A SNOWFALL IMPACT SCALE DERIVED FROM NORTHEAST STORM SNOWFALL DISTRIBUTIONS

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A Northeast snowfall impact scale is presented to convey a measure of the impact of heavy snowfall in the Northeast urban corridor, a region that extends from southern Virginia to New England.

Meteorological impact scales have been devised to relate wind speeds associated with tornadoes (Fujita 1971) and hurricanes (Saffir 1977) to structural damage. These scales provide benchmarks with which to assess the destructive potential of individual storms and to communicate that potential to the public. In the case of tornadoes, that assessment is typically made following the storm's occurrence. In the case of hurricanes, wind measurements are made during the storm's lifetime, allowing an assessment during the evolution of the storm. Thus, the scales can help in decision-making processes involved in either evacuation (in the case of hurricanes), evaluating building codes, or performing other actions necessary to save lives and mitigate potential property loss, as well as providing a historical perspective.

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Snowstorms are complex phenomena whose impact can be affected by a great many factors, including a region's climatological susceptibility to snowstorms, snowfall amounts, snowfall rates, wind speeds, temperatures, visibility, storm duration, topography, and occurrence during the course of the day, weekday versus weekend, and time of season. With such complexity, quantifying the impact of snowstorms with a scale that can be easily conveyed to the general public is difficult. Until recently, relatively little has been done to classify major winter storms.

Hart and Grumm (2001) use a method based on a normalized departure from climatology of tropospheric values of height, temperature, wind, and moisture to rank extratropical and tropical weather events, including Northeast snowstorms, computed from the "reanalysis dataset" over a 53-yr period (Kalnay et al. 1996). Using the Hart and Grumm methodology, the highest-ranked storm (most climatologically anomalous) was the January 1956 "Great Atlantic Low" (Ludlum 1956; also see chapter 11 of Kocin and Uccellini 2004b) while the March 1993 Superstorm ranked third in the 53-yr study period.

Zielinski (2002) also utilizes a synoptic climatology, but focuses on major East Coast snowstorms during a 30-yr period, 1955–85 (Kocin and Uccellini

Table 1. Estimated area ($\times 10^3$ mi^2) and population (in millions, from the 1999 census) affected by snowfall accumulations of 10 in. (25 cm) and greater during 30 Northeast snowstorms within the 13-state area defined in the text.

Date	10" area	10" pop
18–19 Mar 1956	28,588	32.8
14–17 Feb 1958	126,004	53.8
18–21 Mar 1958	62,103	40.7
2–5 Mar 1960	133,734	53.9
11–13 Dec 1960	74,528	48.0
18–21 Jan 1961	62,260	43.0
2–5 Feb 1961	112,171	50.3
11–14 Jan 1964	110,258	48.8
29–31 Jan 1966	122,452	23.8
23–25 Dec 1966	83,389	18.1
5–7 Feb 1967	50,896	44.8
8–10 Feb 1969	66,440	31.2
22–28 Feb 1969	48,370	10.3
25–28 Dec 1969	131,351	25.0
18–20 Feb 1972	140,869	24.5
19–21 Jan 1978	161,583	50.9
5–7 Feb 1978	120,490	47.6
17–19 Feb 1979	56,923	31.5
6–7 Apr 1982	76,839	22.5
10–12 Feb 1983	111,129	51.4
21–23 Jan 1987	132,772	34.9
25–26 Jan 1987	38,008	11.5
22–23 Feb 1987	28,276	16.6
12–14 Mar 1993	212,594	59.9
8–12 Feb 1994	54,951	39.0
2–4 Feb 1995	97,971	29.9
6–8 Jan 1996	137,918	56.6
31 Mar–1 Apr 1997	32,021	13.0
24–26 Jan 2000	59,567	19.7
30–31 Dec 2000	56,484	28.0

1990) and several historic and recent storms to devise a scale for winter cyclones. As is the case for Hart and Grumm, Zielinski's scale relies mostly on the meteorological attributes of the winter storms. The low pressure depth, pressure gradient, deepening rates, and storm duration provide the basis for an instantaneous, or local measure, of the storm intensity. While the Zielinski scale provides a measure of the intensity of the low pressure system, this measure may or may not relate to snow impact either at a local or regional level. The scale also does not necessarily provide a measure of the impact that the storm has on the population centers in the United States or Canada during its entire lifetime.

For example, the highest-rated category-5 storms in Zielinski (2002) include one in eastern Canada on 1200 UTC 18 December 2000, a cyclone that had little effect or impact on the major population centers along the East Coast of the United States [e.g., there is no mention of this storm by the National Climate Data Center (NCDC) 2001]. The second-highest-rated storm in Zielinski (2002), the storm of 1200 UTC 21 January 2000, was a rapidly deepening cyclone, but its impact in the United States and Canada was also relatively small. The greatest intensity for this storm occurred over the Atlantic Ocean, well east of New England. There are likely many more examples of oceanic Atlantic cyclones that are more intense (i.e., deeper, larger pressure gradients, implied higher wind speeds) and have a minimal impact on the coastal population centers.

An updated synoptic climatology of the major Northeast snowstorms presented by Kocin and Uccellini (2004a,b) emphasizes that each storm is largely characterized by a unique, but extensive distribution of snowfall that occurs within the Northeast urban corridor. Furthermore, the synoptic climatology illustrates that snowfall amounts do not necessarily correlate with the intensity of the surface low pressure system, associated pressure gradients (as demonstrated by the weak surface low associated with the February 2003 "Presidents' Day II" Snowstorm) and wind characteristics.

In this article, a Northeast snowfall impact scale (NESIS) is presented. The NESIS differs from the Fujita tornado scale and the Saffir–Simpson hurricane scale in that NESIS focuses on the amount of snow that falls, mapped onto the population density that experiences the snow, rather than focusing on wind as the major impact agent. Furthermore, NESIS values are computed directly and provide an objective measure of the impact of a snowstorm on the population distribution.

The definition of NESIS, the means by which it is derived, and the equation calibrated for the northeast United States, are defined in the next section. The application of the NESIS equation to 30 major Northeast snowstorms from 1950 to 2000 (Kocin and Uccellini 2004a,b) is presented in the section titled "Generating NESIS values for the entire storm snowfall distribution." In the section titled "Application of the NESIS to other cases," NESIS is further evaluated, utilizing (i) an additional 30 cases that were considered by Kocin and Uccellini to be either "moderate" snowstorms or "interior" snowstorms in the northeast United States; (ii) four historic Northeast snowstorms; and (iii) six recent cases, which include the snowstorm of 4–6 March 2001 and several snowstorms during the winter of 2002/03, including the 15–18 February 2003 Presidents' Day II Snowstorm. A categorical ranking system is introduced in the section titled "Categorizing NESIS values" and is applied to all 70 storms. A brief assessment of the NESIS during the course of the twentieth century, reflecting the possible effects of population changes on the scale, are addressed in the section titled "The effect of population change between 1900 and 1999 on NESIS values." The summary is provided in the last section.

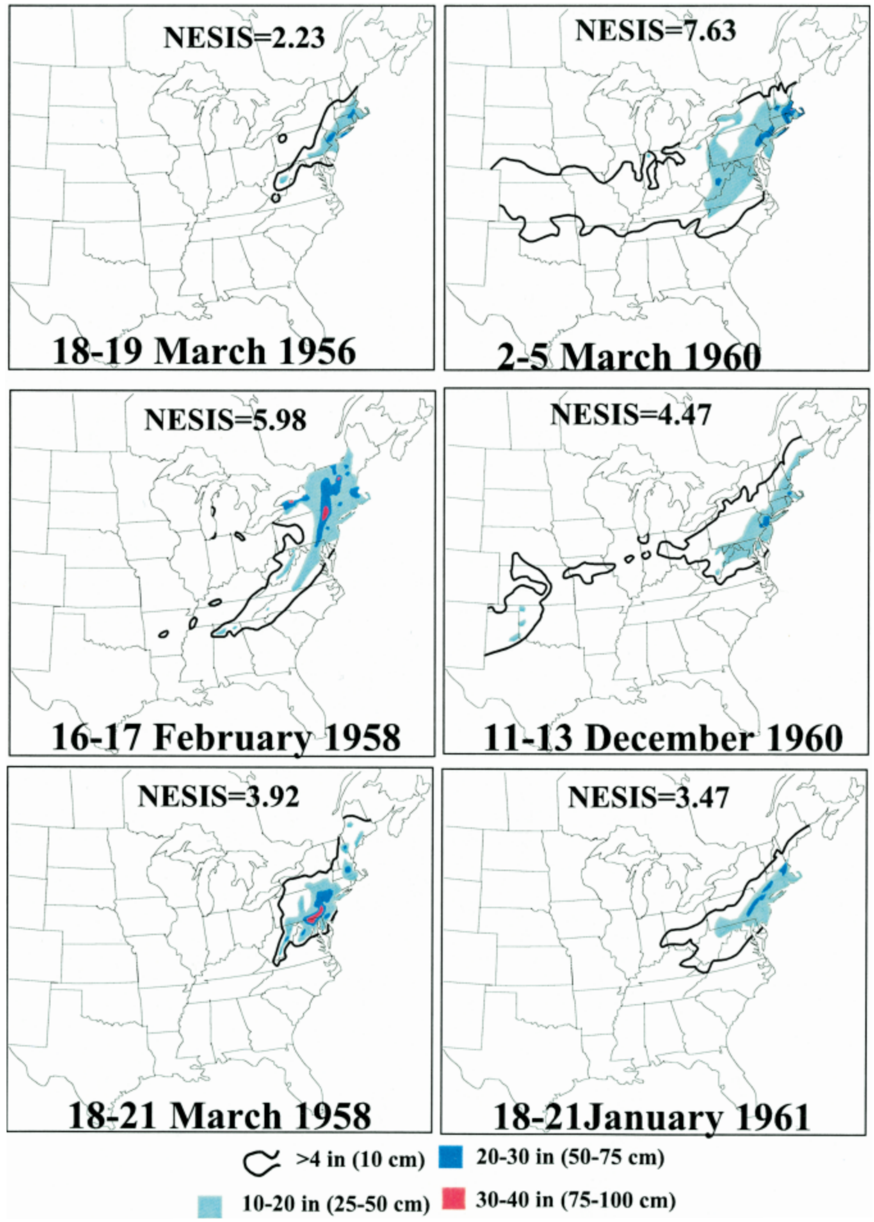

Fig. 1a. Storm snowfall in excess of 10 cm (solid line); > 25 cm (light blue); > 50 cm (dark blue); and > 75 cm (red) for six of the 30 snowstorms used to generate the NESIS scale, with corresponding NESIS value (using the 1999 census). The other 24 storms are shown in Figs. 1b–1e on following pages.

DESCRIPTION. Thirty snowstorms described in chapters 3 and 4 of Kocin and Uccellini (2004a) and chapter 10 of Kocin and Uccellini (2004b) form the basis for NESIS. These 30 snowstorms were all high-impact snowstorms that occurred in the Northeast urban corridor (Fig. A1), characterized by snowfall distributions with large areas of 10-in. (25-cm) accumulations and greater that affected large numbers of people (Table 1; see Kocin and Uccellini 2004a, Figs. 3-2a,b). The NESIS makes use of Geographic Information Systems (GIS) technology, which facilitates the digital mapping of snowfall distribution and population density and takes the following form:

$$\text{NESIS} = \Sigma_n^x \,[n(A_n/A_{\text{mean}} + P_n/P_{\text{mean}})]. \qquad (1)$$

yr from 1950 to 2000 (Table 1). Here P_n is the population (in 1999 census figures) estimated to live within the snowfall area A_n (Table 1), and P_{mean} is the mean population for the 30 cases (also computed with 1999 census figures) within the area of snowfall greater than 10 in. (25 cm). Area and population are estimated in the GIS system by utilizing a county database and selecting all counties in which *at least half* of the county is analyzed to lie within a given snowfall interval (i.e., 4 in. or greater, n = 0.4; 10 in. or greater, n = 1; 20 in. or greater, n = 2; etc.).

The scale is calibrated by first computing A_{mean} and P_{mean} for 10-in. (25-cm) snowfall accumulations within the 13-state area from West Virginia–Virginia northeastward to Maine for each of 30 cases (Table 1; also see Kocin and Uccellini 2004a, Figs. 3-2a,b). Final values of NESIS are then computed for the total snowfall distribution east of the Rocky Mountains (Fig. 1, Table 2). These steps recognize that the basis for the application of NESIS is to quantify the impact of heavy snowfall on the Northeast urban corridor, while also accounting for the total snow history associated with these storms as they track across the United States.

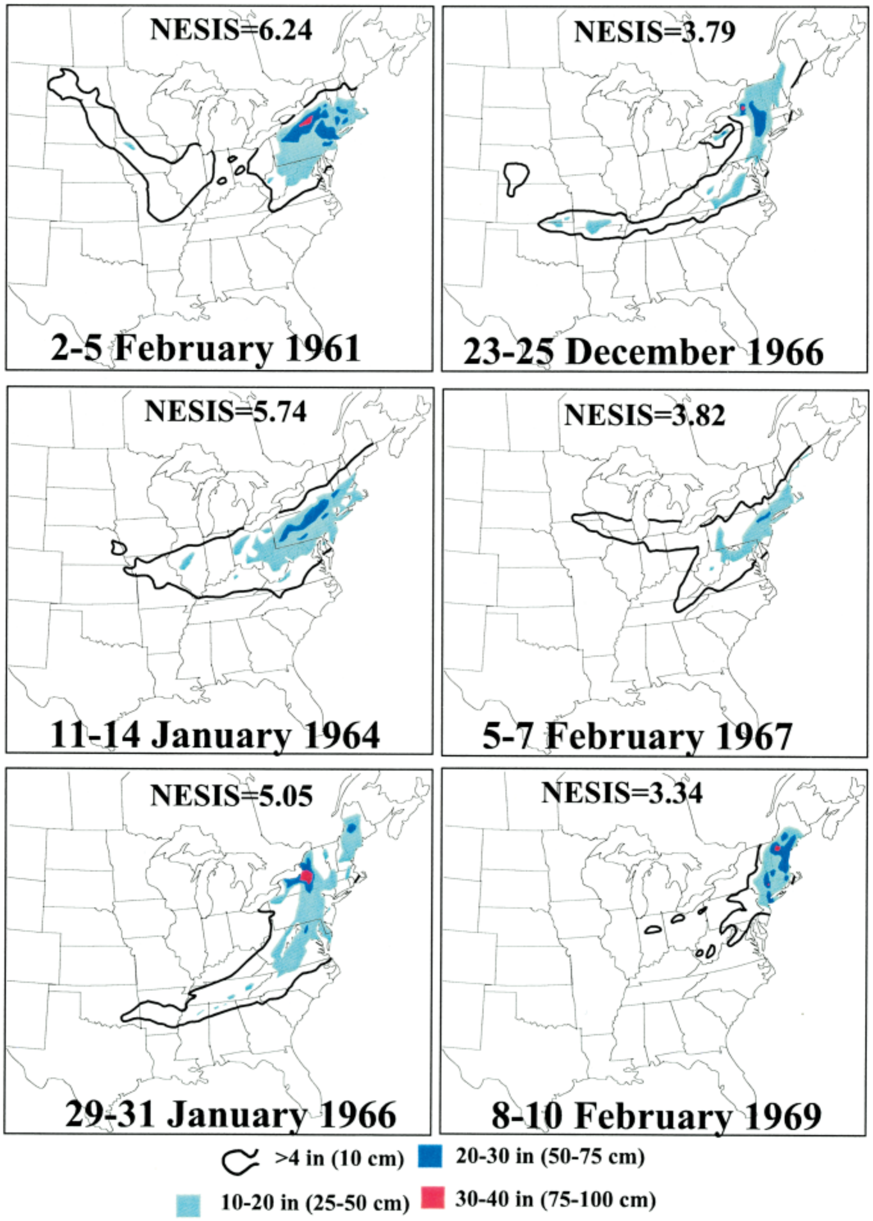

Fig. 1b. Storm snowfall in excess of 10 cm (solid line); > 25 cm (light blue); > 50 cm (dark blue); and > 75 cm (red) for six more of the 30 snowstorms used to generate the NESIS scale, with corresponding NESIS value (using the 1999 census).

In (1), n represents selected values of snowfall (in inches) divided by 10: n = 1 is used for the distribution of snowfall 10 in. (25 cm) and greater, n = 2 is used for the distribution 20 in. (50 cm) and greater, and so on. To account for snowfall exceeding 4 in., n = 0.4 is also included in (1).

In (1), A_n is the estimated area of snowfall exceeding n (× 10) inches for any given snowstorm. Here A_{mean} is the mean area of snowfall greater than 10 in. (25 cm) derived from the 30 major snowstorms described by Kocin and Uccellini (2004a,b) for the 50

For example, heavy snowfall from the New England snowstorm of late February 1969 (Fig. 1c) was confined solely to eastern New England, while many other snowstorms, such as March 1960, January 1964, and February 1979 (Figs. 1a–1c) were part of more widespread storm systems affecting larger portions of the nation. Thus, NESIS represents a measure of the integrated, or total, impact of a snowfall within and outside the Northeast, calibrated by the 30 storms from 1950 to 2000 that had the largest apparent impact in the Northeast urban corridor. Furthermore, the scale provides added weight to the higher snowfall increments (n = 2, 3, ...,), which are generally maximized in the northeastern part of the United States for these selected storms, reflecting the greater potential disruption when very heavy snow falls in the most densely populated areas.

Values of A_n and P_n (area and population) are derived using the Arcview 3.0 GIS software for total areas of snowfall exceeding 10 in. (25 cm) for each case. The areal coverage of 10-in. (25-cm) accumulations from all 30 storms (Table 1) ranges from 28×10^3 to 212.5×10^3 mi^2, with a mean area (A_{mean}) of 91.03×10^3 mi^2. The population, derived from 1999 census figures, affected by snowfall accumulations greater than 10 in. (25 cm), ranges from 10.3 million to 59.9 million in the 30-case sample, with a mean population (P_{mean}) of 35.4 million.

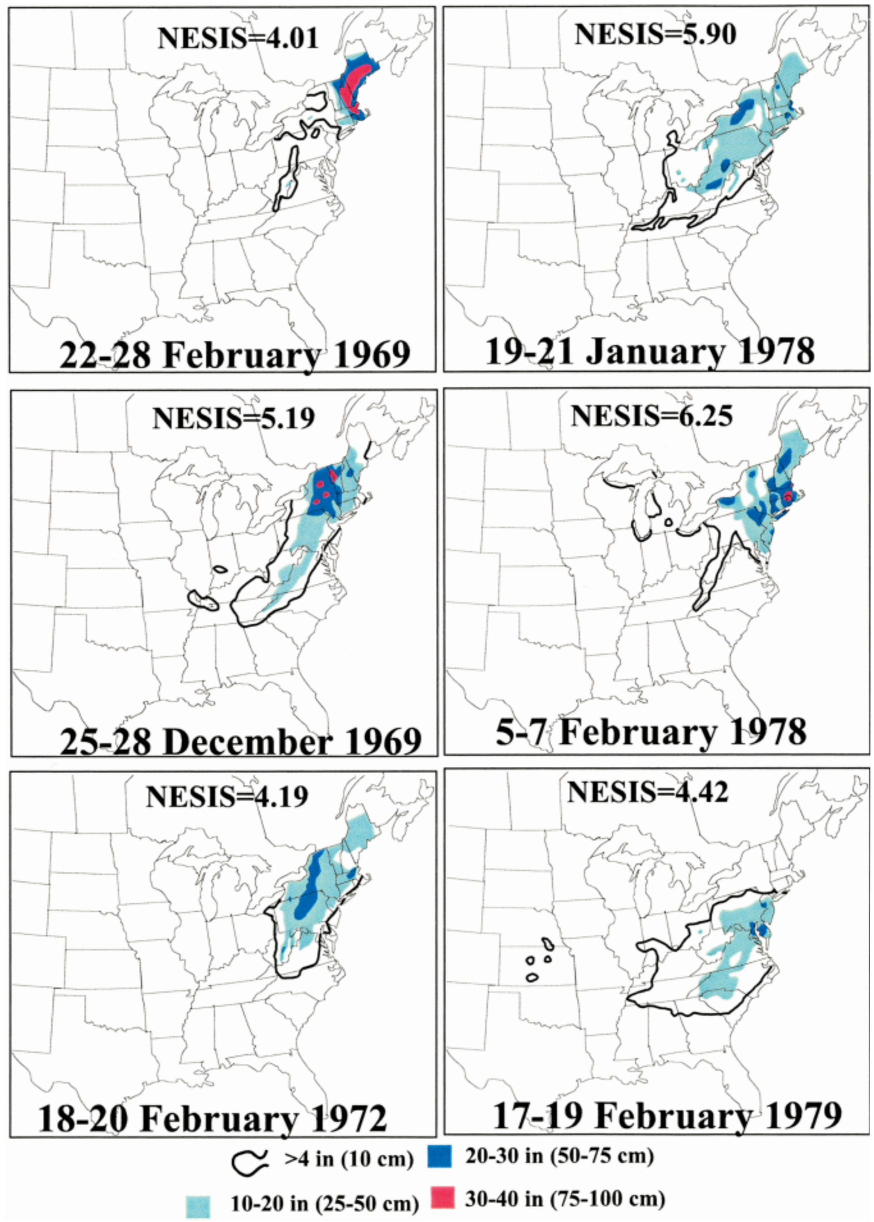

Fig. 1c. Storm snowfall in excess of 10 cm (solid line); > 25 cm (light blue); > 50 cm (dark blue); and > 75 cm (red) for six more of the 30 snowstorms used to generate the NESIS scale, with corresponding NESIS value (using the 1999 census).

GENERATING NESIS VALUES FOR THE ENTIRE STORM SNOWFALL DISTRIBUTION.

The NESIS values computed for the 30 cases are ranked from highest to lowest in Table 2 and range from 1.46 to 12.52 (Fig. 1), with an average value of 4.80. The snowstorm of March 1993 has the largest NESIS value of 12.52, given the large areal extent of 4-, 10-, and 20-in. (10-, 25-, and 50-cm) snows extending west into the Ohio Valley and south across the southeast United States (Fig. 1d). The March 1993 storm has, by far, the largest areas of greater than 10- and 20-in. (25- and 50-cm) snowfall than any of the 30 other storms (Table 2). The Blizzard of January 1996 scores second highest of the 30 cases, and scores closest to March 1993, in part, because it has the largest population affected by 20-in. (50-cm) snows (Table 2). Both March 1993 and January 1996 are the only two storms in which the area of 10-in. (25-cm) snowfall exceeds 200×10^3 mi^2. March 1960 scores third highest in the sample with 7.63, reflecting the largest area and population affected by greater than 4-in. (10-cm) snowfall of all 30 cases, much of which occurred west of the Appalachians (Fig. 1a). The three snowstorms of February 1983, February 1978, and February 1961 all score above 6. Each case produced large areas of 10- and 20-in. (25-

Table 2. Estimated area (× 10^3 mi^2) and population (in millions, from the 1999 census) affected by snowfall accumulations of 4, 10, 20, and 30 in. (10, 25, 50, and 75 cm) during 30 Northeast snowstorms (Fig. 2). Ranked (from highest to lowest) NESIS values (using the 1999 census) computed from the total snowfall distribution of 30 cases used to calibrate the NESIS equation.

Rank	Date	4" area	4" pop	10" area	10" pop	20" area	20" pop	30" area	30" pop	NESIS
1	12–14 Mar 1993	386.0	89.2	283.5	66.8	142.4	19.6	12.9	1.8	12.52
2	6–8 Jan 1996	313.8	82.3	200.1	66.1	90.2	39.8	15.1	5.1	11.54
3	2–5 Mar 1960	590.4	108.6	140.8	57.0	7.6	8.5			7.63
4	10–12 Feb 1983	157.1	58.5	112.6	51.6	33.7	25.7	0.9	0.2	6.28
5	5–7 Feb 1978	220.2	67.4	132.3	48.0	30.7	16.0	0.9	1.2	6.25
6	2–5 Feb 1961	369.3	85.0	114.0	50.7	19.4	8.7	1.4	0.2	6.24
7	14–17 Feb 1958	282.6	72.0	129.2	54.6	20.2	6.0	3.4	0.8	5.98
8	19–21 Jan 1978	295.2	79.5	167.7	53.1	8.3	3.2			5.90
9	11–14 Jan 1964	356.5	87.6	129.6	51.2	10.3	1.5			5.74
10	25–28 Dec 1969	250.6	61.2	138.7	25.9	37.6	4.0			5.19
11	29–31 Jan 1966	371.4	83.1	111.7	22.2	12.3	2.4	1.5	0.5	5.05
12	21–23 Jan 1987	286.9	79.1	153.7	38.4	2.0	0.1			4.93
13	8–12 Feb 1994	280.0	86.5	57.7	39.3	4.4	13.4			4.81
14	11–13 Dec 1960	302.9	68.0	78.5	48.0	0.6	2.5			4.47
15	17–19 Feb 1979	304.0	72.1	88.2	36.9	4.3	3.0			4.42
16	18–20 Feb 1972	206.3	59.5	140.9	24.5	13.5	1.4			4.19
17	22–28 Feb 1969	101.7	20.6	48.4	10.3	40.8	8.2	24.2	4.2	4.01
18	18–21 Mar 1958	146.7	53.7	62.1	40.7	13.8	7.5	3.5	0.7	3.92
19	5–7 Feb 1967	246.0	81.1	50.9	44.8					3.82
20	23–25 Dec 1966	292.2	63.0	89.8	18.1	9.9	1.4			3.79
21	6–7 Apr 1982	258.3	75.5	79.3	28.7	2.1	0.6			3.75
22	2–4 Feb 1995	200.1	62.6	98.0	29.9					3.51
23	18–21 Jan 1961	144.9	57.4	62.3	43.0	5.7	2.9			3.47
24	8–10 Feb 1969	107.5	40.4	66.4	31.2	11.6	9.6			3.34
25	24–26 Jan 2000	205.6	64.9	74.2	23.6	0.3	0.2			3.14
26	30–31 Dec 2000	103.8	40.0	56.5	28.0	3.7	1.4			2.48
27	31 Mar–1 Apr 1997	76.4	31.9	32.0	13.0	13.1	7.0	3.1	2.2	2.37
28	18–19 Mar 1956	64.9	44.8	28.6	32.8	2.6	2.6			2.23
29	25–26 Jan 1987	74.3	34.8	38.0	11.5					1.70
30	22–23 Feb 1987	61.3	35.6	28.3	16.6	0.3	0.1			1.46

and 50-cm) snowfalls over highly populated regions (Table 2), although impacting noticeably smaller areas than the top three storms in the 30-case sample.

Five cases score between 5 and 6 (Table 2) and were also widespread storms over populated areas but the smaller numbers reflect very heavy snowfall greater than 20 in. (50 cm) falling either over smaller areas or less populated areas from those cases that scored 6 or greater (Table 2). Six cases score between 4 and 5 and, with one exception, are either widespread snowfalls exceeding 4 or 10 in. (10 or 25 cm), with small areas of 20 in. (50 cm) or greater. The one exception is the snowstorm of late February 1969, which scores greater than 4 despite a relatively small area of 4- and 10-in. (10- and 25-cm) snows, but an unusually large area of 20- and 30-in. (50- and 75-cm) snows (Table 2). Eight storms score between 3 and 4 and these storms have 10-in. (25-cm) snowfalls that tend to cover smaller areas than higher-scoring cases (ranging between 50 × 10^3 and 100 × 10^3 mi^2; roughly the area between the size of New York and the combined states of New York, Pennsylvania, and New Jersey; Table 2). The snowstorm of March 1958 scores close to 4 because of the relatively higher area and populations affected by greater than 20- and 30-in. (50- and 75-cm) snowfalls. Five cases score less than 3 primarily due to relatively small areas of greater than 10-in. snowfalls (38 × 10^3 mi^2 and less, roughly an area smaller in size than the state of Virginia; Table 2).

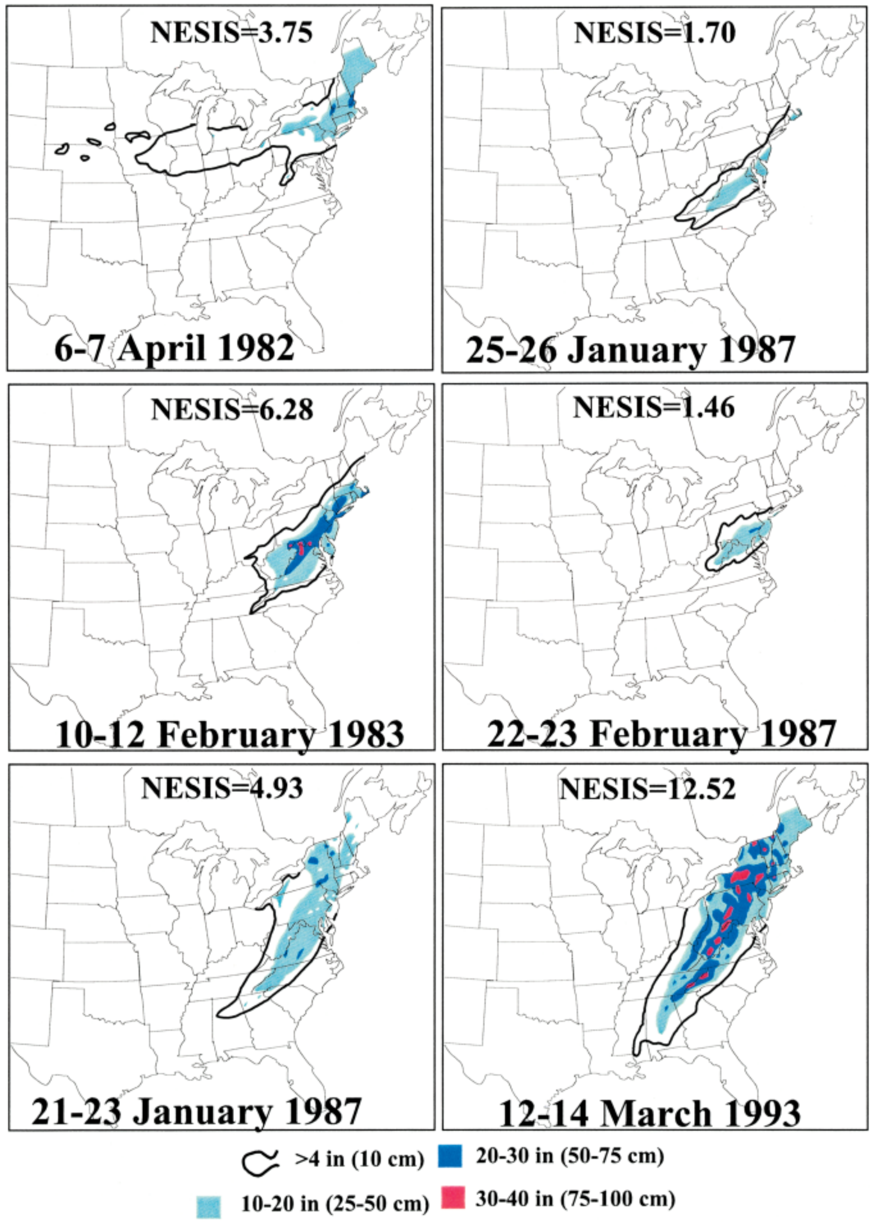

Fig. 1d. Storm snowfall in excess of 10 cm (solid line); > 25 cm (light blue); > 50 cm (dark blue); and > 75 cm (red) for six more of the 30 snowstorms used to generate the NESIS scale, with corresponding NESIS value (using the 1999 census).

APPLICATION OF THE NESIS TO OTHER CASES.

In this section, the NESIS is applied to an independent sample of 30 "near-miss" snowstorms [defined in the next section and described by Kocin and Uccellini (2004a,b)]; four historic cases, a major storm system on 4–6 March 2001, which received extensive media coverage for a perceived lack of impact on the major metropolitan areas in the Northeast; and five cases during the winter of 2002/03, including the heavy snowfall associated with the Presidents' Day II Snowstorm of 15–18 February 2003.

Near-miss snowstorms for the Northeast urban corridor. The near-miss cases described by Kocin and Uccellini

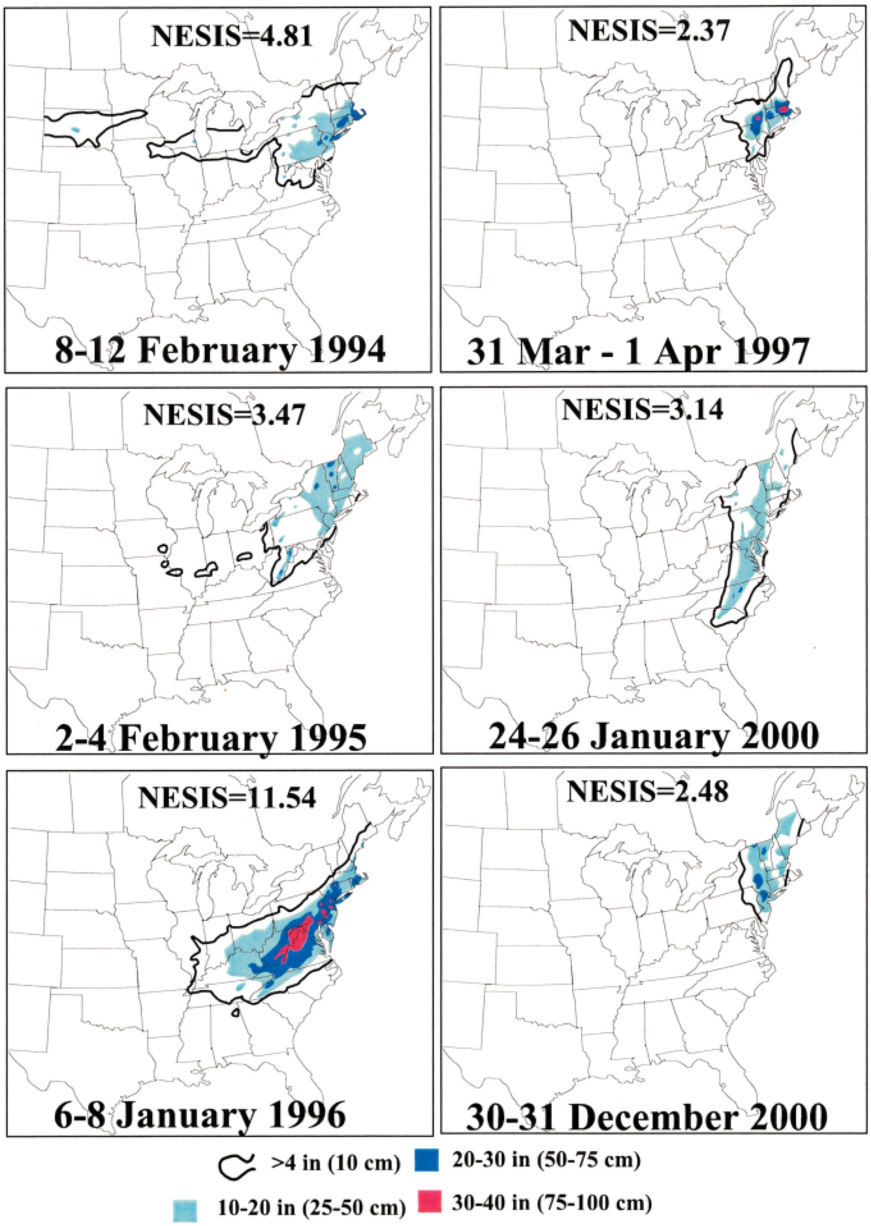

FIG. 1e. Storm snowfall in excess of 10 cm (solid line); > 25 cm (light blue); > 50 cm (dark blue); and > 75 cm (red) for the last six of the 30 snowstorms used to generate the NESIS scale, with corresponding NESIS value (using the 1999 census).

(2004a,b) either produced 1) the heaviest snowfall in the interior locations, west and north of the Northeast urban corridor; 2) moderate snowfall amounts related to storms whose snowfall is generally limited by a number of factors (i.e., rapidly moving storms) described in Kocin and Uccellini (2004a,b); or 3) precipitation that fell more as sleet or freezing rain rather than snow. Total snowfall distributions for 30 near-miss cases are analyzed (only interior and moderate snowstorms are included) and areas and populations for 4-, 10-, and 20-in. (10-, 25-, and 50-cm) total snowfall distributions are shown in Table 3, as well as the resultant NESIS values.

NESIS values for the interior snowstorms range from 1.86 to only 4.45, and average 3.0, well below the average of 4.8 for the 30 original cases. NESIS values for the moderate snowstorms range from 1.20 and 4.85 and average 2.1. Smaller NESIS values tend to occur with storms in which snowfall is limited to areas of the interior Northeast (or smaller areas of generally lower snowfall amounts) while the storms with higher values tend to be more widespread snowfalls covering larger portions of the nation.

Three representative examples of "interior" snowstorms are shown in Fig. S1 (left-hand side; all "S" figures cited in this article can be found exclusively in the online supplement noted in the affiliations box on page 177). These three cases are selected from 15 interior snowstorms described in Kocin and Uccellini (2004a,b) and produced the heaviest snow inland away from the major metropolitan areas of the Northeast urban corridor. The three cases, 10–11 December 1992, 3–5 January 1994, and 2–4 March 1994 (Figs. S1a,b,c) each produced a large region of greater than 10 in. (25 cm) of snow, as well as significant areas of greater than 20 in. (50 cm) of snow. NESIS values for these interior cases are 3.10, 2.87, and 3.46 (Table 3), respectively, reflecting the relatively large areas of heavy snowfall, but which fell over less populated areas than the "major" storms discussed in the previous section.

Three representative examples of moderate snowstorms are also shown in Fig. S1 (right-hand side) and represent snowfalls in the Northeast urban corridor

TABLE 3. Dates of 30 interior (INT) and moderate (MOD) cases, area and population (in millions) affected by greater than 4-, 10-, and 20-in. (10-, 25-, and 50-cm) snowfall (× 10^3 mi^2), and NESIS values (using the 1999 census).

Date	Type	4" area	4" pop	10" area	10" pop	20" area	20" pop	NESIS
16–17 Feb 1952	INT	125.2	23.2	66.7	10.2	12.4	1.1	2.17
16–17 Mar 1956	INT	195.5	56.8	92.3	14.6			2.93
12–13 Mar 1959	INT	215.3	56.6	121.1	19.2	7.7	0.2	3.64
14–15 Feb 1960	INT	353.9	47.4	142.1	15.1	23.3	0.6	4.17
6–7 Mar 1962	INT	148.6	37.6	70.0	10.8	19.3	1.3	2.76
19–20 Feb 1964	INT	169.7	54.3	53.4	12.2	3.5	0.4	2.39
22–23 Jan 1966	INT	296.4	60.9	145.1	22.6	6.6	1.5	4.45
3–5 Mar 1971	INT	195.7	37.6	101.6	10.5	23.3	1.9	3.73
25–27 Nov 1971	INT	163.4	26.9	73.4	10.6	6.6	1.1	2.33
16–18 Jan 1978	INT	364.4	62.0	122.1	16.2			4.10
28–29 Mar 1984	INT	124.6	31.0	53.3	11.2	2.1	0.2	1.86
1–2 Jan 1987	INT	164.6	34.0	76.6	11.1			2.26
10–12 Dec 1992	INT	118.7	28.6	61.6	15.1	21.5	5.5	3.10
3–5 Jan 1994	INT	222.3	41.3	76.4	9.3	10.5	1.7	2.87
2–4 Mar 1994	INT	165.4	47.9	109.1	12.3			3.46
3–5 Dec 1957	MOD	87.2	44.8	9.4	11.7			1.32
23–25 Dec 1961	MOD	105.5	44.0	14.8	8.6			1.37
14–15 Feb 1962	MOD	101.4	33.0	33.8	12.7	0.4	0.6	1.59
22–23 Dec 1963	MOD	374.2	75.9	51.3	21.0			3.17
16–17 Jan 1965	MOD	214.5	69.0	15.3	10.3			1.95
21–22 Mar 1967	MOD	62.3	35.9	7.0	15.6			1.20
31 Dec 1970–1 Jan 1971	MOD	151.0	55.3	46.4	6.8	4.4	0.2	2.10
13–15 Jan 1982	MOD	382.2	83.6	133.9	13.4			3.08
8–9 Mar 1984	MOD	120.9	53.0	54.6	5.5			1.29
7–8 Jan 1988	MOD	488.5	80.5	129.7	9.5			4.85
26–27 Dec 1990	MOD	166.0	58.4	12.7	8.8			1.56
19–21 Dec 1995	MOD	260.3	62.0	85.4	19.0			3.32
2–4 Feb 1996	MOD	157.3	56.4	44.1	7.1	0.9	0.1	2.03
16–17 Feb 1996	MOD	136.7	52.6	12.2	11.4			1.65
14–15 Mar 1999	MOD	180.3	49.5	58.8	5.8	1.4	0.1	2.20

Table 4. Dates of four historic snowfall cases and six recent snowfall cases, area and population (in millions) affected by greater than 4-, 10-, 20-, and 30-in. (10-, 25-, 50-, and 75-cm) snowfall (× 10^3 mi²), and NESIS values (using the 1999 census).

Historical	4" area	4" pop	10" area	10" pop	20" area	20" pop	30" area	30" pop	NESIS
11–14 Mar 1888*	144.9	52.7	87.9	37.9	48.2	26.1	24.8	12.8	**8.34**
11–14 Feb 1899	362.1	81.7	181.8	61.7	33.0	20.0			**8.11**
27–29 Jan 1922	107.1	46.3	62.3	26.0	22.4	1.0	10.5	1.4	**3.63**
26–27 Dec 1947	114.0	46.9	35.4	31.1	5.3	16.5	0.5	1.7	**3.50**
2001–03									
4–6 Mar 2001	161.1	40.2	105.1	21.6	30.4	5.6	1.8	0.1	**3.53**
4–5 Dec 2002	269.7	64.7	6.1	0.4					**1.99**
24–25 Dec 2002	345.3	72.8	91.3	18.5	13.8	1.5	4.4	0.2	**4.42**
3–4 Jan 2003	211.1	35.6	77.4	10.9	11.0	1.5			**2.65**
6–7 Feb 2003	88.4	50.2	6.1	5.5					**1.18**
15–18 Feb 2003	303.5	78.2	142.0	59.2	51.9	40.9	2.7	0.2	**8.91**

* Mar 1888 also has areas and populations for snowfall exceeding 40 in. (100 cm; area = 7.8 × 10^3 mi²; pop = 1.9 million) and 50 in. (125 cm; area = 0.8 × 10^3 mi²; pop = 0.2 million; 1999 census).

that are dominated by snowfalls of 4–10 in. (10–25 cm; with some areas of greater than 10 in., 25 cm). The three cases, 8–9 March 1984, 26–27 December 1990, and 16–17 February 1996 (Figs. S1d,e,f) each affected much of the Northeast urban corridor with 4–10 in. (10–25 cm) of snow, with smaller areas of greater than 10 in. (25 cm). NESIS values for these cases are 1.29, 1.56, and 1.65, respectively (Table 3).

Four snowstorms that affected the Northeast as either moderate or interior snowstorms but were also widespread snowfalls across other areas of the United States are shown in Fig. S2. Three cases, 14–15 February 1960, 22–23 January 1966, and 16–18 January 1978 (Figs. S2a,b,c) were selected as interior snowstorms because heaviest snows fell across interior portions of the Northeast. However, these three storms also produced heavy snows greater than 10 in. (25 cm) also across widespread areas of the Ohio Valley, Southeast or Tennessee Valleys. These three storms have NESIS values of 4.17, 4.45, and 4.10, respectively (Table 3). These values are higher than other interior snowstorms shown in Fig. S1 because the heavy snow fell in areas well beyond the Northeast, impacting other major metropolitan areas, thus, elevating the NESIS values. While the moderate snowstorms represented by the three cases in Fig. S1 score between 1 and 2, one moderate case in the Northeast on 7–8 January 1988 was also part of a heavy snowstorm across the Southern Plains and the Southeast. As a result of the widespread snowfall, this moderate snowfall scores 4.85 (Fig. S2d; Table 3).

Therefore, while the 30 major snowstorms of the preceding section have an average NESIS value near 5, interior snowstorms that do not extend far outside the Northeast have NESIS values generally between 2 and 4, while moderate snowstorms within the same bounds have NESIS values generally between 1 and 2. More widespread snowfalls that move across the United States and ultimately affect the Northeast score higher and can raise the NESIS value by as much as 1–2 or more points.

Historic cases. The NESIS is also applied to four historic Northeast snowstorms (Table 4), which are described by Kocin and Uccellini (2004a,b) and shown in Fig. 2. The 1888 "Blizzard of '88," perhaps the most infamous of all Northeast snowstorms (see Kocin 1983), has a NESIS value (8.34), using the 1999 census, lower than either the Superstorm of March 1993 (12.52) or the Blizzard of January 1996 (11.54). An examination of the snowfall distribution of the Blizzard of '88 (Fig. 2a) shows that the total areal coverage of the snowfall is relatively small, especially when compared with the 1993 and 1996 cases (Figs. 1d,e). However, the NESIS value computed for this storm is larger than 28 of the 30 cases examined in Table 2, due to the unusually large regions of snowfall greater than 20, 30, and 40 in. (50, 75, and 100 cm, respectively) over populated areas (using 1999 census values).

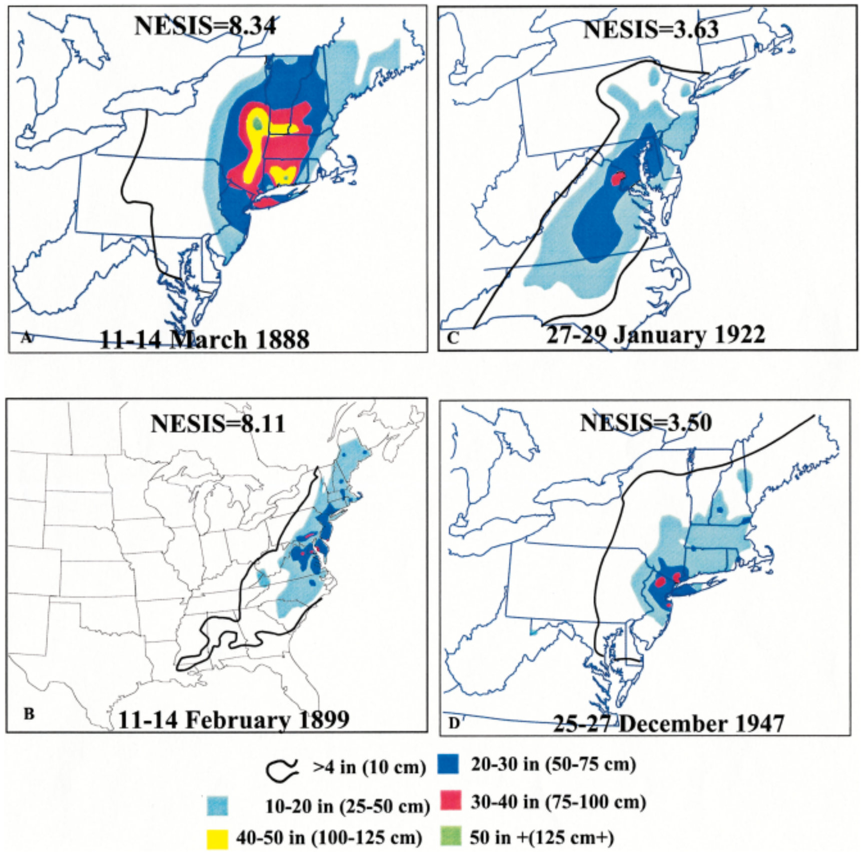

Fig. 2. Storm snowfall in excess of 10 cm (solid line); > 25 cm (light blue); > 50 cm (dark blue); and > 75 cm (red) for four historic snowstorm cases, including (a) the 11–14 Mar 1888 "Blizzard of '88"; (b) the 11–14 Feb 1899 Blizzard of 1899; (c) the "Knickerbocker" Snowstorm of Jan 1922, and (d) New York City's "Big Snow" of Dec 1947 and corresponding NESIS value (using the 1999 census).

The Blizzard of 1899 (Fig. 2b; see Kocin et al. 1988) was a widespread snowstorm from the southeastern United States northeastward to New England. This storm culminated one of the coldest periods ever recorded in the eastern United States and paralyzed the eastern third of the country. The NESIS value of 8.11 computed with the 1999 census population is also higher than 28 of the 30 cases and is slightly lower than the 1888 blizzard. The relatively high value is due mainly to the large distribution of greater than 10- and 20-in. (15- and 50-cm) snowfall amounts along the entire coast from Virginia to Maine, home to a large proportion of Northeast residents, as well as significant snow throughout the Southeast and Tennessee Valleys (Fig. 2b).

Both the 1922 "Knickerbocker" storm (Fig. 2c) and the December 1947 New York City snowstorms (Fig. 2d) produced record snowfall for Washington, D.C., and New York City, respectively, but have NESIS values of only 3.63 and 3.50, respectively. These values are less than the average for the 30-case sample, due to the comparatively small areal extent of heavy snowfall, even though the heavy amounts are both focused locally in densely populated regions. Therefore, while the greatest snowstorms in New York City and Washington, D.C., histories factor into the NESIS computations, the storms have a lower overall impact given the small areal extent of the snowfall associated with these storms. These two examples illustrate the role of NESIS in providing an integrated measure of the regional snowfall, rather than focusing on local snowfall measurements as a major impact agent.

Recent cases. The 4–6 March 2001 Snowstorm. As another illustration of how the scale may be applied to assess the impact of a storm, NESIS is applied to a snowstorm that occurred on 4–6 March 2001. For a week to 3 days prior to the snowstorm, numerical weather prediction models and forecasters saw the potential for this storm to affect the Northeast urban corridor with heavy snow from Washington, D.C., to New York City. Forecasters in several local media outlets warned about the potential impact of this storm up to 4 days in advance. The storm was viewed by many as a disappointment because the dire fore-

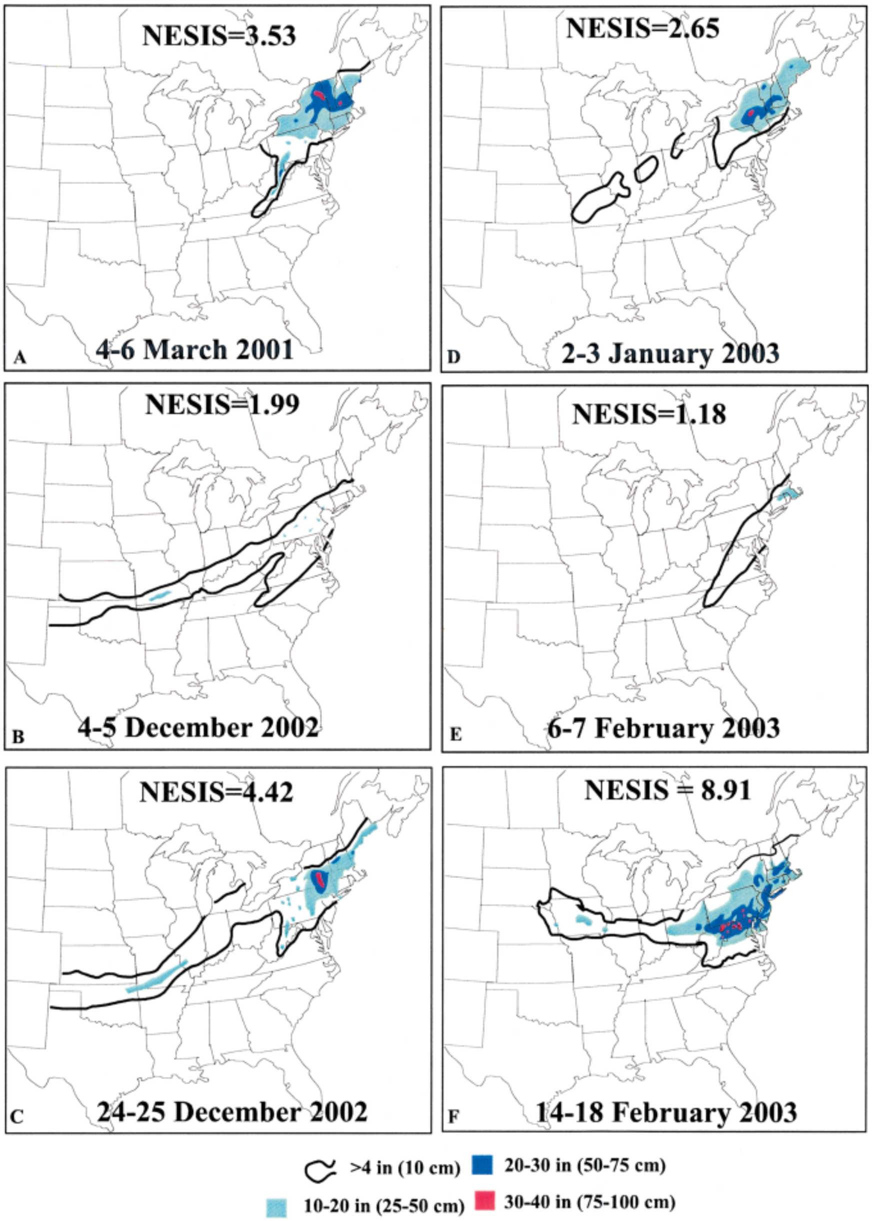

Fig. 3. Storm snowfall in excess of 10 cm (solid line); > 25 cm (light blue); > 50 cm (dark blue); and >75 cm (red) for six recent snowstorms, including (a) 4–6 Mar 2001; (b) 4–5 Dec 2002; (c) 24–25 Dec 2002; (d) 2–3 Jan 2003; (e) 6–7 Feb 2003; and (f) the Presidents' Day II Snowstorm of 15–18 Feb 2003, and corresponding NESIS value (using the 1999 census).

casts (and resulting "hype") for a major snowstorm did not materialize from New York City southward.

A major cyclone did develop along the East Coast on Monday, 5 March, as predicted, but the snowstorm occurred farther north and inland. The storm left an area of heavy snowfall (greater than 25 cm; Fig. 3a) larger than the mean area for the 30 major snowstorms shown in Table 1 (105×10^3 mi^2 versus A_{mean} of 91×10^3 mi^2). This area covered much of the Boston metropolitan area but missed the urban corridor between Washington, D.C., and New York City, although eastern suburbs of New York City received up to 16 in. (40 cm) of snow. Using the 1999 census, an estimated 21 million people were affected by greater than 10-in. (25-cm) amounts, considerably less than the P_{mean} of 35.4 million for the 30 cases shown in Table 1. In addition, more than 5 million people are estimated to have been affected by greater than 20-in. (50-cm) amounts.

This case yields a NESIS value of 3.53 (Table 4), which is considerably lower than the average of 4.80 for the 30 major snowstorm cases but slightly higher than the representative examples for interior snowstorms shown in Fig. S1. Had the earlier forecasts verified and the heaviest snowfall occurred approximately 300 km farther south, affecting the New York to Washington, D.C., corridor, more than 45 million people would have witnessed snowfall accumulations exceeding 10 in. (25 cm), resulting in a NESIS value estimated between 4.5 and 6. The NESIS demonstrates that this storm was comparable in area and populations affected by some of the lower-scoring major snowstorms documented by Kocin and Uccellini (2004a,b) and scored similar to the many interior snowstorms also discussed in Kocin and Uccellini (2004a,b). However, the media and public reaction that this snowstorm did not "measure up" to expectations raised by forecasts prior to its development is also validated by the use of the NESIS scale.

THE SNOWSTORMS OF 4–5 DECEMBER 2002, 24–25 DECEMBER 2002, 3–4 JANUARY 2003, AND 6–7 FEBRUARY

2003. The first significant snowfall threat in two winters that greeted much of the Northeast urban corridor in early December 2002 as a general snowfall of 5–9 in. (13–23 cm) occurred from Virginia to southern New England. The area of heaviest snowfall in the Northeast (Fig. 3b) is similar in location to the snowstorms of February 1983 and January 1996 (Figs. 1d and 1e), but maximum amounts were much less. Few sites reported 10 in. (25 cm) or greater but the region exceeding 4 in. (10 cm) was widespread, including the Ohio Valley and the Southern Plains. The Christmas 2002 Snowstorm was associated with a rapidly developing cyclone that left a large band of snowfall exceeding 20–30 in. (50–75 cm; Fig. 3c) across the Mohawk and Hudson Valleys of New York and the Catskill Mountains. Snow changed to rain and then back to snow in the metropolitan areas from Washington, D.C., to Boston. This storm also affected a large area outside the northeast United States, including the Southern Plains and Great Lakes. Only a week later, on 3–4 January 2003, another cyclone developed and was associated with the heaviest snows again occurring over the Mohawk and Hudson Valleys of New York and the Catskills (Fig. 3d), as well as central New England. On 6–7 February 2003, an area of 4–10 in. (10–25 cm) of snow affected the entire Northeast corridor again from Virginia to Massachusetts with a region from northeastern Connecticut, northern Rhode Island, and eastern Massachusetts experiencing greater than 10 in. of snow (25 cm; see Fig. 3e).

NESIS values were computed for all four storms (Table 4). The early December snowfall scores a 1.99 from the widespread occurrence of greater than 4-in. (10-cm) snows from the Southern Plains and Missouri and Tennessee Valleys into the Northeast, but scores less than the values exhibited by many of the 30 cases used to derive the scale, since few areas received 10 in. (25 cm) or greater. This snowfall was a classic moderate snowstorm, as described by Kocin and Uccellini (2004a,b), that had a NESIS value scoring near 2 because snowfall was widespread outside the Northeast. The Christmas storm scores a NESIS value of 4.42, scoring heavily because of widespread areas of greater than 4 in. (10 cm) of snow from the Southern Plains through the Ohio Valley and the Northeast. This storm represents a classic "interior snowstorm" for the Northeast in which heaviest snows fell mostly outside the major metropolitan areas. It also scored higher than a representative interior snow because significant snows extended well outside the Northeast. Meanwhile, the January 2003 storm scores 2.65, another typical interior snowstorm with similarities to the Christmas snowstorm. This storm was, however, less widespread, but still covered a large area of the Midwest and Ohio Valley, as well as the interior Northeast. The snowstorm of 6–7 February 2003 scores a 1.18, representative of a moderate snowstorm that affected a similar area of the Northeast, as did the snowfall of 4–5 December 2002, but this snowstorm was more limited in scope, with little significant snow outside the Northeast.

Presidents' Day II Snowstorm (15–18 February 2003). The most significant and widespread snowstorm since the January 1996 "Blizzard of '96" affected many major metropolitan areas of the Mid-Atlantic states and New England on 16–18 February 2003 (it affected the Midwest on 14–15 February). For the Northeast urban corridor from Washington, D.C., to Boston, the snowfall was one of the heaviest on record and paralyzed a wide area during the long holiday weekend. An area of 4–10 in. (10–25 cm) of snow affected much of the Northeast with a large area of greater than 10-in. (25-cm) accumulations from northern Virginia through central New England (Fig. 3f). Snowfall exceeding 20 in. (50 cm) was unusually widespread within the area from Washington, D.C., to Boston, and some notable totals include 27.5 in. (70 cm) at Boston (the greatest 24-h snowfall on record) and a storm total of 28.2 in. (72 cm) at Baltimore, Maryland (the greatest snowfall storm total on record). The population of the area (using the 1999 census) affected by snowfall exceeding 20 in. (50 cm) was comparable to, if not slightly larger than, the Blizzard of 1996 (41 million, cf. 39.8 million; Table 4 versus Table 2). Scattered areas of 30-in. (75-cm) totals were reported from West Virginia to New York, with a few reports of greater than 40 in. (100 cm) near the western panhandle of Maryland. The heavy snow extended into the Ohio Valley and Midwest (Fig. 6f), resulting in a NESIS value of 8.91, the third-highest value of 70 cases examined to date. Nearly 80 million people are estimated to have been affected by greater than 4 in. (10 cm) of snow from the Midwest to the Northeast, while nearly 60 million people experienced greater than 10 in. (25 cm) of snow.

CATEGORIZING NESIS VALUES. The NESIS values calculated for the 70 snowfall cases, including the ranges and means of the snowfall distribution and populations affected, allow a quantitative means to partition the NESIS values into several categories. A categorical ranking of 1–5 is proposed (similar to the Saffir–Simpson scale) that utilizes the divisions inherent in the NESIS values (all 70 cases scored between 1 and 12) to separate the snowfalls into similar cat-

TABLE 5. NESIS categories, their corresponding NESIS values, number of 70 total cases within each category, and a descriptive adjective.

Category	NESIS values	No. of cases	Description
1	1–2.499	23	"Notable"
2	2.5–3.99	22	"Significant"
3	4–5.99	16	"Major"
4	6–9.99	7	"Crippling"
5	10.0+	2	"Extreme"

egories based on area, population, and the occurrence of very heavy snowfall. These categories, their corresponding NESIS values, and the total number of cases within each category are shown in Table 5.

Category 1 (NESIS = 1.0–2.49), "Notable." All storm snowfall distributions examined in this paper score NESIS values of 1 and greater. A total of 23 out of 70 cases occur in this category, including 5 of the 30 cases used to calibrate the scale, 5 of the interior snowstorms, and 11 of the moderate snowstorms. Of the recent cases, the 3–5 December 2002 and 6–7 February 2003 snowstorms fall into this category. These storms are notable for their large areas of 4-in. (10-cm) accumulations and small areas of 10-in. (25-cm) snowfall. An example of a category 1 snowfall is shown in Fig. A2a.

Category 2 (NESIS = 2.5–3.99), "Significant." A total of 22 cases out of 70 occur in this category, including 8 of the 30 original cases, 7 of the interior snowstorms, and 3 of the moderate snowstorms. The historic snowstorms of January 1922 and December 1947, the heaviest snowfalls in Washington, D.C., and New York City, fall into this category. Of the recent cases examined, two cases (March 2001 and January 2003) also fit into this category. This category includes storms that produce significant areas of greater than 10-in. (25-cm) snows while some include small areas of 20-in. (50-cm) snowfalls. A few cases may even include relatively small areas of very heavy snowfall accumulations [greater than 30 in. (75 cm)], including the greatest snowfalls of Washington, D.C., and New York City (see the section titled "Historic cases").

Category 3 (NESIS = 4.0–5.99), "Major." A total of 16 cases occur in this category, including 11 of the 30 original cases, and this category includes the mean of 4.80 for the 30 cases. This was the highest category attained by only two of the interior snowstorms; one moderate snowstorm occurred in this category because it was associated with a very widespread distribution of snow. This category encompasses the typical major Northeast snowstorm, with large areas of 10-in. snows (generally between 50 and 150 $\times$ 10^3 mi^2—roughly 1–3 times the size of the state of New York—with significant areas of 20-in. (50-cm) accumulations. An example of a category 3 snowfall is shown in Fig. A2b.

Category 4 (NESIS = 6.0–9.99), "Crippling." A total of 7 cases occur in this category, including 4 of the original 30 cases, 2 historical cases (the Blizzards of 1888 and 1899), and the recent Presidents' Day II Snowstorm of 15–18 February 2003. These storms consist of some of the most widespread, heavy snows of the sample and can be best described as crippling to the northeast United States, with the impact to transportation and the economy felt throughout the United States. These storms encompass huge areas of 10-in. (25-cm) snowfalls, and each case is marked by large areas of 20-in. (50-cm) and greater snowfall accumulations.

Category 5 (NESIS = 10.0+), "Extreme." Only two cases, the Superstorm of March 1993 and the January Blizzard of 1996, occur in this category, representing the most extreme snowfall distributions, blanketing large areas and populations with snowfalls greater than 10, 20, and 30 in. (25, 50, and 75 cm). These are the only storms in which the 10-in. (25-cm) accumulations exceed 200 $\times$ 10^3 mi^2 and affect more than 60 million people (1999 census; Table 2). The Superstorm of March 1993 derives the highest ranking given the largest area covered by snowfall greater than 10 in. (25 cm) in the entire sample, compounded by large areas of 20- and 30-in. (50- and 75-cm) snowfall. The January 1996 snowstorm has similarities to other category 3 and 4 storms, except that this storm was accompanied by unusually large areas of snowfall greater than both 20 and 30 in. (50 and 75 cm) that affected large population centers within the entire Northeast urban corridor. The snowfall distribution of the January 1996 storm is shown in Fig. A2c as an example of a category 5 snowfall.

THE EFFECT OF POPULATION CHANGE BETWEEN 1900 AND 1999 ON NESIS VALUES. Given the large population shifts that have occurred in the United States during the course of the twentieth century, NESIS is evaluated utilizing census values from several periods between 1900 and 1999 to assess if the scale changes significantly as the population of the Northeast changes. In certain parts of the United States (especially portions of the Southeast and the Southwest), significant changes in population distribution during the twentieth century would indicate that impact scales related to population density would change significantly over time. However, many of the metropolitan areas and population centers of the northeast United States were already established by 1900. Populations of some major metropolitan areas actually peaked in 1950 and decreased in subsequent years. The resulting shifts in population to suburban areas surrounding the cities in the Northeast corridor and the general shift of the populations from inland to coastal areas raise this question: Would the changing population distributions during the twentieth century change the NESIS values in a fundamental way?

The U.S. census for 1900, 1950, 1960, 1970, 1980, 1990, and 1999 are used to compare the NESIS values of several storms given the change of population across the Northeast during the twentieth century. Within the area called the Northeast urban corridor (Fig. A1), the population has increased over 200% since 1900 (from 14 to 45 million), while the remainder of the 13-state region between the Virginias and Maine has increased roughly 100% (from 10 to 20 million) in the same period. While there are some differences in the values for the 30 cases during the course of the century, the NESIS values remain relatively constant. Several cases increase slightly over time and others decrease slightly. While the Superstorm of March 1993 is ranked highest in 1900 (13.27) and 1999 (12.52), its value drops over the course of the century, while the NESIS values for the second-ranked storm, the Blizzard of January 1996, remains relatively constant from 1900 (11.47) to 1999 (11.54). These differences reflect the decrease of population across some interior portions of the Northeast after 1950 (heaviest snows in the March 1993 storm occurred over the interior Northeast, while the heaviest snows in January 1996 were centered over the Northeast urban corridor) and a slight general shift of the population toward the coastal areas during the same period. However, most of the values throughout the century fluctuate within 10% of the 1999 values for nearly all cases, indicating that the NESIS scale provides a consistent measure of impact for the northeast United States whose population distribution has shifted from the interior and city locations more toward the cities and the burgeoning suburbs during the twentieth century. Given the population shifts that will continue to occur in the twenty-first century, we recommend that as new storms occur, their NESIS value should be computed with the most recent census count.

SUMMARY.

A Northeast snowfall impact scale (NESIS) is derived to convey a measure of the impact of snowstorms over the Northeast urban corridor as a function of the total snowfall distribution, snowfall amounts, and population density (based on the 1999 census). The scale is derived and calibrated by the snowfall distributions of 30 high-impact snowstorms from a synoptic climatology provided by Kocin and Uccellini (2004a,b) and applied to a total of 70 cases. The NESIS is an integrated measure of snowfall impact, rather than relying on instantaneous descriptions of a variety of parameters associated with the surface low. The scale also accounts for a greater impact associated with heavier snow amounts. Computed values are used to construct a categorical ranking from 1 to 5. NESIS provides a *simple* quantitative means to convey a measure of the impact of those storms in which the areal coverage of the snowfall upon large population centers contribute to widespread human and economic disruption.

The NESIS is applied to 70 cases, including 30 major snowstorms, 30 "near-miss" cases that occurred over the 50-yr period from 1950 to 2000 (as described by Kocin and Uccellini 2004a,b), 4 historic cases, and 6 recent cases. NESIS differentiates limited "moderate" snowstorms that produce snows of mainly 4–10 in. (10–25 cm; NESIS scores generally between 1 and 2; category 1) over a relatively small area over the Northeast, from "interior snowstorms" that miss the major cities but drop widespread heavy snowfall (NESIS scores generally between 2 and 4; category 1–2). NESIS also differentiates major snowstorms with sizable areas of 10-in. snows over relatively large, populated areas (NESIS scores between 4 and 6; category 3) from the rare "megastorm" that drops 10–20 in. (25–50 cm) and greater over large populated regions (NESIS values greater than 6; category 4). Only two cases, March 1993 and January 1996, exhibit NESIS values in excess of 10 (category 5). For the 30 major snowstorms used to generate the scale, NESIS averages 4.8. For the 70 cases, NESIS averages near 3.8.

Out of the 70 cases, 26 score greater than a NESIS value of 4, and include 3 interior snowstorms and 1 moderate snowstorm. The interior and moderate snowstorms that score greater than 4 are typically widespread snowstorms that affect the interior Northeast and other sections of the nation as the storm traverses the country toward the East Coast. Addi-

Table 6. Seventy cases ranked from highest to lowest by NESIS value (using the 1999 census), including NESIS category (1–5) and description (see Table 5).

No.	Date	NESIS	Cat.	Description	No.	Date	NESIS	Cat.	Description
1	12–14 Mar 1993	12.52	5	Extreme	36	18–21 Jan 1961	3.47	2	Significant
2	6–8 Jan 1996	11.54	5	Extreme	37	2–4 Mar 1994	3.46	2	Significant
3	15–18 Feb 2003	8.91	4	Crippling	38	8–10 Feb 1969	3.34	2	Significant
4	11–14 Mar 1888	8.34	4	Crippling	39	19–20 Dec 1995	3.32	2	Significant
5	11–14 Feb 1899	8.11	4	Crippling	40	22–23 Dec 1963	3.17	2	Significant
6	2–5 Mar 1960	7.63	4	Crippling	41	24–26 Jan 2000	3.14	2	Significant
7	10–12 Feb 1983	6.28	4	Crippling	42	10–12 Dec 1992	3.10	2	Significant
8	5–7 Feb 1978	6.25	4	Crippling	43	13–15 Jan 1982	3.08	2	Significant
9	2–5 Feb 1961	6.24	4	Crippling	44	16–17 Mar 1956	2.93	2	Significant
10	14–17 Feb 1958	5.98	3	Major	45	3–5 Jan 1994	2.87	2	Significant
11	19–21 Jan 1978	5.90	3	Major	46	6–7 Mar 1962	2.76	2	Significant
12	11–14 Jan 1964	5.74	3	Major	47	3–4 Jan 2003	2.65	2	Significant
13	25–28 Dec 1969	5.19	3	Major	48	30–31 Dec 2000	2.48	1	Notable
14	29–31 Jan 1966	5.05	3	Major	49	19–20 Feb 1964	2.39	1	Notable
15	21–23 Jan 1987	4.93	3	Major	50	31–1 Apr 1997	2.37	1	Notable
16	7–8 Jan 1988	4.85	3	Major	51	25–27 Nov 1971	2.33	1	Notable
17	8–12 Feb 1994	4.81	3	Major	52	1–2 Jan 1987	2.26	1	Notable
18	11–13 Dec 1960	4.47	3	Major	53	18–19 Mar 1956	2.23	1	Notable
19	22–23 Jan 1966	4.45	3	Major	54	14–15 Mar 1999	2.20	1	Notable
20	17–19 Feb 1979	4.42	3	Major	55	16–17 Feb 1952	2.17	1	Notable
21	24–25 Dec 2002	4.42	3	Major	56	31–1 Jan 1971	2.10	1	Notable
22	18–20 Feb 1972	4.19	3	Major	57	2–4 Feb 1996	2.03	1	Notable
23	14–15 Feb 1960	4.17	3	Major	58	4–5 Dec 2002	1.99	1	Notable
24	16–18 Jan 1978	4.10	3	Major	59	16–17 Jan 1965	1.95	1	Notable
25	22–28 Feb 1969	4.01	3	Major	60	28–29 Mar 1984	1.86	1	Notable
26	18–21 Mar 1958	3.92	2	Significant	61	25–26 Jan 1987	1.70	1	Notable
27	5–7 Feb 1967	3.82	2	Significant	62	16–17 Feb 1996	1.65	1	Notable
28	23–25 Dec 1966	3.79	2	Significant	63	14–15 Feb 1962	1.59	1	Notable
29	6–7 Apr 1982	3.75	2	Significant	64	26–27 Dec 1990	1.56	1	Notable
30	3–5 Mar 1971	3.73	2	Significant	65	22–23 Feb 1987	1.46	1	Notable
31	12–13 Mar 1959	3.64	2	Significant	66	23–25 Dec 1961	1.37	1	Notable
32	27–29 Jan 1922	3.63	2	Significant	67	3–5 Dec 1957	1.32	1	Notable
33	3–5 Mar 2001	3.53	2	Significant	68	8–9 Mar 1984	1.29	1	Notable
34	2–4 Feb 1995	3.51	2	Significant	69	21–22 Mar 1967	1.20	1	Notable
35	26–27 Dec 1947	3.50	2	Significant	70	6–7 Feb 2003	1.18	1	Notable

tional snowfall from areas outside the northeast United States can contribute as much as 3 points to the overall NESIS value when snowfall is widespread.

The occurrence of the three highest-ranked storms since 1990 represents an intriguing coincidence. Even when the population criteria are dropped from NESIS (not shown; the scale then simply becomes a measure of the snowfall distribution alone), the Superstorm of March 1993 and the Blizzard of January 1996 stand alone as the most widespread snowfalls of the 70-case sample. The 2003 Presidents' Day II Snowstorm moves down the ranking from third to fifth highest, scoring slightly less than the widespread snowstorms of March 1960 and the Blizzard of February 1899. Therefore, while seasonal snowfall appears to be diminishing in recent years in the Northeast urban corridor as the number of storms producing significant snowfall decreases (see Kocin and Uccellini 2004a,b, chapter 2), it appears that for the storms that do produce significant snowfall, some of these storms may be producing heavier, more widespread snows than the storms that occurred during the first 90 years of the twentieth century. Given uncertainties and temporal changes in data quality, changes in the density of the snow-observation network, and subjectivity in contouring and spatial interpolation, more research is needed to quantify the significance of this finding.

At present, the NESIS is best used as a relative assessment of storms that have already occurred. Furthermore, similar scales can also be developed and applied to other parts of the country where synoptic climatologies of snowstorm snowfall are available. Given the current difficulties in forecasting precipitation type and snowfall amounts and areal distribution associated with these events, we do not yet recommend the use of the NESIS in a predictive manner. As confidence and accuracy in predicting snowfall amounts and areal distribution increases, the NESIS can provide an estimate of the upcoming impact of these storms relative to preceding historic storms, both in scope and population affected. The scale provides meteorologists, transportation officials, economists, planners, the media, and emergency managers the means to alert the public and business communities to take steps that can mitigate the impact of these storms.

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APPENDIX: SUPPORTING FIGURES.

FIG. A1. The oval region is referred to as the "Northeast Urban Corridor" and is home to nearly 50 million people. Larger circles represent the major metropolitan areas around Washington, D.C., Baltimore, MD, Philadelphia, PA, New York, NY, and Boston, MA. Smaller circles refer to other smaller metropolitan areas.

FIG. A2. Representative examples of snowfall distributions for (a) category-1, (b) category-3, and (c) category-5 storms.

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