et al. 2008). While the difficulty in spotting and breakdown in warning dissemination would also apply to non-tornadic convective wind fatalities, the low percentage of overnight fatalities indicates that occupying even a weak structure may provide considerably better shelter against non-tornadic convective wind compared to tornadoes.

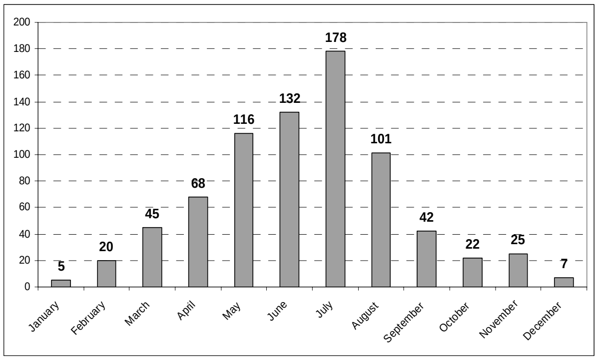

Figure 3. Non-tornadic convective wind fatalities by month of occurrence, 1977-2007.

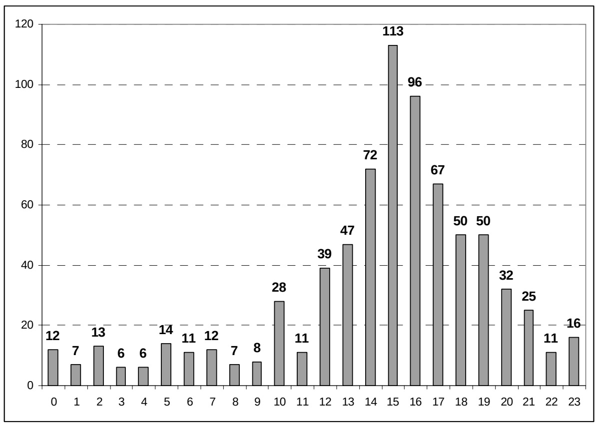

Figure 4. Non-tornadic convective wind fatalities by hour of occurrence (in LST), 1977-2007.

When examining non-tornadic convective wind fatalities by area and/or circumstance of occurrence, most fatalities took place outdoors (29.8%), in a vehicle (28.3%), or while boating (22.9%). These three categories, collectively, account for 81.2% of all non-tornadic convective wind fatalities (Figure 5). Previous studies (Ashley and Mote 2005, Ashley and Black 2008) illustrate that 69% of derecho fatalities and over 90% of nonconvective wind fatalities were in vehicles, while boating or outdoors. Again, a large contrast in circumstance or place of occurrence exists between non-tornadic convective wind fatalities and tornado fatalities. For example, over 70% of tornado fatalities occur within housing structures, and less than 10% of tornado fatalities occur in vehicles or boats (Ashley 2007). These results support the hypothesis of Ashley and Black (2008) that people are more likely to take shelter during a tornado than in non-tornadic convective or non-convective wind situations. This may, in part, explain the low percentage of overnight non-tornadic convective wind fatalities as the public is more likely to be in a shelter compared to the daylight hours.

Overall, 42% of non-tornadic convective wind fatalities involved a felled tree; although, this may be a conservative estimate as each fatality was only classified as tree related if enough information was available from *Storm Data* to make that distinction. Of

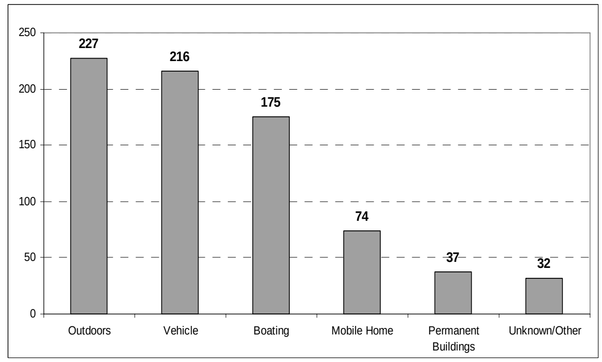

Figure 5. Non-tornadic convective wind fatalities by location of occurrence, 1977-2007.

the outdoors fatalities, 62% involved a felled tree with the remainder attributed to other causes including, but not limited to: collapses of buildings under construction or construction equipment, the victim being struck by flying debris, or the victim being blown down by or off a structure by the wind. Most (72%) vehicle fatalities were tree related. The most common circumstances for vehicle-tree related fatalities were a tree falling on to a vehicle or a vehicle striking a felled tree. Additional fatalities were the result of the vehicle being blown off of the road by the non-tornadic winds, colliding with downed power poles, leaving the roadway while swerving to avoid debris, or due to reduced visibility when dust was kicked up by non-tornadic convective winds. Fatalities due to blowing dust were only included in this analysis if it was clear from the description of the event that dust was raised by non-tornadic convective winds. Cases lacking a description of the event or where the circumstances of the event were unclear were excluded from this analysis.

Spatial examination of non-tornadic convective wind fatalities reveals several unique trends and vulnerabilities. A primary fatality axis stretches from the Great Lakes to the Northeast and Mid-Atlantic states with a secondary axis across the South and Southeast, including Texas, Louisiana, Alabama, and Georgia (Figure 6). Each of the top five states in terms of fatalities falls in to one of these fatality corridors with the Great Lakes states of Ohio (59 fatalities), Michigan (58) and New York (42) accounting for 21% of fatalities in the dataset. The other two states in the top five, Texas (48) and Alabama (33) lie within the secondary fatality axis and experience 11% of all non-tornadic convective wind fatalities. Standardizing the state fatality totals by area reveals a considerably different spatial pattern (not shown). Of the top five states in terms of standardized fatalities, four of them are in the Northeast or Mid-Atlantic (New Jersey, Maryland/Washington D.C., Delaware, and New Hampshire). The only state with no non-tornadic convective wind fatalities reported during the period was Rhode Island.

The leading states in terms of fatalities and standardized fatalities share similar characteristics. First, these states are adjoined to large bodies of water, which increases the probability of a boating related-fatality. Further, the two fatality axes correspond to highly forested areas, which enhance the likelihood of a felled-tree fatality. These same areas have high population densities that result in a greater number of people at risk. Finally, each of these high-fatality regions (the Northeast, Great Lakes, and the Southeast) coincide with areas associated with an enhanced climatological risk of severe convective winds (Doswell et al. 2005). The relative high frequency of non-tornadic convective winds in these regions may increase public awareness of the hazard, but it also may cause residents to ignore warnings and not seek shelter (due to complacency) and increase, ultimately, their vulnerability to the hazard. Future surveys of residents within these high-frequency and high-fatality areas may help identify socio-economic factors and attitudes that contribute to the unique vulnerabilities found in these areas.

Ashley (2007) found that tornado fatalities are most common in the interior South, especially the lower-Arkansas, Tennessee, and lower-Mississippi River Valleys (Figure 7).Conversely, this is an area that has relatively few non-tornadic convective wind fatalities, indicating that the factors that increase vulnerability to tornadoes may have little effect on non-tornadic convective wind vulnerability. Conversely, non-convective and non-tornadic convective wind fatalities occur in many of the same locations and may share similar physical and social vulnerabilities. Non-convective wind fatalities are most common on the West Coast and Northeast and many non-tornadic convective wind fatalities occur in the Northeast (Ashley and Black 2008). The lack of non-tornadic convective wind fatalities along the West Coast is likely due to the relatively infrequent occurrence of these events in this region (Doswell et al. 2005).

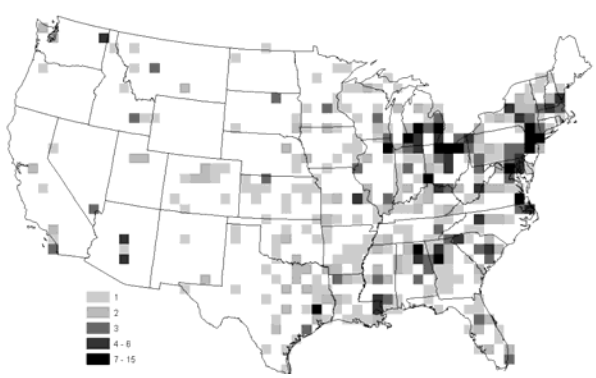

Figure 6. Number of non-tornadic convective wind fatalities in an 80 km x 80 km grid, 1977-2007.

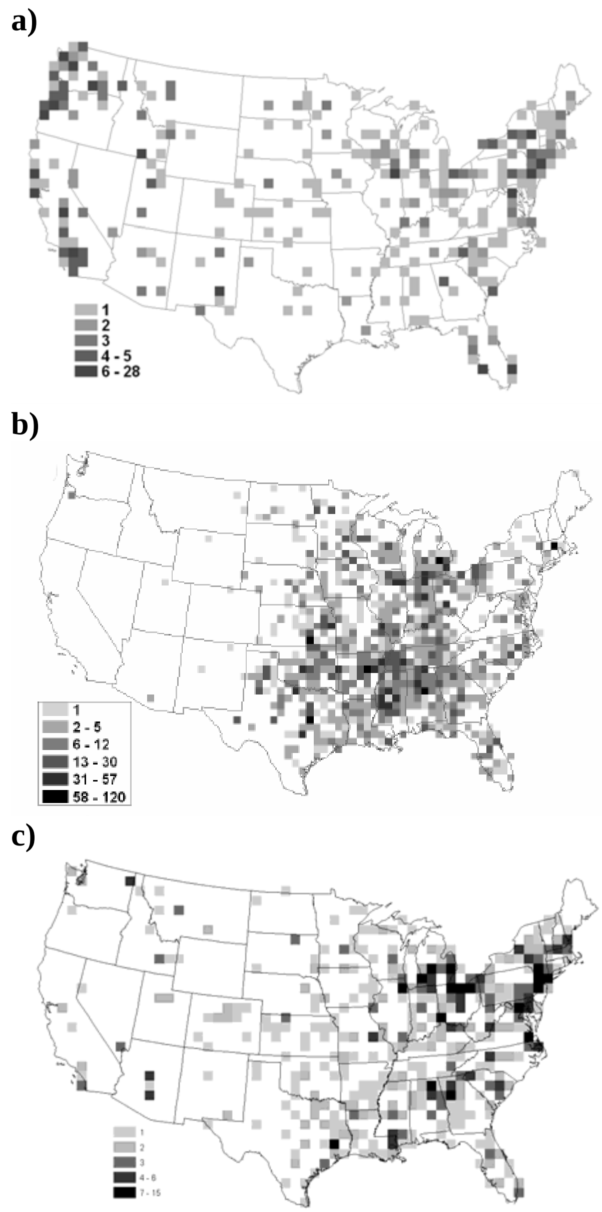

Figure 7. Number of a) nonconvective wind fatalities in an 80 km x 80 km grid 1980-2005 (from Ashley and Black 2008), b) tornado fatalities in a 60 km x 60 km grid 1950-2005 (from Ashley 2007), and c) non-tornadic convective wind fatalities in an 80 km x 80 km grid, 1977-2007.

3.2 *Aircraft-related fatalities*

As previously mentioned, 465 aircraft-related, non-tornadic convective wind fatalities were recorded from 1977-2007, over twice as many as the next closest fatality “location of occurrence” category of outdoors. An initial examination of *Storm Data* revealed only 29 aircraft fatalities during the period of record; the remaining fatalities were documented in the NTSB database. Several high fatality events such as the 9 July 1982 crash of Pan Am Flight 759 upon take off from New Orleans, LA and the crash of Delta Flight 191 during landing in Dallas, TX on 2 August 1985 were missing from *Storm Data*. Both of these accidents were the result of the aircraft encountering a convective microburst, and were responsible for 288 fatalities or 62% of aircraft-related non-tornadic convective wind fatalities. At best, only 6% of aircraft related non-tornadic convective wind fatalities were recorded in *Storm Data.* This illustrates further the need for improvement in the methods used to gather damage and casualty information from weather-related hazards as suggested in several other studies (Curran et al. 2000, Trapp et al. 2006, Ashley 2007, Ashley and Black 2008).

4. CONCLUSIONS

Assessment of the human impact of non-tornadic convective winds is essential to improving mitigation of this hazard and has received relatively little attention compared to tornadoes. Analysis of 31 years of United States fatality data associated with non-tornadic convective wind events illustrates that they are responsible for approximately one in three wind-related deaths. The highest vulnerability to non-tornadic convective winds exists in the Great Lakes eastward through the Northeast and Mid-Atlantic States, as well as areas of American South. Climatologically, these regions see a high frequency (i.e., risk) of non-tornadic convective wind events (Doswell et al. 2005). Vulnerability is further enhanced in these regions by large forested areas, proximity to bodies of water, and relatively high population densities. Excluding aircraft fatalities, the most common fatality locations are outdoors, in vehicles, and boating, which combined for 81.2% of all non-tornadic convective wind fatalities. Only about 32% of non-tornadic convective wind fatalities are attributable to derechos; other less organized, severe windstorms are responsible for the remaining fatalities.

This study supports the recommendations of Ashley (2007) and Ashley and Black (2008); namely, that a concerted effort to collect information on all weather-related casualties and damage is needed to improve watch-warning activity and reduce casualties. Non-tornadic convective wind fatalities are likely under-reported as they receive less attention than more prominent windstorms such as tornadoes and hurricanes and because most events result in only one fatality, reducing the likelihood that the fatality will be reported.

In conclusion, this analysis provided a small view into the complex human-environment interplay of risk and vulnerability that culminates in human impacts in these non-tornadic convective wind events. In addition to increasing our meteorological knowledge of these wind events in the future, gathering a more robust understanding of public perception and response to these hazards will offer the best approach to reducing potential human impacts of these events.

5. REFERENCES

Ashley, W.S., A.J. Krmenec, and R. Schwantes, 2008: Vulnerability due to nocturnal tornadoes. *Wea. Forecasting*, **23**, 795-807.

____, and A. W. Black, 2008: Fatalities associated with nonconvective high-wind events in the United States. *J.Appl. Meteor. Climatol*., **47**, 717-725.

____, 2007: Spatial and temporal analysis of tornado fatalities in the United States: 1880-2005. *Wea. Forecasting*, **22**, 1214-1228.

____, and T. L. Mote, 2005: Derecho hazards in the United States. *Bull. Amer. Meteor. Soc.*, **86**, 1577-1592.

Bentley, M. L., and T. L. Mote, 1998: A climatology of derecho-producing mesoscale convective systems in the central and eastern United States, 1986–95. Part I: Temporal and spatial distribution. *Bull. Amer. Meteor. Soc.,* **79,** 2527-2540.

Coniglio, M. C., and D. J. Stensrud, 2004: Interpreting the climatology of derechos. *Wea. Forecasting,* **19,** 595-605.

Curran, E. B., R. L. Holle, and R. E. Lopez, 2000: Lightning casualties and damages in the United States from 1959 to 1994. *J. Climate*, **13**, 3448-3464.

Doswell, C. A., III, H. E. Brooks and M. P. Kay, 2005: Climatological estimates of daily local nontornadic severe thunderstorm probability for the United States. *Wea. Forecasting*, **20**, 577-595.

Johns, R. H., and W. D. Hirt, 1987: Derechos: Widespread convectively induced windstorms. *Wea. Forecasting,* **2,** 32-49.

Kelly, D. L., Schaefer, J. T., and Doswell, C. A., 1985: Climatology of nontornadic severe thunderstorm events in the United States. *Mon. Wea. Rev.*, **113**, 1997–2014.

Trapp, R. J., D. M. Wheatley, N. T. Atkins, R. W. Pryzbylinski, and R. Wolf, 2006: Buyer beware: Some words of caution on the use of severe wind reports in postevent assessment and research. *Wea. Forecasting*, **21**, 408-415.