Changes in Ice Storm Impacts over Time: 1886–2000

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ABSTRACT

Ice storms have a variety of negative effects on society. Through an analysis of newspaper accounts of nine exceptional ice storms, the most widespread and longest lasting impact is the loss of electrical power. Power outages also cause secondary effects, such as carbon monoxide poisoning and fire, and they can force people to leave their homes because of a lack of heat. Other impacts of ice storms are transportation disruptions, school and business closings, and economic losses to agriculture and some business sectors. However, some businesses, such as those associated with the hospitality sector, actually benefit from ice storms.

Modern power outages have a longer duration than those associated with earlier storms. Rural areas are most likely to suffer from long power outages because utilities prioritize areas with greater numbers of customers and because fallen trees may limit accessibility. Several suggestions for reducing electrical disruption, such as aggressive tree-trimming programs and burial of lines, are analyzed. While these may help, less reliance on electricity for lighting and heating systems could also provide a benefit.

1. Introduction and background

Ice storms cause millions of dollars in insured losses every year, and insured losses are probably only a small fraction of total economic losses (DeGaetano 2000; Changnon 2003a). Ice storms primarily consisting of freezing rain (as opposed to those with sleet and snow) generally cause the most damage because freezing rain “sticks” to tree limbs and power lines, causing them to fail. This failure can cause problems such as power outages, transportation disruptions, and economic losses.

Several climatologies of ice storms within the continental United States (Bennett 1959; Changnon 2003a; Cortinas et al. 2004) have established that freezing rain is most common in the Northeast and to a lesser extent in the northern Midwest. Climatologist S. Changnon has found that ice storm “catastrophes” are most common in the northeastern and southeastern United States (Changnon 2003a). This is because ice storms in the Southeast, while less common than those farther north, often have greater amounts of precipitation, which increases the weight of ice on trees and power lines (Rauber et al. 2001).

The impacts of ice storms have been studied by researchers interested in a specific sector, such as forestry (Deuber 1940; Lafon 2000; Proulx and Greene 2001; Kraemer 2003). A broader, more comprehensive risk assessment is lacking; such an assessment is important for reducing the costs of disasters (Blaikie et al. 1994; Smith 2004, p. 49). To complete the risk assessment for ice storms, the author developed the research questions listed below before beginning this research project:

1) What hazards are associated with ice storms?
2) What is the risk of each hazard?
3) How have these risks changed over time?
4) How does the interaction of ice with other hazards, such as snow, affect its impact?
5) Do the impacts vary spatially between urban and rural areas?

This article will present answers to those questions through an analysis of accounts of ice storm impacts associated with nine storms that affected the eastern or southern United States from 1886 to 2000. It will also examine the vulnerability of electrical distribution systems to ice storms and offer some suggestions for changes in practice by utility companies. Ice storms disrupt utility service, force schools to close, and hurt the agricultural sector but benefit hotels and hardware stores. Nonetheless, the biggest impact of ice storms is the disruption of electrical service.

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2. Methodology

Perhaps the most challenging part of this study was determining what storms to study and what data to collect. Changnon and Creech (2003) detail some of the difficulties in studying historic ice storms. First, freezing rain data have a number of temporal inconsistencies, that even when corrected, still yield a dataset with rather low spatial resolution (ibid.). Second, official accounts prior to the publication of Storm Data (which began in 1959) are incomplete when compared to other contemporary sources, such as railroad records (Bennett 1959), and the U.S. Weather Bureau (USWB) did not keep track of such storms prior to 1925 (Changnon and Creech 2003). Even the more modern accounts in Storm Data have been considered incomplete (Branick 1997), and Changnon notes that such data are “inadequate” when attempting to measure ice storms on even a regional level (Changnon and Creech 2003). There are numerous case studies of ice storms in the meteorological and other scientific literature spanning the study period (e.g., Henry 1921; Deuber 1940; Harlin 1952; Ackley and Itagaki 1970; Pfost 1996; DeGaetano 2000), but as might be expected, they vary widely in the quantity, quality, and types of data presented. In summary, choosing what storms to study, what information to collect, and how to collect that data were all major challenges. Each one will be discussed individually in the next three subsections.

a. Storm selection

After searching through the literature and reviewing the meteorological archives of the National Oceanic and Atmospheric Administration (NOAA) Central Library, three relatively comprehensive listings of severe ice storms emerged. While none of these provided complete coverage for the entire study period, when combined and compared with each other, it appeared that they probably listed all the significant storms potentially worthy of study. A list of “outstanding” ice storms compiled by the NWS (1962) provided summary information for ice storms early in the study period. Weather historian D. Ludlum’s (1982) book on North American weather helped collaborate the information and augmented the record later in time. A database of insured losses from 1949 to 2000 (Changnon 2003b) provided a quantitative measure of the impacts associated with ice storms and extended the record. Recent publications of Storm Data (NCDC 2000; and subsequent volumes) and Kocin and Uccellini’s (2004) monograph about snowstorms helped complete the remainder of the study period and cross-referenced the other sources.

An informal list of about 30 severe ice storms for potential study was then derived. The list was reduced to a final list of nine storms, which appears in Table 1, by searching through the literature for more information about specific storms and keeping the research questions in mind. Since one research goal was to determine changes in impacts over time, if several storms occurred close in time to each other, one was often deleted. For example, the December 1929 storm in Maine was not studied because of other stronger storms in 1921 and 1935. Conversely, to avoid large temporal gaps, several relatively minor storms were kept, such as the December 1973 storm in Connecticut. Another research goal was to see if regional differences occurred. Thus, although the 1998 storm occurred close in time to several other storms, it was studied because it was the only major storm to severely affect New England in the late 1990s. Finally, since the primary goal was to examine impacts, specific storm accounts in sources such as Monthly Weather Review were consulted to better understand the impacts associated with each storm, and Changnon’s (2003b) damage estimates were weighted more heavily than other sources.

Because the selection process involved both objective and subjective criteria, by no means does the list of storms represent an authoritative listing of the worst storms to affect the United States during the study period. Rather, it is a sample of widely recognized severe ice storms from a variety of time periods and locations that was constructed to address the research questions.

b. Information collected

To collect data on impacts, the accounts mentioned in the previous section were consulted, reports in Monthly Weather Review and Storm Data were read, and relevant journal articles and books were evaluated. For some storms, additional information was available at the NOAA Central Library, or found serendipitously at various archives, such as the Alabama Department of Archives and History. Nonetheless, most of the data came from newspaper reports. Newspapers are commonly used in similar studies about impacts of weather because they are easily accessible and offer general coverage (Call 2005; Changnon and Changnon 2005). The National Weather Service’s premier publication on storm impacts, Storm Data, also relies on local newspapers for data (Lopez et al. 1993; Changnon and Creech 2003).

Newspapers are not unbiased sources though. Local news outlets serve an important function in creating identity and helping regions determine what problems and opportunities exist (Kaniss 1991, p. 2). As members of the local economy, media outlets are also subject to the rises and falls of that economy, which encourages boosterism (Kaniss 1991, p. 2; Steinberg 2000, 15–16). Additionally, systematic changes in the publishing industry occurred during the study period. Early accounts
of ice storms were largely textual, while later ones included images, reflecting the increasing use of technology. Nonetheless, the amount of text also increased. The tone of coverage also changed. While earlier accounts offered the perspective of an impersonal observer, modern accounts regularly included stories about how individuals and families coped. Since the research questions focused on what happened (such as the number of people without power) rather than coping strategies, this change did not have a big effect.

For each storm, the author read newspapers within the worst affected area from 2 days before the storm to when there was no coverage of the storm for at least 2 days. This approach is similar to one used in an earlier study of snowstorms (Call 2005). Determining the “worst affected” area was a challenge. If a map of accumulation amounts was available, this was consulted. If a table of amounts was available, these data were plotted on a map. If neither of these were available (more common with older storms), written accounts were consulted to see what states and areas were mentioned; basic information for nearly all of the older storms appeared in multiple sources, even if it was less detailed compared to modern storms.

To see how the effects varied from place to place, newspaper accounts from six different cities, on average, were read for each storm. Reading multiple accounts also helped dilute the influence of any slanted newspaper accounts. Notes were taken any time a newspaper account mentioned any of the following impacts:

- electric utility disruption (number of customers without power, area without power)
- other utility disruptions (public water, telephone, cable)
- utility company response (number of workers, press releases, “Q and A” with spokespersons)
- emergency management response (shelters, travel bans, requests for outside aid)
- transportation disruptions (road closings, accidents, airport closings, train disruptions)
- economic losses or benefits (agriculture, forestry, hardware, hospitality)
- school closings (duration, plans to reschedule cancelled classes)
- meteorological information (amount of ice, prior forecasts)

Obtaining other types of data about ice storms, such as the exact extent of power outages, duration of school closings, and economic costs, was problematic. For example, utility companies are often reluctant to share outage information lest state-run public utility boards use it against them, and schools in many areas cannot produce detailed records of school closings for recent years. It is important to note that the data collected were limited to what was reported in newspapers, and thus may not be a complete representation of the impacts that occurred.
years, much less past years (Marcotte 2007). Naturally, with the passage of time, many data for the earlier storms have simply disappeared. Ascertaining economic impacts is especially challenging. Literature on businesses’ economic losses from winter storms is limited and conflicting. Studies sponsored by the Salt Institute (a trade organization) have suggested daily losses ranging from hundreds of millions to several billion dollars due to lost wages, retail sales, and government tax revenues (Adams et al. 2004). In contrast, climatologists Changnon and Changnon (2005) estimated a mere $15 million in “business losses,” representing fewer than 2% of the total economic losses associated with an ice and snowstorm in 2004. The process used to create this figure is unknown. Even estimates generated with more detailed methodologies can vary by millions of dollars (see DeGaetano 2000), and for larger disasters like hurricanes, these variations can be of even greater magnitude. Other problems with economic loss figures may be inflation to gain federal disaster relief funds, inclusion (or not) of indirect losses and potential future losses, and improper adjustments for the effects of inflation. Two additional problems specific to ice storms are inclusion of losses from other hazards in other areas (e.g., tornadoes) and variations in losses resulting from differences in population density. To summarize, while the author wanted to obtain quantitative data regarding the impacts of ice storms, the large time period and large study area limited the ability to obtain consistent, reliable data for all of the storms sampled.

3. Results

While ice storms have a variety of negative impacts, loss of electrical power is the most widespread and longest lasting. Transportation difficulties, while also widespread, linger for a much shorter time. Other impacts, such as forest destruction, are severe but tend to affect small segments of the population. Additionally, loss of electrical power also causes a variety of other negative impacts, such as disruptions to commerce, school closings, and carbon monoxide (CO) poisoning though improper use of generators.

a. Utility impacts from ice storms

Widespread power outages associated with intense ice storms can easily last for weeks after a storm ends. For example, 30% of customers in Clarksdale, Mississippi, still lacked power 2 weeks after the 1994 ice storm, as did an unknown number of additional customers in outlying areas (Clarksdale Press Register, 26 February 1994). In northern New York State, close to 35 000 customers remained without power more than 10 days after the 1998 ice storm (Plattsburgh Press-Republican, 21 January 1998), and the last customer did not have service restored until a month after the storm (T. Phelan 2007, personal communication). An estimated 32 500 Arkansans remained without power a week after the second ice storm of December 2000, in spite of 18-h workdays by 10 000 linemen and other workers (Arkansas Democrat Gazette, 2 January 2001).

Power losses are longer with modern ice storms. As shown in Fig. 1, the most recent storms studied (1994, 1998, and 2000) caused power losses of several weeks, while only one earlier storm (December 1935) caused a power loss of more than 1 week. In that case, nearly all power was restored within 2 weeks of the 1935 storm (Atlanta Constitution, 8 January 1936). It is not clear why modern power outages last longer. The newspaper and journal articles consulted did not explore the longer-term reasons behind this, and utility company representatives contacted in connection with this article had no explanation. Perhaps modern ice storms deposit greater amounts of freezing rain or occur more often but at a recurrence interval that still permits trees to grow back fully between storms. Possible nonmeteorological explanations would include a greater number of utility customers, sprawl into rural areas, or issues relating to utility companies themselves (e.g., fewer employees and poor capitalization).

Of course, other utilities such as telephone and cable television are disrupted by ice storms. Curiously, news coverage of earlier storms (1951 especially) was more likely to discuss telephone service than power outages (see Fig. 1) while modern coverage almost always includes a discussion of power outages. Conversely, newspapers today devote less space to discussing the loss of other utilities, and such discussion tends to focus on how customers can be reimbursed for lost service instead of the extent of outages (see, e.g., Nashville Tennessean, 22 February 1994; Plattsburgh Press-Republican, 22 January 1998). There are several probable reasons for the lack of modern coverage. Loss of telephone or cable is much less disruptive than loss of electricity, which makes the story less newsworthy. Coverage may be lacking because telephone companies simply follow electricity companies as they restore service, which is what Valor Telecom did in Texarkana, Texas, following the 2000 ice storms (Texarkana Gazette, 29 December 2000). Since cable television does not work without power, newspapers may have ignored this news story insofar as customers without power do not have cable television either, although this may be changing as generators becomes more widespread. Finally, electric service is more likely to fail than other utilities. In Maine, for example, the top 4 ft of the utility pole are reserved for electric service.
Fig. 1. Chart indicating what days newspapers published articles about local power outages.
(Portland Press-Herald, 17 January 1998), and this appears to be common elsewhere too. A tree falling on an electric line will almost surely affect electric service by either breaking the line or pole or shorting the line, while lower wires on the pole (such as telephone or cable) may be unaffected.

Regardless of the utility, “rural” customers lose service for a longer time period than “urban” customers, assuming that accumulation amounts are similar and the utility companies respond equally. There are several reasons for the difference. First, utility companies concentrate on restoring main feed lines and high-priority individual lines (National Grid 2006; T. Phelan 2007, personal communication). Thus, where customers are clustered together (urban areas and town centers), power is restored faster (see, e.g., Memphis Commercial Appeal, 13 February 1994; Shreveport Times, 16 February 1994; Arkansas Democrat Gazette, 30 December 2000; Texarkana Gazette, 3 January 2001). Second, fallen trees and lines often isolate customers outside developed areas and prevent utility crews from accurately assessing damage. Utility companies then fail to call enough workers or order sufficient supplies. Following the second December 2000 storm, dangerous road conditions prevented utility workers from assessing conditions in Bowie County, Texas, until several days after the storm (Texarkana Gazette, 29 December 2000). In Arkansas, major roads were clear soon after the second ice storm in 2000. In contrast, roadways in the mountainous areas remained impassible, and a state highway spokesman remarked that fallen trees in these areas were a bigger problem than the ice (Arkansas Democrat Gazette, 29 December 2000). Newspapers reported that utility companies had similar difficulty in assessing the magnitude of damage in northern New York in 1998 (Plattsburgh Press-Republican, 11 January 1998; Watertown Daily Times, 11 January 1998). A third and somewhat related problem is the difficulty in hiring qualified electricians to make repairs to weatherheads and areas around the utility meter (see Fig. 2). When power lines fall, weatherheads are often damaged, but individual customers are responsible for repairing them, not the utility company, and the utility will not restore power until the repairs are made. Rural poverty may also contribute, because rural areas are less likely to have programs to aid homeowners. In Memphis, Tennessee, for example, the city-owned electric company offered a grant to low-income homeowners to help them pay for the cost of weatherhead repairs, which typically cost $250–$375 following a storm (Memphis Commercial Appeal, 15 February 1994). Farther east, the Nashville Electric Service offered to do the work for “needy” customers and bill them in monthly installments (Nashville Tennessean, 19 February 1994).

None of the 11 sampled newspapers reported a similar program for rural areas affected by the 1994 storm (or the storms in 1998 or 2000, for that matter).

Telephone and cable companies also restore service more slowly to rural customers. Following the December 2000 storms, Valor Telecom noted that 10 000 customers in the Texarkana area, representing 10% of their subscribers, lacked telephone service 3 days after the storm. Included in that total were 30 rural areas with fewer than 25 customers in each area (Texarkana Gazette, 29 December 2000). In northern New York, Bell Atlantic focused on restoring Subscriber Loop Carrier Systems (which carry the dial tone from the central office to substations) before working on individual drop wires after the 1998 storm (Plattsburgh Press-Republican, 11 January 1998).

b. Indirect impacts of power losses

Power losses can trigger other negative impacts, with carbon monoxide poisoning and fire being among the most common. Carbon monoxide poisoning usually results from improper generator use, such as operating a generator in an unvented garage (Shelbyville Times-Gazette, 14 February 1994). Following the 1998 ice storm, at least five people in New York died in several
different incidents (Plattsburgh Press-Republican, 14 January 1998). In Maine, 2 people died and more than 153 sought hospital treatment (Portland Press Herald, 14 January 1998). Following the first ice storm in December 2000, 30 people were treated at Shreveport, Louisiana, hospitals for CO poisoning (Shreveport Times, 20 December 2000).

Power outages also increase the risk of fire due to the use of candles and other improvised light and heating. For example, 32 fires in Memphis were blamed on the 1994 storm (Memphis Commercial Appeal, 18 February 1994), and 15 fires in Little Rock, Arkansas (in 1 day), occurred after the first 2000 ice storm (Arkansas Democrat Gazette, 18 December 2000). Fires have always been a problem associated with ice storms, and transportation difficulties can complicate the problem. Two Portland, Maine, buildings and their contents were destroyed by fire following the 1886 storm because crews with horses simply could not get there (Portland Sunday Times, 31 January 1886).

Certain types of crime increase because of power losses. Opportunists may loot powerless businesses (Memphis Commercial Appeal, 13 February 1994) or steal generators (Portland Press Herald, 15 January 1998). While property crimes like this appear to increase, other reports and police statistics suggest an overall decrease in crime (Plattsburgh Press-Republican, 24 January 1998), similar to snowstorms (Call 2004, p. 85). The magnitude of looting following a natural disaster is currently under debate by the hazards community (see Quarantelli 2007; Frailing 2007). Because of the dramatic nature of looting and theft, the media, especially television, heavily cover such incidents (Kaniss 1991, p. 108); it is unclear how prevalent these crimes really are since the statistics are not readily available. Further study of this topic would probably involve examining individual police reports to determine exactly what percentage of crimes were storm related.

Without power, many people cannot heat their homes, and this forces them to vacate their homes. People migrate to homes of friends or family with heat, hotels, and free shelters at schools, community centers, and churches. (Such places may have power following a storm because electrical companies restore power to major trunk lines and large customers first, and they are also more likely to own generators or have access through governmental connections.) Sheltering is a modern phenomenon; the first mention of shelters in news accounts was in connection with the 1940 ice storm, in northern Louisiana (Monroe News-Star, 11 February 1994; Shreveport Times, 12 February 1994), northwestern Mississippi (Memphis Commercial Appeal, 14 February 1994), and Memphis (Memphis Commercial Appeal, 12 February 1994). Wide-spread sheltering was needed following the 1998 ice storm, especially in Quebec, Canada, where hundreds of thousands of people had to abandon their homes since “all-electric” homes are common there. Shelters were also widely used in and near Arkansas following the 2000 ice storms. A likely reason for the rise in shelters is that coal boilers and other old heating systems have been replaced by electric-ignition furnaces. Of course, all-electric residences have no source of heat whatsoever when the power fails, and these were not in existence before the mid–twentieth century. Given current trends, it appears shelters will be needed for future ice storms as well.

c. Other impacts of ice storms

Although the utility impacts of ice storms are the longest lasting, ice storms also disrupt transportation, force schools and businesses to close, and adversely affect agriculture, timber, and related industries. In contrast, ice storms can be a boon for hardware stores, hotels, and restaurants—assuming that they have power. Ice storms disrupt all forms of transportation. Even so, it is surprising that relatively few additional automotive deaths, injuries, and accidents are associated with ice storms given the obvious road hazards. Without exact numbers of accidents before, during, and after a storm, it is difficult to quantitatively assess this effect, but newspapers devote little coverage to traffic accidents caused by ice. In fact, a large number of news accounts mention that few or only minor accidents occurred, as if in reaction to readers’ expectations that many accidents occurred (see, e.g., Memphis Commercial Appeal, 30 January 1951; Hartford Courant, 17 December 1973; Arkansas Democrat Gazette, 14 December 1951; Texarkana Gazette, 27–28 December 2000). Accidents are less significant than expected for several reasons. First, even the worst storm deposits just a few inches of ice, and the use of deicers (such as sodium chloride) and normal wear from traffic quickly erode the ice from well-traveled roads (Changnon 2004, p. 2). Second, the closings of schools, businesses, and civic organizations reduce the need to drive. For example, Connecticut State Police reported lighter than usual traffic volume during the 1973 storm with only minor accidents (Hartford Courant, 17 December 1973). Government representatives from Shreveport and Monroe, Louisiana, reported reduced traffic volume in 1951 (Monroe News-Star, 31 January 1951; Shreveport Times, 31 January 1951). In Memphis, while 125–150 traffic accidents were blamed on icy roads during the initial phase of the 1994 ice storm, “wreck reports slowed to a trickle” as motorists stopped traveling (Memphis Commercial Appeal, 11 February 1994). Previous research by the author found that severe snowstorms...
The 1998 storm, a local traffic official observed sharply a healthy respect for the hazard of icy roadways. During even in areas accustomed to snow and ice, seem to have than television (Kaniss 1991, p. 117). Finally, motorists, even in areas accustomed to snow and ice, seem to have a healthy respect for the hazard of icy roadways. During the 1998 storm, a local traffic official observed sharply reduced speeds because of icy conditions (Plattsburgh Press-Republican, 6 January 1998).

Ice storms also disrupt other forms of transportation. News reports for early storms focused on rail and pedestrian disruptions. Area streets were impassible and hazardous to pedestrians in several early examples (Portland Press, 30 January 1886; Worcester Evening Post, 28 November 1921). Trolley service ceased entirely in Worcester, Massachusetts, for the better part of the week following the 1921 storm, and railroad companies experienced delays (Worcester Evening Post, 2 December 1921). In Portland, heavy snow associated with the 1921 storm merely “handicapped” trolley service, but problems with severe icing in Massachusetts disrupted long-distance rail service (Portland Evening Express, 28 November 1921). In 1935, traffic in northern South Carolina was merely slowed by minor glaze (less than 1 cm; Columbia State, 30 December 1935; Souder 1935), but citizens in Atlanta, Georgia, dealt with “paralyzed” trolley service when more than 100 streetcars became stuck and the entire system shut down (Atlanta Constitution, 30 December 1935). Nonetheless, most of the trolley lines in Atlanta resumed service within 4 days. As a sign of the growing importance of automobiles, this account of the 1935 storm was the first to mention traffic disruption (Atlanta Constitution, 30 December 1935). Modern storm reports also mention disruption to air travel. Power problems caused several airports to close during the 1998 ice storm (Plattsburgh Press-Republican, 9 January 1998) and the Texarkana airport to close in 2000 (Texarkana Gazette, 29 December 2000). The Little Rock airport closed from the evening of 25 December through midday 27 December 2000, because of ice on runways—its longest closing since 1975 (NCDC 2000, p. 5).

Ice storms disrupt school schedules. If schools remain closed for more than a week, officials may engage in convoluted maneuvers to satisfy the state-mandated minimum of instructional hours. Following several weeks of lost time in 1994, Clarksdale, Mississippi, schools added an extra 70 min of instruction time to each day and shortened holiday breaks (Clarksdale Press Register, 4 March 1994). Adjacent Coahoma County schools eliminated all breaks, and added three Saturday school sessions to recover the 12 days of instruction lost from 10 February through 25 February (ibid., 9 March 1994). In Maine, more than 15 school districts petitioned the governor’s office for a shorter school year following the 1998 ice storm, although state officials doubted that the request would be successful since Maine had a relatively short school year at the time (175 days; Portland Press Herald, 14 January 1998).

With utility service and travel disrupted, some economic losses to businesses are inevitable, but the amount of loss is difficult to measure as discussed earlier. The newspapers studied were more likely to report on businesses that benefited from ice storms, perhaps because this seemed more newsworthy. Hotels and motels experience above-average occupancy rates, assuming that they have power and water service. For example, the occupancy rate at Shreveport’s Sheraton-Pierremont increased from 30% to 70% in the aftermath of the 1994 ice storm (Shreveport Times, 12 February 1994). Ice storms benefit hotels and motels far outside the worst affected area; following the second December 2000 storm, Texarkana residents traveled 290 km to Dallas, Texas, for hotel rooms (Texarkana Gazette, 27–28 December 2000). Another business sector that benefits, both locally and regionally, is hardware. All types of products sell well, but generators are especially popular (Shreveport Times, 12 February 1994). Following the 1998 ice storm, a large hardware store near Syracuse, New York, sold an estimated 600–750 generators, even though the storm mainly affected Watertown (100 km north) and places more distant (Watertown Daily Times, 13 January 1998). The impressive sales figures were partially due to a prescient store manager who ordered extra generators 2 days before the storm hit (ibid.). Other businesses that benefit from storms include those involved in damage cleanup and restoration, such as tree services, rental stores, and electricians (Shreveport Times, 12 February 1994). With people unable to cook or travel easily, restaurants and convenience stores experience an increase in sales. Even though many people lack power, video rental stores also reap increased business (ibid.).

Some unscrupulous entrepreneurs take advantage of the situation. For example, the New York attorney general’s office charged a hardware store in Chazy, New York, with gouging after they allegedly increased the price of their generators from $780 to $1190 following the 1998 storm (Plattsburgh Press-Republican, 21 January 1998). Stores in Gouverneur and Pulaski (both in New York) were also charged with gouging; one store allegedly sold four C-sized batteries for $44 (Watertown Daily Times, 14 January 1998). In the aftermath of the 1994 storm, a hotel owner in Jackson, Mississippi, allegedly quadrupled
the nightly room rate (Clarksdale Press Register, 16 February 1994). Nonetheless, while allegations of gouging generate dramatic headlines and ostentatious pronouncements from politicians, these incidents were the only ones reported by the press. This suggests that the vast majority of businesspeople behave ethically.

Several business sectors suffer disproportionate losses due to ice storms. Agricultural losses can be tremendous. Because of the 1998 ice storm, 30% of the 20 500 dairy cows in Clinton County, New York, contracted mastitis (an infection of the udder) because they were not milked, and another 6% died (Plattsburgh Press-Republican, 24 January 1998). Even a healthy cow that is not milked within a 36-h interval will stop producing milk for about 10 months, causing long-term financial loss (ibid.). DeGaetano (2000) reported the economic costs of this storm to be $34–$44 million for the New York State dairy industry. He also noted that losses to the maple syrup industry, for just that year alone, were estimated at $9–$13 million in the state (ibid.). The 1994 storm devastated 2500–2800 ha (6000–7000 acres) of pecan orchards in Mississippi; this area produced about half of the state’s annual production (Clarksdale Press-Register, 19 February 1994). Local experts predicted that it would take 8–10 yr for yields to recover to prestorm levels (ibid.).

Other trees suffer large amounts of damage as well. The Mississippi Forestry Commission estimated that $1.3 billion in damage occurred because of the 1994 ice storm (Clarksdale Press-Register, 19 February 1994). The 1998 ice storm severely damaged forests from northern New York to Maine. Nonetheless, area foresters commented that while the damage was unsightly and some trees would die, natural forests regularly experience disturbances; thus, negative long-term consequences were unlikely (St. Johnsbury Caledonian-Record, 17 January 1998; Burlington Free Press, 18 January 1998). [In the years since then, some researchers have noticed long-term consequences such as reduced stem growth (Pisaric et al. 2008) or changes in species composition (Rhoads et al. 2002).] Urban trees also fare poorly, in part because their crowns are larger and their branches more horizontally oriented. An estimated 20%–25% of trees were lost in Burlington, Vermont, because of the 1998 ice storm (Burlington Free Press, 18 January 1998).

One final impact of ice storms is personal injury. Besides the injuries like carbon monoxide poisoning and electrocution, which are associated with power failures, people are injured from slips and falls (Cullman Tribune, 1 February 1951), falling tree limbs or bricks (Memphis Commercial Appeal, 12 February 1994), and heart attacks from trying to clear ice or snow (Texarkana Gazette, 2 February 1951). Reports of such incidents are usually only mentioned as part of stories about overwhelmed hospital emergency rooms (such as in Buffalo, New York, following a snowstorm in 2006; Buffalo News, 15 October 2006) or in general reports about an ice storm’s aftermath. Counting injuries from ice storms is a tricky process because slip-and-falls, carbon monoxide poisoning, heart attacks, and other injuries may not always be reported. For example, Storm Data lists only 17 injuries from the 1994 ice storm (even though more were reported in the newspapers studied; see earlier section), and fails to note the hundreds of people who sought treatment for carbon monoxide poisoning or other injuries. The point of this discussion is not to criticize Storm Data, but to illustrate the challenges of collecting quantitative death and injury data for events like ice storms, where many deaths and injuries occur well after the hazardous weather has ended.

### d. Relationship with other hazards

One research question in this study concerned the relationship of ice storms to other hazards. In most cases, the impact is small. While some areas (e.g., Bristol, Tennessee/Virginia, 1951; Lowville, New York, 1998) experienced flooding in association with an ice storm, these places did not have substantial icing. In another example, Portland, Maine, experienced snow but no ice with the 1886 ice storm. Thus, even though an ice storm may be associated with multiple meteorological hazards, most places experience just one or two hazards to a significant degree.

There are two exceptions, however. First, the relationship between extreme cold and ice storms is worth exploring. Ice storms that are followed by prolonged periods of cold weather, such as the 1951 or 1998 storms, are associated with longer cleanup periods and more problems with fire and hypothermia. Part of this is because the ice lasts longer; one set of researchers found more than 0.5 in. of ice was found on trees in New Hampshire 3 weeks after the 1998 storm ended (Jones and Mulherin 1998). Ice and wind also interact. There is a large and deep pool of studies that have examined this phenomenon (Kuroiwa 1965; Jones 1998; Makkonen 1998), but the interaction of ice and wind was almost never discussed in news accounts of the storms studied. The author speculates that perhaps most wind occurs with the storm itself, and storms are often followed by either cold, dry Arctic air masses with weak wind
fields or by warmer air that quickly melts the ice away. Nonetheless, if cold weather causes the ice to persist, later storms can wreak havoc. Four days after the first 2000 ice storm, bitter cold and winds gusting to 30 mph slowed utility efforts to clean up in Arkansas (Arkansas Democrat-Gazette, 18 December 2000). That said, the utility companies did not blame the winds for any additional line failures; they indicated that the problems arose from poor working conditions (ibid.).

e. Reducing utility disruption

Since electrical power losses are the primary impact of ice storms, the impacts of ice storms can be reduced by having utility companies reduce the risk of power losses. Many news reports included “question and answer” style interviews with utility representatives about methods to reduce the impacts. The author also spoke with several utility workers and managers in upstate New York to gain additional insight. Utilities can reduce the impacts of ice storms through aggressive tree trimming, line burial, and improved public relations. Unfortunately, none of these ideas provides a cure-all.

Utility companies annually spend millions of dollars trimming tree limbs away from power lines. Central Maine Power, for example, spent $10.3 million in 1997, more than double the $4.7 million spent in 1993, yet this was insufficient when the 1998 ice storm occurred (Portland Press Herald, 16 January 1998). National Grid, in upstate New York, also spends millions of dollars every year (T. Phelan 2007, personal communication).

Although tree-trimming programs can reduce the impacts of ice storms, aggressive programs lead to complaints from the general public. Following the 1998 ice storm, the Plattsburgh Press-Republican editorial board praised the aggressive tree-trimming program of the municipal electrical utility for reducing the disruption caused by the storm. But the board noted that homeowners on Grace Street interfered with tree trimming during the previous summer, and claimed that this action caused the street to be among “the worst hit and last restored” (Plattsburgh Press-Republican, 26 January 1998). Plattsburgh residents are not the only people to complain about tree trimming. When discussing customer complaints following the 1994 ice storm, SWEPCO and Memphis LG&W spokespersons noted that the majority of complaints under normal conditions relate to their tree-trimming program (Memphis Commercial Appeal, 19 February 1994). Central Maine Power, according to a utility spokesman, trims less aggressively along roadways to avoid the “huge protest” that would occur if they trimmed as aggressively as they do around transmission lines (Portland Press Herald, 16 January 1998).

Finally, as this article was being revised, Indiana-Michigan Power was implementing a newly aggressive tree-trimming program in Muncie and other portions of central Indiana. Although a severe ice storm had affected the area just 4 yr earlier, residents became so angry that some considered lawsuits, and the Indiana Utility Regulatory Commission opened an investigation in response to residents’ complaints (Muncie Star Press, 11 July 2009). Utility company representatives defended their actions by claiming that the aggressive program had resulted in a 70% reduction in power losses since 2005 (ibid., 25 June 2009).

Outside of these examples, it is difficult to objectively measure the value of utilities’ tree trimming. In other parts of upstate New York, National Grid trims trees along its 58 000 km (36 000 miles) of power lines on a 5–6-yr rotation (Niagara Mohawk 2002).1 According to Chief Arborist B. Skinner (2007, personal communication), some areas are trimmed even more often. He notes that factors such as outage history, vegetation, terrain, and weather affect how often trees in a given area are trimmed. Similar to how streets are plowed during a snowstorm (see Call 2004, p. 67), tree-trimming knowledge is largely esoteric and governed by the collective experience of workers rather than scientific research findings. Thus, it is unclear if a 5-yr cycle is sufficient or whether workers are aggressive enough in trimming. An aggressive tree-trimming program does not necessarily solve power problems either. Following the 1994 storm, SWEPCO noted that problems resulted not just from falling limbs but also from trees well outside the utility right-of-way falling onto the lines (Shreveport Times, 16 February 1994). An analyst with the Maine Public Utilities Commission remarked that the magnitude of the 1998 storm was so extreme that even a modest increase in tree trimming by Central Maine Power would not have made much of a difference (Portland Press Herald, 16 January 1998). Counterclaims about the adequacy of any tree-trimming program are difficult to validate. While cuts in the tree-trimming budget were blamed for problems in Nashville, Tennessee, following the 1994 storm, the company blamed the problems on whole trees (rather than branches) falling onto the lines—something beyond their control (Nashville Tennessean, 19 February 1994).

Utility companies could reduce the impact of ice storms by burying lines underground, but the companies argue that this strategy is not cost-effective. Paul Sedano, the commissioner of the Vermont Public Service Department,

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1 Niagara Mohawk was purchased by National Grid in 2000, and in 2005 National Grid began phasing out the Niagara Mohawk name.
noted that the cost of burying a 3-km power line in the previous summer (to improve a view of Lake Champlain) was about 2–3 times more than simply rebuilding the line (Burlington Free Press, 19 January 1998). A spokesman for Vermont’s largest utility claimed that the cost of installing a line underground ranges from $24 to $200 per foot, which is substantially higher than the $8–$20 cost to install one above ground (ibid.). According to the spokesperson, the added increase in cost is because of expensive switches; some prices increase from $300 to $15 000 because of the need for weatherization (Burlington Free Press, 19 January 1998). Former emergency planning manager T. Phelan (2007, personal communication) for Niagara Mohawk Power (now National Grid) notes that specialized equipment and training are necessary to splice line underground, and in northern New York State, bedrock near the surface is another problem. Memphis LG&W spokespeople noted that repair costs to underground lines are much greater than those for aboveground lines (Memphis Commercial Appeal, 20 February 1994). One spokesperson remarked that Palo Alto, California, began burying lines in 1966 but the project remained less than half finished nearly 30 yr later (ibid.).

Utility customers are more likely to accept long power outages when companies provide accurate restoration estimates and adequate customer relations. This also helps people more easily cope with power losses. Following the 1994 ice storm, residents around both Memphis and Nashville lost power for similar lengths of time (see Fig. 1). The Nashville Electric Service, while criticized by some customers, escaped widespread disapproval by providing realistic expectations and meeting them (Nashville Tennessean, 16 February 1994). By contrast, Memphis LG&W underestimated the number of customers without power and then added fuel to the fire with various customer service problems (Memphis Commercial Appeal, 19 February 1994). In north Little Rock, angry residents without power complained about being uninformed following the first December 2000 storm (Arkansas Democrat Gazette, 18 December 2000). Residents near Shreveport complained about not being able to reach SWEPCO representatives following the 1994 storm and of overly optimistic power restoration projections. They also accused the company of insufficient tree trimming (Shreveport Times, 16 February 1994 and 20 December 2000). Simultaneous complaints about customer service and tree trimming are not surprising actually, because a company slashing its tree-trimming budget is probably not investing in hiring and training customer service representatives. Thus, improvement in restoration estimates and public relations represents a relatively inexpensive technique for utility companies to reduce systematic problems with extensive aboveground infrastructure or insufficient tree trimming, although it does not solve the problems of outages. However, additional customer service representatives do improve the accuracy of restoration estimates, since utility companies learn about power outages in part through telephone calls from customers (T. Phelan 2007, personal communication).

4. Conclusions

To summarize, newspaper and other accounts of nine catastrophic ice storms that occurred over a 118-yr period were sampled for this study. While ice storms have numerous impacts on society, the data collected suggest that the most significant effects relate to disruption of the electrical grid. Power outages can persist long after the ice has melted—up to several weeks, perhaps even a month following the most severe storms. Loss of power increases the risk of hazards such as fire and carbon monoxide poisoning, and people may be forced to abandon their homes because of a lack of heat. Ice storms also disrupt transportation and school schedules, and they cost businesses and the agriculture sector untold dollars. But, some business sectors fare relatively well, especially the hospitality and restaurant sectors.

Several significant changes in the impacts of ice storms have occurred in the past 118 yr. Power outages with recent storms are more widespread and longer lasting than those with earlier storms (see Fig. 1). The data did not point to a specific reason, meteorological or social, behind this. Because society is more reliant on electricity, people now need to be sheltered after ice storms. Secondary power-related hazards have changed; while electrocution deaths are rare now, carbon monoxide poisoning is more likely. Although transportation methods have changed, ice storms cause problems for all forms of transportation, and because of improvements in street clearing and deicing, the problems may be less serious today. It is unclear whether the impacts on agriculture and trees are worse today than in the past.

Ice storms affect urban and rural areas differently, with power typically restored much more quickly to urban areas if other factors, including accumulation amounts and competency of individual utility companies, are similar. Urban areas also experience fewer problems with transportation because highway crews clear heavily traveled roads more quickly. Finally, utilities and highway crews intentionally favor urban areas. By focusing on areas with the largest number of customers (or motorists) first, they can maximize the benefits of their labor.
**Future research that may reduce the impacts of ice storms**

When conducting this research, the author was hampered by a lack of objective freezing rain measurements for past storms. Recent developments in freezing rain measurement techniques (see Ryerson and Ramsay 2007) and the increasing availability of ice accumulation maps should ameliorate this problem for researchers studying future ice storms.

With a standardized, consistent ice observation program in place, future research into “tipping points” would greatly improve the ability of utility companies and first responders to assess damage quickly. Such tipping points may also assist meteorologists in creating better warning products. The few newspaper reports with measurements suggested that damage shifts from being isolated to widespread at around 2.0–3.0 cm of accumulation. This is in line with other researchers’ findings. Proulx and Greene (2001) found that 2.0 cm roughly corresponds to the minimal value for substantial damage to trees. Changnon’s (2003a) climatology of ice storms suggests that 2.0 cm of ice thickness would place a storm in the top 25% of ice storms for all regions of the United States. Thus, such a storm would be exceptional and likely to cause devastating damage where ice accumulates to that thickness. Of course, such tipping points may vary regionally depending on forest composition or other factors.

A study of tree-trimming practices would probably help utility companies improve them. Additionally, such research would help capture some of the knowledge lost when employees with many years of service retire—something that already concerns the industry (Kitterman and Dugan 2006). While better tree-trimming programs are no panacea, they may help lessen the effects of ice storms, a benefit for society at-large.

Finally, while risk-reducing measures like tree trimming may reduce the impacts of ice storms, it remains highly probable that electrical systems will still fail when exceptional storms occur. Thus, an approach aimed at reducing society’s vulnerability to power failures may also be beneficial. A full discussion of the merits of a vulnerability-based approach is beyond the scope of this article, but ways to reduce vulnerability may include changes in building design (e.g., increasing natural lighting) and systems design (e.g., requiring a way to manually ignite natural gas furnaces). Such an approach may reduce the need for consistent, constant electrical power, helping people better cope with ice storm catastrophes.

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