Climatic Change (2007) 84:131–139
DOI 10.1007/s10584-007-9289-5

Catastrophic winter storms: An escalating problem

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Received: 24 February 2006 / Accepted: 27 April 2007 / Published online: 3 August 2007

Abstract Winter storms are a major weather problem in the USA and their losses have been rapidly increasing. A total of 202 catastrophic winter storms, each causing more than $1 million in damages, occurred during 1949–2003, and their losses totaled $35.2 billion (2003 dollars). Catastrophic winter storms occurred in most parts of the contiguous USA, but were concentrated in the eastern half of the nation where 88% of all storm losses occurred. They were most frequent in the Northeast climate district (95 storms), and were least frequent in the West district (14 catastrophic storms). The annual average number of storms is 3.7 with a 1-year high of 9 storms, and 1 year had no storms. Temporal distributions of storms and their losses exhibited considerable spatial variability across the nation. For example, when storms were very frequent in the Northeast, they were infrequent elsewhere, a result of spatial differences in storm-producing synoptic weather conditions over time. The time distribution of the nation's 202 storms during 1949–2003 had a sizable downward trend, whereas the nation's storm losses had a major upward trend for the 55-year period. This increase over time in losses, given the decrease in storm incidences, was a result of significant temporal increases in storm sizes and storm intensities. Increases in storm intensities were small in the northern sections of the nation, but doubled across the southern two-thirds of the nation, reflecting a climatic shift in conditions producing intense winter storms.

1 Introduction

Winter storms are one of the major weather problems in the USA. They halt transportation, damage structures and property, and kill 30 to 40 persons each year. Catastrophic winter storms, defined as those causing $1 million of more in insured property losses during 1949–2003, were assessed to get a measure of the national and regional losses and to define their temporal climatology. Insured property losses include all forms of damaged property plus costs related to business problems. This 55-year period experienced 202

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catastrophic winter storms and their insured losses amounted to $35.2 billion (2003 dollars). Losses from winter storms rank high nationally among other severe storm conditions. Average annual insured losses from hurricanes, floods, or from thunderstorms rank higher than those from winter storms, but the winter storm average loss value exceeds those of hail or tornadoes.

Catastrophic winter storms have occurred in most parts of the contiguous USA. They were most prevalent in the Northeast climate district, an area where storms have undergone intensive study (Kocin and Uccellini 1990). They were least frequent in the West district but that area still experienced 14 storms during the 1949–2003 period. The nation's annual average number of storms is 3.7. Large numbers in one year included nine storms in 1979 and eight in 1996, and one year, 1995, had no catastrophic winter storms.

Catastrophic winter storms were found to be the product of three weather conditions: snow, freezing rain, and high winds. In 16 percent of the storms, rapid melting of the snow and ice led to damaging floods within a few days of the storm.

The data for this study were provided by the property insurance industry which has recorded all forms of catastrophic damaging events since 1949 (Insurance Information Institute 1988). For each event causing $1 million or more in insured property losses, the industry recorded the date/s, the amount of loss, the states where losses occurred, and the cause of loss. The loss values have been carefully adjusted for factors influencing losses over time (Changnon and Changnon 1998). A major property-casualty insurance firm systematically analyzed in each year since 1949 the historical catastrophe data, to update the past catastrophe values to match the current year conditions. This resulted in a database allowing the company to perform, at any time, unbiased comparisons of current catastrophe losses with those in past years, and to assess shifting risk of losses in all or parts of the nation. This firm provided their adjusted catastrophe data base, allowing a meaningful study of storms over time, all adjusted to 2003 monetary values.

This annual loss adjustment effort was a sizable and complex task requiring assessment of each past event. Three adjustment calculations have been made to the original loss value for the locations of each catastrophe. One adjustment corrected for time changes in property values and the cost of repairs/replacements, and hence, this also adjusted for inflation. The second adjustment addressed the relative change in the size of the property market in the areas affected by the catastrophe using census data, property records, and insurance records. This act adjusted losses for shifts in the insured property between the year of a given storm's occurrence and the updated year (2003 in this study). The third adjustment was based on estimates of the relative changes in the share of the total property market that was insured against weather perils in the loss areas, done by using insurance sales records.

These three adjustments were used to calculate a revised monetary loss value for each catastrophe so as to make it comparable to current year values. Thus, adjustments made in 2003 for all past catastrophes dating back to 1949 allow a comparative temporal assessment of their losses. For example, a storm-related loss in Pennsylvania during 1953 was adjusted by the insurance experts upwards by a factor of 31.3, whereas a 1953 catastrophe loss in Oregon, where coverage and other conditions like structural design for snow loads differed from those in Pennsylvania, was adjusted by 37.8. In the resulting loss values, the loss from a catastrophe whether it occurred in 1949, 1973, or 1989 could be assessed in the terms of 2003 conditions. The adequacy of this adjustment method was examined using regional comparisons involving population data to address the demographic shifts over the last half of the twentieth century when considerable movement and growth of population occurred in the nation's western and southern sections, and was found to adequately measure on-going changes (Changnon and Changnon 1998).

The cause of loss in the 52-year insurance data base was used to identify those catastrophes caused principally by winter storms. Assessment of the cause/s of loss of the 202 catastrophic winter storms showed that snow and freezing rain occurred in all events. Snow was the primary factor in 111 storms; freezing rain was the primary condition in 40 storms; and the these two conditions together were the prime cause in 51 storms. High damaging winds accompanied 149 of the storms, and flooding was associated with 33 storms.

An assessment by the National Academy of Sciences of all forms of loss data for the nation's natural hazards identified the insurance catastrophe data as the nation's best available loss data (NRC 1999). Analysis of insured and uninsured losses from a variety of severe storms found that on average, insured losses account for 90% of all property losses in the nation (NRC 1999).

2 National storm characteristics

The average loss per storm was $174 million (2003 dollars). The highest single storm loss was $1.82 billion from the Superstorm of 11–14 March 1993 (Kocin et al. 1995), and the lowest storm loss was $6.2 million on 8 January 1980. The five highest and lowest storm losses are listed in Table 1. The lowest ones are all 1-day events and one-area occurrences, whereas the top five catastrophes are all multiple day events with losses across two or more climate districts. These results indicate that the magnitude of loss is a function of a storm's duration and size.

Storm sizes varied from 1 state up to 29 states with an average of 7.1 states per storm. Nine storms occurred in only one state and these events occurred in New York, Oregon, Michigan (two times), Texas, California (three), and Illinois. A storm on 19–21 January 1985 produced losses in 29 states (Fig. 1a), and the record highest loss storm on 11–14 March 1993 produced losses in 21 states (Fig. 1b). The correlation coefficient determined for storm sizes and amounts of loss was 0.82. For each storm, the areas of the states with loss were calculated.

The temporal distribution of the 202 storms during 1949–2003 is shown in Fig. 2. The peak 5-year period value was 26 storms occurring in 1959–1963 and in 1964–1968, with a secondary peak of 24 storms in 1979–1983. The trend of storm incidences for 1949–2003 is downward with a statistical significance of 5%. During the last 20 years (1984–2003) there were 59 storms, as compared to 77 in the previous 20 years. In contrast, the temporal distribution of storm losses (Fig. 2) has a significant (10% level) upward trend, reaching a peak of $5.3 billion in 1999–2003. Comparison of the frequency and loss distributions

Table 1 Winter storms causing the five highest and lowest losses during 1949–2003

Highest			Lowest		
Loss, $ billions	Date	Climate districts	Loss, $ millions	Date	Climate districts
1.820	3/11–14/93	S, SE, NE, C	6.2	1/8/80	NW
1.605	4/4–8/03	S, C	6.4	1/13/76	C
1.398	12/17–18/83	NW, WNC, ENC, SW	7.6	1/31/79	W
1.226	1/29–31/51	S, C, NE	8.3	1/20/83	SE
1.124	2/5–7/78	NE, C	8.4	1/25/71	ENC

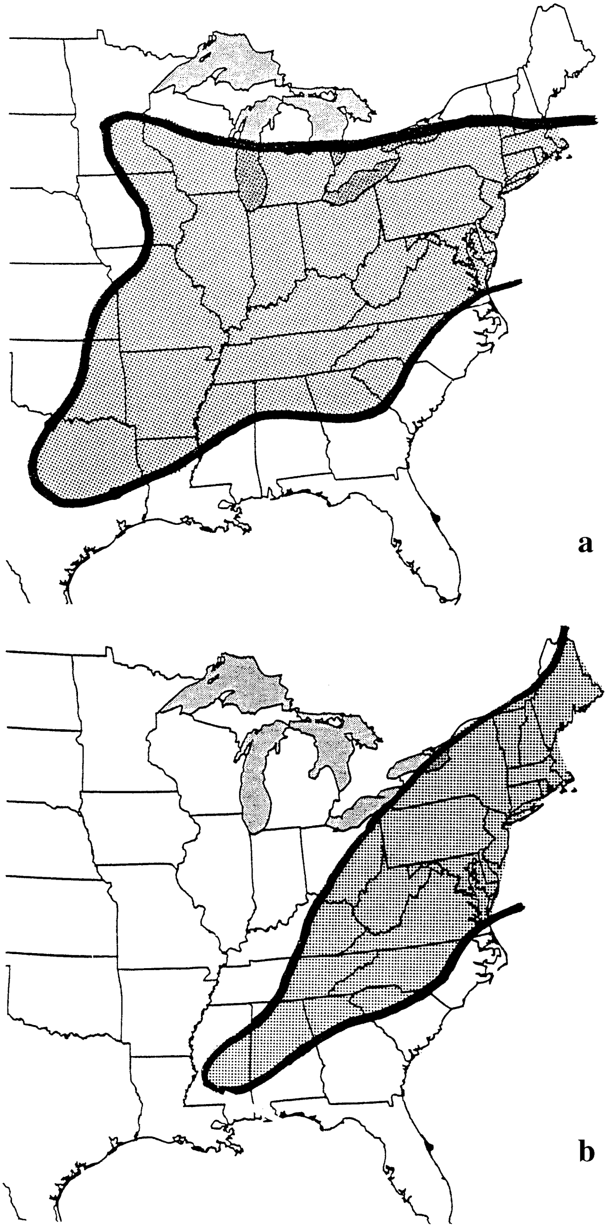

Fig. 1 The two largest winter storms during 1949–2003: **a** storm on 19–21 January 1985, and **b** storm on 11–14 March 1993

reveals poor trend agreement except for 1979–1983 when both had a relatively high value, and in 1969–1973 when both had low values.

The distribution over time of average storm sizes (Fig. 3) shows that the smallest values occurred in early years (1954–1963) with an average of five to six states per storm. Storm sizes increased over time, reaching a peak of 10 states in 1994–1998. The 55-year linear trend of storm sizes was upward and statistically significant (2%). The upward trends in

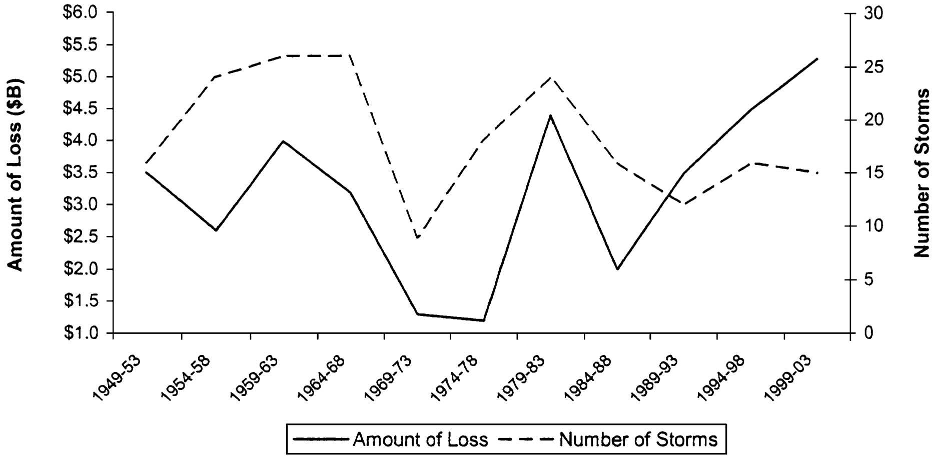

Fig. 2 Temporal distributions of the 202 winter storms during 1949–2003 and their losses that totaled $ 35.2 billion

storm sizes and losses, given the downward trend in storm frequencies, indicates a marked increase over time in storm intensity.

A measure of storm intensity was calculated for storms in each 5-year period for the climate districts and nation. The average loss per storm in a 5-year period was divided by the period's average storm size, as measured by the sizes of the states where loss was reported. This resulted in an intensity measure based on the average loss per state per storm. The resulting 5-year average intensity values for the nation (Fig. 3) show the lowest value occurred in 1974–1978 ($8.4 million) followed by an increase to a peak value of $40.2 million in 1999–2003. The distribution has a marked upward trend significant at the 1% level.

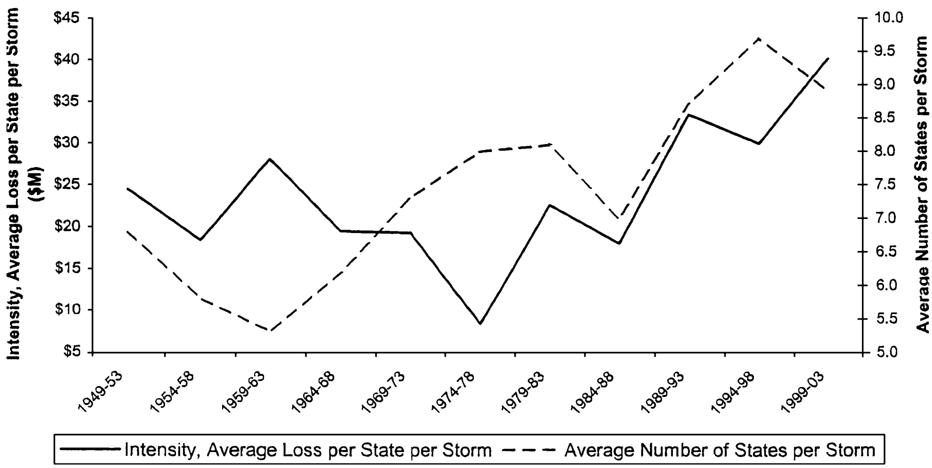

Fig. 3 Temporal distributions of the 5-year average storm sizes and the intensity values for 1949–2003

3 Regional storm characteristics

The frequency of winter storm catastrophes in the nation's nine climate districts (Fig. 4) shows a maximum of 95 storms in the Northeast, with other high values in the Central, Southeast, and South districts. A study of the impacts of snowstorms in the northeast during 1950–2003 identified 66 bad storms (Kocin and Uccellini 2004), but only 32 of these storms were also winter storm catastrophes. The other 34 storms identified as being severe did not produces losses amounting to $5 million. Call (2005) assessed major winter storms that impacted cities in upper New York state and only a third of those between 1950 and 2003 qualified as catastrophic winter storms. These regional findings reveal many storms can be intense and damaging on a local scale but their total damages do not reach the multi-million dollar level of catastrophes.

When a storm caused losses in two or more districts, a count of an occurrence was made in each district; hence, the sum of the values on Fig. 4 exceeds the storm total of 202. As expected, the lowest frequencies occurred in the far western districts. Assessment of the state frequencies of storms revealed that New York (83 storms) and Pennsylvania (77) experienced the most during 1949–2003. Other states with many storm incidences included Massachusetts (67), Connecticut (65), New Jersey (61), Maryland (51), and Virginia (46). States with few storms included Arizona and Idaho, each with only three storms.

The regional distribution of the total losses (Fig. 4) shows a high of $10.6 billion in the Northeast (NE), followed by $6.6 billion in losses in the Southeast (SE), and $6.3 billion in the Central (C) district. The eastern half of the nation, which includes five climate districts, experienced storm losses totaling $31.3 billion, or 88% of the nation's total losses during 1949–2003.

Temporal distributions of the regional occurrences of winter storms (Fig. 5) differed considerably. The NE distribution over time is very similar to that of the nation (Fig. 2) reflecting the impact of the district's large incidence of winter storms. The temporal frequency of the *C* values is very different than that in the NE, although both have low values in 1969–1973. Except for a low value in 1969–1973, the numerically lower temporal distribution of storms in the South (*S*) district paralleled those of the NE in the early years (1949–1979) but deviating thereafter. The South distribution is markedly different from those of the *C*. Frequencies in the S peaked in 1984–1988 when those in the C and NE were low, and the *S* values were low in 1994–2003 when those in the C and NE were relatively

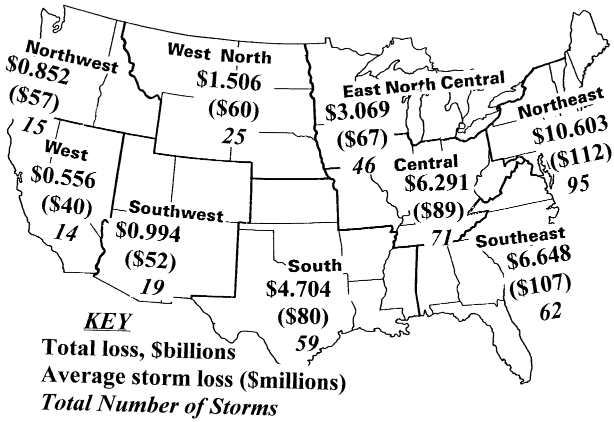

Fig. 4 Climate district values of total losses for 1949–2003, the average loss per storm, and total number of storms

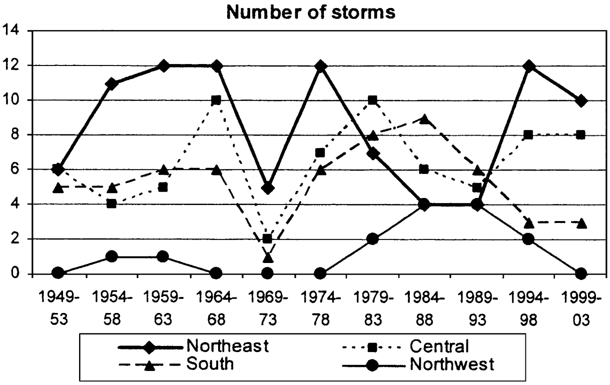

Fig. 5 Temporal distributions of the number of winter storms for selected climate districts, 1949–2003

high. Storms in the West climate district were infrequent in most 5-year periods, but the region's values became relatively high during 1984–1993, a time when values in the other three districts (Fig. 4) were all relatively low. These regional differences reveal that factors causing major winter storms shifted regionally over time and seldom produced nationwide effects on storm incidences. Numerous studies of synoptic weather conditions associated with winter storms confirm these regional storm differences over time (Branick 1999; Rauber et al. 2001; Zelinski 2002).

The time distributions of storm losses for selected regions (Fig. 6) reveal their distributions are also quite different. For example, the NE losses peaked in 1959–1963 and again in 1994–1998; C district losses peaked in 1999–2003; and S losses maximized in 1999–2003 and also in 1984–1988. The Northwest district losses were quite low during the 1949–1978 period then peaked in 1979–1983, and values from 1984 to 2003 were notably higher than those before 1978.

Losses were relatively high during the recent 15 years (1989–2003) in the SE, S, SW, and W districts. In this period, values in the NE, East North Central (ENC), and West North Central (WNC) were relatively low. This north–south difference could be partly due to the more rapid population growth and density of structures in the south, southwest and western USA during the last 20+ years, creating more vulnerability for damages from storms. The temporal distributions of storm sizes showed all districts except those for the NE, ENC, WNC, and NW had grown sizably, 20 to 90%, from the 1950s to the 1990s. In this time

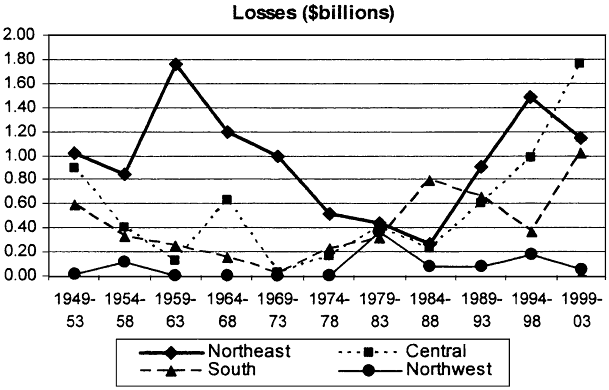

Fig. 6 Temporal distributions of the amount of winter storm losses for selected climate districts, 1949–2003

Table 2 Temporal changes in regional winter storm intensities, as measured by the average dollar loss per state per storm (2003 dollars)

Average loss, $ millions			Difference as percent	
District	1964–1983	1984–2003	Difference	Of 1964–1983 value
Northeast	19.0	28.5	+9.5	+50
Southeast	14.4	30.2	+15.8	+110
Central	16.7	30.0	+13.3	+80
South	11.5	45.0	+33.5	+291
East North Central	18.5	11.3	−7.3	−39
West North Central	22.5	12.2	−10.5	−46
Southwest	10.5	23.0	+12.5	+120
West	9.3	25.0	+15.7	+169
Northwest	18.0	23.0	+5.0	+29

period, the storm sizes in the four northernmost districts increased, but by only 5 to 15%. States with sizable time increases in storm occurrences existed in the south-central USA. States with storm occurrences in 1984–2003 that were more than 100% greater than those in the prior 20 years (1964–1983) included Texas (220%), Oklahoma (105%), Tennessee (100%), Virginia (130%), and North Carolina (110%). This suggests a transition in storm intensity (losses and sizes), and that storm intensities grew substantially over time in the southern two–thirds of the USA. Assessment of the time distribution of a primary winter-storm producing synoptic weather condition, Arctic fronts, revealed a temporal shift since 1980 to more southerly positions in the winter seasons.

Most climate district intensity values had time distributions similar to the national distribution (Fig. 3). However, the ENC and WNC districts had slight temporal decreases in storm intensity. Table 2 presents a comparison of the regional intensity values for the recent 20 years (1984–2003) and those of the preceding 20 years (1964–1983). Increases over time ranged from 29 to 291%, with the largest values (>100%) in the SE, S, SW, and W districts. The ENC and WNC had decreases of 39 and 46%, respectively, and the NE and NW districts had the smallest increases in intensity over time. Collectively, these findings reveal that strong storm-producing conditions having shifted southwards over time, greatly increased the intensity of winter storms in the southern two-thirds of the nation.

4 Summary

The total insured property losses from the 202 catastrophic winter storms during 1949–2003 was $35.2 billion, and this created an average storm loss of $174 million. Catastrophic winter storms were caused by a mix of heavy snow and freezing rain, and often were accompanied by high damaging winds. Catastrophic winter storms occurred in all parts of the nation, but were concentrated in the eastern half where 88 percent of all storm losses occurred.

Temporal distributions of storms and their losses exhibited considerable spatial variability across the nation. For example, when storms were very frequent in the Northeast, they were infrequent elsewhere, a result of regional shifts in storm–producing synoptic weather conditions over time. The 1949–2003 time distribution of the 202 storms had a significant downward trend, whereas the storm losses had an upward trend for the 55-year period. Significant temporal increases in storm losses, storm sizes, and storm intensity have occurred in the United States. The national increase over time in losses, given the decrease in storm incidences, was a result of the increases over time in storm sizes and intensities. The marked temporal increases in storm sizes and storm intensities were greatest across the southern two-thirds of the nation.

These findings agree with expectations of winter storm conditions under global warming (National Assessment Synthesis Team 2001). The temporal shifts in storm size and intensity during 1949–2003 were in agreement with those found in a study of snowstorms, as defined on snowfall amount and duration (Changnon et al. 2006).

Acknowledgment This research was funded by a grant from National Oceanic and Atmospheric Administration and the National Aeronautics and Space Administration, as part of the Climate Change Enhanced Data Set Project, NA16GP1585. The views expressed herein are those of the author and do not necessarily reflect the views of NOAA or NASA.

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