The Northeast Snowfall Impact Scale

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Abstract

While the Fujita and Saffir-Simpson Scales characterize tornadoes and hurricanes respectively, there is no widely used scale to classify snowstorms. The Northeast Snowfall Impact Scale (NESIS) developed by Paul Kocin of The Weather Channel and Louis Uccellini of the National Weather Service, characterizes and ranks Northeast snowstorms. NESIS has five categories: Extreme, Crippling, Major, Significant, and Notable. The NESIS is not only based on snowfall amount, but also aerial extent and population affected. Thus NESIS is an effective measure of a storm's societal impacts. Some of the GIS computational issues encountered while calculating NESIS include quality control, development of a robust population density grid, and selection of an appropriate spatial interpolation scheme. All of the geoprocessing tasks are done with scripts and models. This paper describes the different methodologies used to calculate NESIS, examines differences between methodologies, and recommends procedures for calculating NESIS operationally beginning with the 2005-06 winter season.

Background

The Northeast Snowfall Impact Scale (NESIS) was developed by Paul Kocin and Louis Uccellini (Kocin, 2004) to characterize and rank Northeast snowstorms. The index is not only based on snowfall amount, but also aerial extent and population affected. Thus NESIS is an effective measure of a storm's societal impacts. This paper describes the method used to calculate NESIS by Kocin and a method used by NCDC, then examines the differences, and recommends procedures for calculating NESIS operationally beginning with the 2005-06 winter season.

The algorithm for computing the NESIS is:

$$NESIS = \sum_{n=4}^{n=30} \left[\frac{n}{10} \left(\frac{A_n}{A_{mean}} + \frac{P_n}{P_{mean}} \right) \right]$$

where: n = snowfall category {4 for > 4", 10 for > 10", 20 for > 20", 30 > 30"}
A_n = area of snowfall greater than or equal to category n (mi^2)
P_n = population affected by snowfall greater than category n (2000 census)
A_{mean} = mean area of >10" snowfall within the 13-state Northeast region for the 30 historical storms (91,000 mi^2)
P_{mean} = mean population affected by snowfall >10" within the 13-state Northeast region for the 30 historical storms (35.4 million)

This algorithm results in values between 1 and 13 which are then transformed into one of five categories; Extreme, Crippling, Major, Significant, or Notable. The highest severity case is the March 1993 super storm with a NESIS value of 12.52 placing it in the "Extreme" category. Figure 1 shows examples of snowstorms in all five categories.

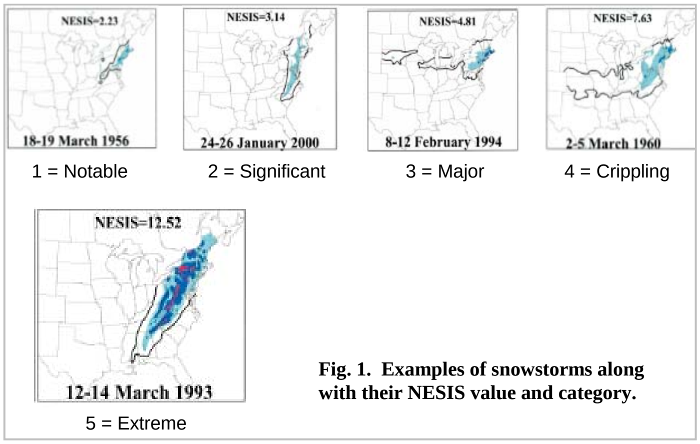


Fig. 1. Examples of snowstorms along with their NESIS value and category.

In February 2005, NCDC developed techniques for calculating NESIS so it could assign values to recent storms. Point snowfall amounts for a particular storm come from NCDC's archive of daily data collected by the Cooperative Observer Program (COOP). The techniques used by NCDC and Kocin are similar, but there are some fundamental differences. Although Kocin used a GIS (Arc View 3) as part of his process to compute the NESIS, he analyzed maps by hand and then selected affected counties in the GIS visually. The counties contain the aerial and population information used in the calculations. If more than half of a county was affected by a snowfall category, its population and area were used in the calculations.

The NCDC NESIS calculations are done entirely within a GIS (ArcGIS 9) including contouring the COOP snowfall amounts (which converts point values to areas). If NESIS is to be produced operationally with consistent results between storms, contouring techniques for all storms needs to be consistent. Also, NCDC uses a population density grid instead of county census values to account for the population portion of the NESIS algorithm. The population density grid is based on census data, but it is converted to an aerial density grid (population per square kilometer) that coincides with the snowfall grids. There are several advantages to using gridded population density. The amount of population and area used from a particular county is directly related to the proportion of the county affected. For example, if 20% of the county is affected, than 20% of the area and 20% of the population are used in the calculations. Using the population density grid ensures that the process of specifying the amount of population affected by a storm is objective and consistent between storms.

Computational Issues

There are several issues that must be considered when attempting to calculate the NESIS. First and foremost is quality control. Although NCDC quality control of COOP data is quite extensive and corrects many problems, the data still needs to be scrutinized before being used for these calculations. Figure 2 shows snowfall observations and the resulting snowfall grid for the 6-8 January, 1996 storm.

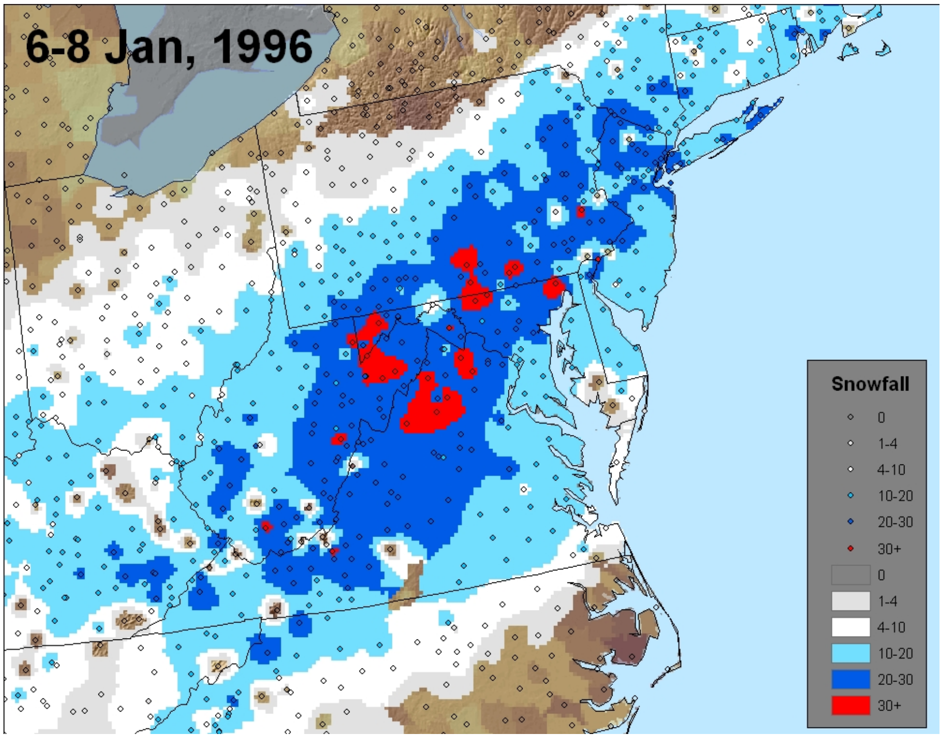


Fig 2. Snowfall observations and interpolated grid for the 6-8 January, 1996 storm.

Many of the "holes" in the snowfall grid result from snowfall observations with values of "zero". It is obvious from this map that these values should be "missing", not "zero". Figure 3 shows the analysis that results for the same storm after the erroneous data are removed. The new map looks much more realistic. This is one part of the NCDC process where the subjective judgment of an analyst comes into play.

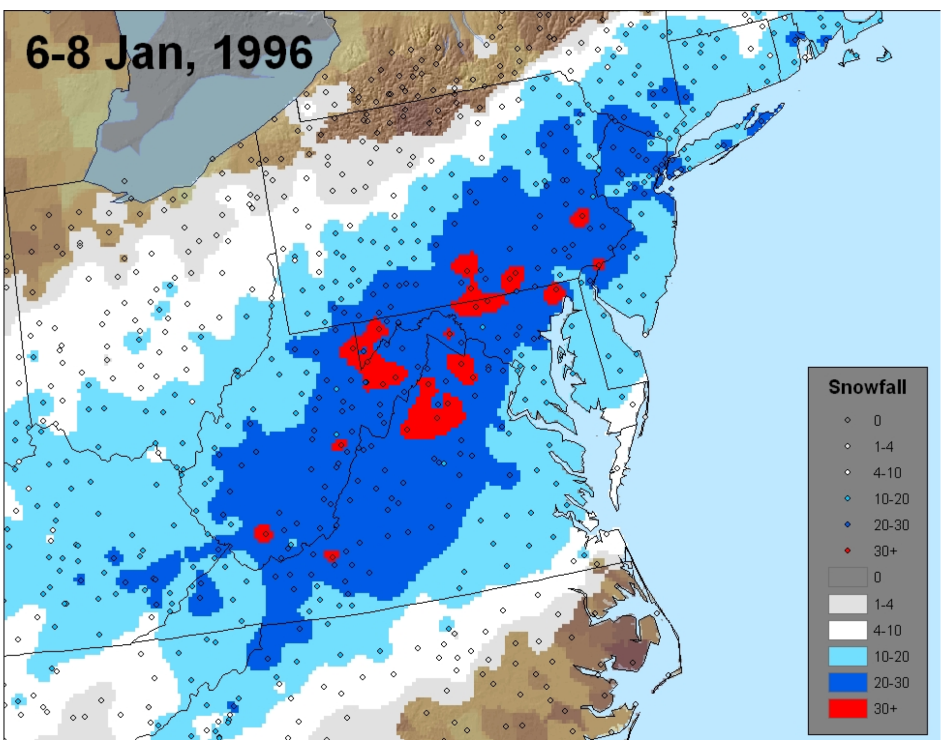


Fig. 3. Same as Fig. 2, however the erroneous data has been removed.

Another issue of concern is the sensitivity of NESIS calculations to area and population. The method chosen to estimate these quantities in a GIS can yield dramatically different results. Figure 4 shows an example of calculating area from county census data for the greater than 4” snowfall region using two different methods. One method selects the counties that intersect the snowfall area while the other only selects the counties that are completely contained within the greater than 4” snowfall area. The *intersection method* estimates an area of 407,000 square miles while the *contained method* estimates an area of 278,000 square miles. This problem is eliminated by using a gridded population density surface that is aligned with the snowfall grid because there is a one-to-one correspondence between the population density grid cells and the snowfall grid cells. Another benefit is that each grid cell is 25 sq. km. so area information for the calculations is inherent in the gridded data. The geoprocessing is done on an Albers Equal Area projection, so area distortion is minimized. The area of snowfall greater than 4” estimated from the population density grid is 367,000 sq. mi.

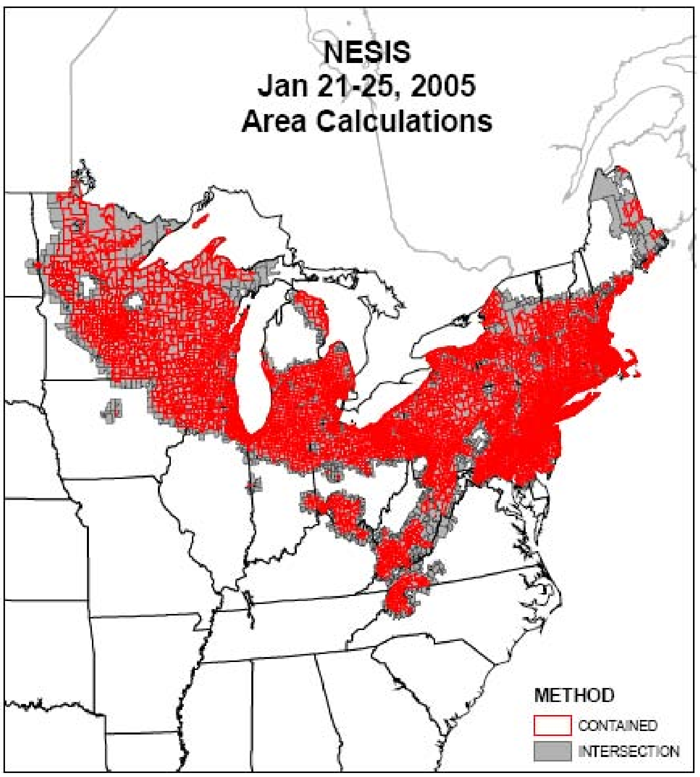


Fig.4. Comparison of different methods used to extract area and population information from census data.

NESIS Calculations at NCDC

The calculation of NESIS values for a particular storm involves a two step process. The first step includes plotting the storm totals for each station and creating a snowfall grid. The grid and station values are then quality controlled as discussed above. Erroneous or suspect station data is removed and a new grid is created. This process continues until the analyst is satisfied with the snowfall grid.

The next step involves running a script in GIS to calculate the area and population values for each of the four thresholds and summing these values according to the NESIS algorithm. Figure 5 shows how NESIS is calculated using the March 1993 storm as an example.

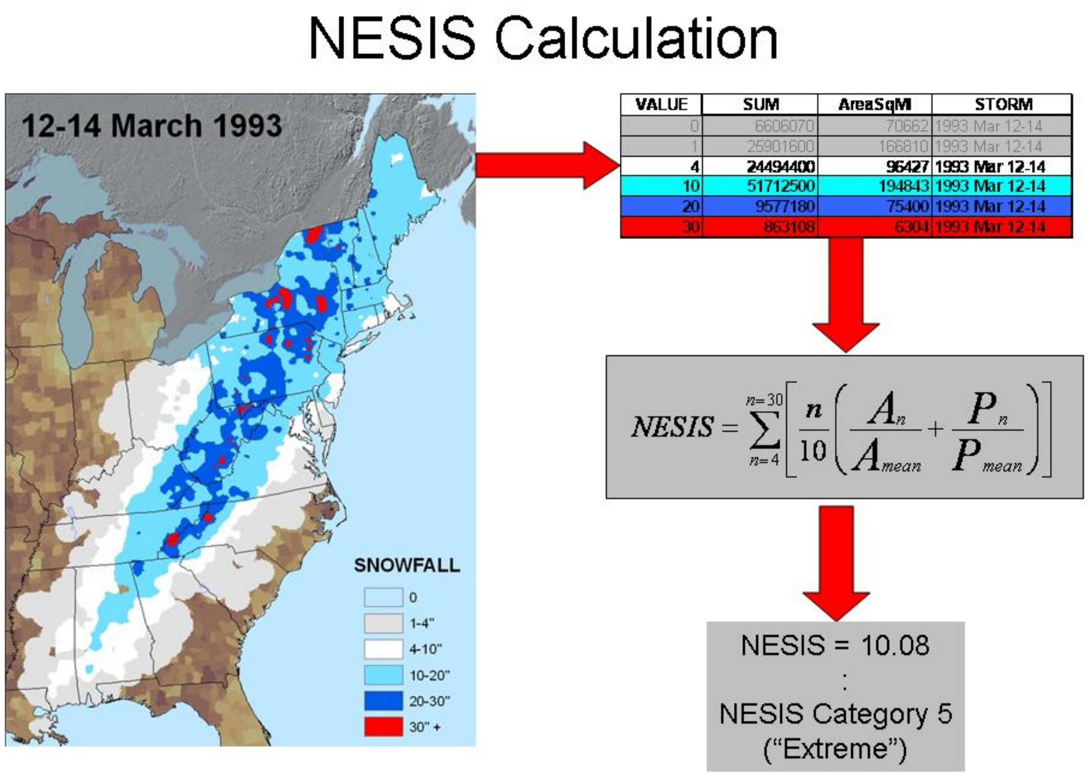


Fig. 5. Conceptual process for calculating NESIS in a GIS.

The population density grid is seen as the "earth tone" shades in the background. The snowfall grid is plotted on top of the population information. Population and area are summarized and extracted from the grids to a table. In the table displayed here, "Sum" refers to the population. The data in the table is used by the algorithm to calculate the NESIS values.

NCDC-Kocin Differences

There will always be differences between the NESIS values calculated by Kocin and those calculated by NCDC. As already pointed out, there are some fundamental differences in the way area and population information are implemented. Another issue is the snowfall data itself. Although NCDC and Kocin both use COOP data, it appears that on some storms, Kocin has more stations with high snowfall values than NCDC. The reason for this is unclear. Finally, Kocin uses hand drawn maps to define snowfall areas while NCDC uses an inverse distance weighted (IDW) method implemented within a GIS. While both methods produce good results, they will never be exactly alike.

NCDC calculated the NESIS for the 30 historical storms from Kocin's original article. Despite the different methods used to calculate NESIS, the results are quite comparable.

Table 1 shows how the NESIS values from the two different methods compare. The NCDC values are always lower than the Kocin's original values. The three largest storms have the same ranks. The differences shown in this table are summarized in Figure 6. The NCDC values have a negative bias of about *-1.0* and mean absolute error of about *1.0*. The differences are greater for the March 1993 and January 1996 super storms. The Spearmen correlation, which is based on ranks, is 0.96. This indicates that although there are some differences between the rankings, they are very similar.

Table 1. Comparison of Kocin and NCDC NESIS values and ranks.

NCDC RANK	Kocin Rank	STORM	NCDC NESIS	Kocin NESIS	DIFF	NCDC CATG	Kocin CATG
1	1	1993 Mar 12-14	10.08	12.52	-2.44	5	5
2	2	1996 Jan 06-08	9.05	11.54	-2.49	4	5
3	3	1960 Mar 02-05	6.72	7.63	-0.91	4	4
4	6	1961 Feb 02-05	5.42	6.24	-0.82	3	4
5	9	1964 Jan 11-14	5.30	5.74	-0.44	3	3
6	8	1978 Jan 19-21	5.01	5.90	-0.89	3	3
7	4	1983 Feb 10-12	4.82	6.28	-1.46	3	3
8	7	1958 Feb 14-17	4.80	5.98	-1.18	3	3
9	10	1969 Dec 25-28	4.80	5.19	-0.39	3	3
10	11	1966 Jan 29-31	4.53	5.05	-0.52	3	3
11	5	1978 Feb 05-07	4.45	6.25	-1.80	3	3
12	13	1994 Feb 08-12	4.16	4.81	-0.65	3	3
13	12	1987 Jan 21-23	4.13	4.93	-0.80	3	3
14	15	1979 Feb 17-19	3.66	4.42	-0.76	2	3
15	16	1972 Feb 18-20	3.65	4.19	-0.54	2	3
16	14	1960 Dec 11-13	3.50	4.47	-0.97	2	3
17	17	1969 Feb 22-28	3.28	4.01	-0.73	2	3
18	23	1961 Jan 18-21	3.12	3.47	-0.35	2	2
19	20	1966 Dec 23-25	2.92	3.79	-0.87	2	2
20	18	1958 Mar 18-21	2.71	3.92	-1.21	2	2
21	24	1969 Feb 08-10	2.71	3.34	-0.63	2	2
22	19	1967 Feb 05-07	2.71	3.82	-1.11	2	2
23	21	1982 Apr 06-07	2.57	3.75	-1.18	2	2
24	25	2000 Jan 24-26	1.93	3.14	-1.21	1	1
25	26	2000 Dec 30-31	1.82	2.48	-0.66	1	1
26	27	1997 Mar 31-01	1.76	2.37	-0.61	1	1
27	28	1956 Mar 18-19	1.45	2.23	-0.78	1	1
28	30	1987 Feb 22-23	1.13	1.46	-0.33	1	1
29	22	1995 Feb 02-04	1.11	3.51	-2.40	1	1
30	29	1987 Jan 25-26	0.91	1.70	-0.79	1	1

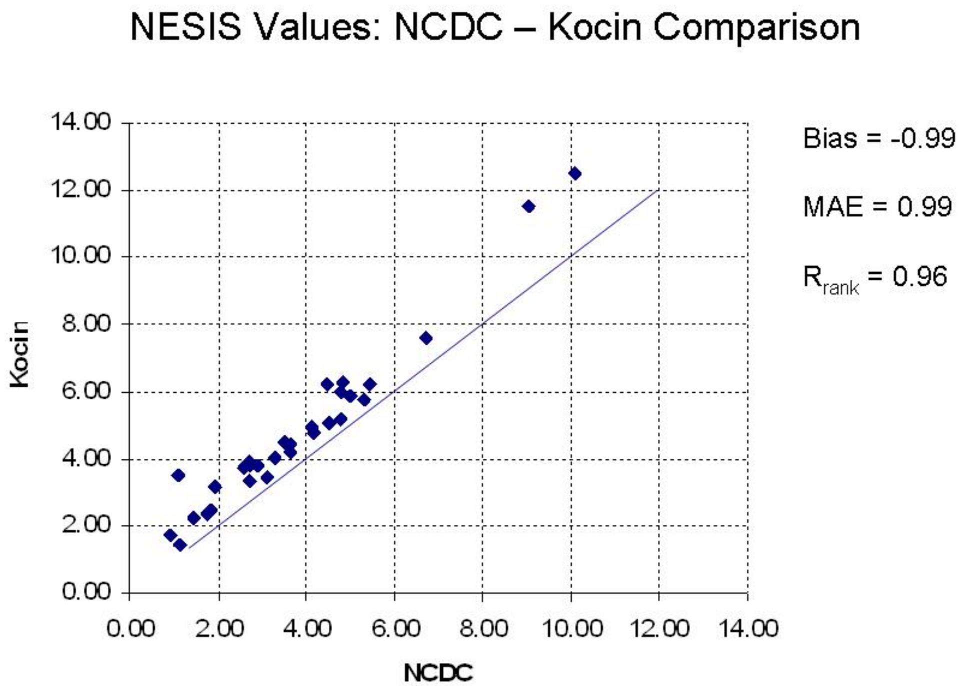


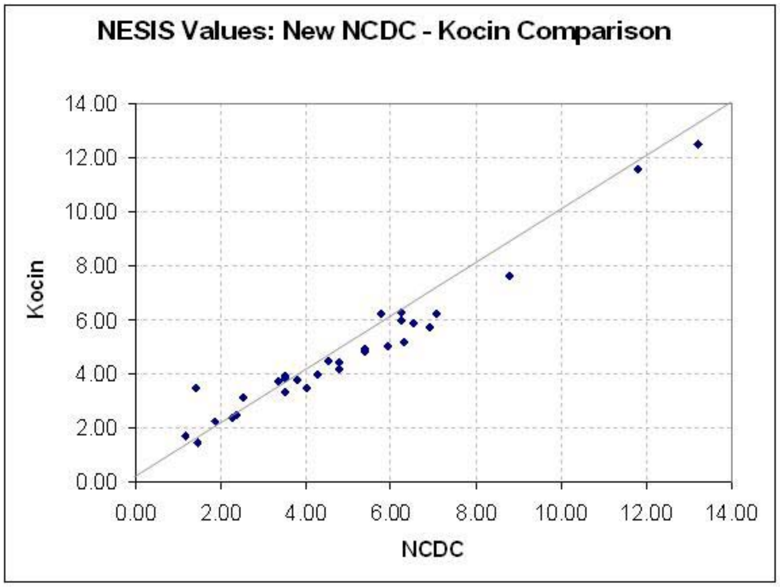
Fig. 6. Scatter plot of NCDC and Kocin NESIS values. MAE is the mean absolute error and R_{rank} is the Spearmen correlation coefficient.

Recall that the algorithm for NESIS contains two constants; the mean area (A_{mean}) and mean population (P_{mean}) for snowfall amounts greater than 10" within the 13 state Northeast region for the thirty historical snowstorms as originally calculated by Kocin. The negative bias indicates that there are systematic differences between NCDC's and Kocin's NESIS values. Therefore, it is appropriate to recalculate A_{mean} and P_{mean} to be consistent with the NCDC method. Since these parameters are in denominators, recalculating them based on NCDC procedures would increase the NCDC values and reduce the systematic differences between the two methods. While the primary purpose for recalculating these parameters is to ensure that the NCDC NESIS values are standardized correctly, it is also desirable for Kocin's and NCDC's methods to produce similar results.

New means were calculated over the 13 state region using NCDC procedures. The new values of A_{mean} and P_{mean} are 68,456 mi^2 and 27.868 million people respectively. The original values of mean area and population were 91,030 mi^2 and 35.4 million. Table 2 shows the new NCDC NESIS values after incorporating the new parameters using the NCDC procedures. The old NCDC values are included for comparison. It is readily apparent that using the new parameters have resulted in the NCDC and Kocin NESIS scores being closer together. The differences are smaller and they are no longer all negative. The new differences are summarized in Figure 7. Compared to Figure 6, the points in the scatterplot are more tightly grouped about the "r = 1" line and are no longer all above the line. The summary statistics confirm the visual evidence with the bias reduced to *0.15* and the MAE almost halved to *0.51*. Since the ranks did change much, the Spearman correlation coefficient is still around *0.95*.

Table 2. Comparison of Kocin and new NCDC NESIS values and ranks.

STORM	New NCDC NESIS	Kocin NESIS	NCDC-Kocin DIFF	Old NCDC NESIS	New NCDC RANK	Kocin RANK	Old NCDC RANK
1993 Mar 12-14	13.20	12.52	0.68	10.08	1	1	1
1996 Jan 06-08	11.78	11.54	0.24	9.05	2	2	2
1960 Mar 02-05	8.77	7.63	1.14	6.72	3	3	3
1961 Feb 02-05	7.06	6.24	0.82	5.42	4	6	4
1964 Jan 11-14	6.91	5.74	1.17	5.30	5	9	5
1978 Jan 19-21	6.53	5.90	0.63	5.01	6	8	6
1969 Dec 25-28	6.29	5.19	1.10	4.80	7	10	9
1983 Feb 10-12	6.25	6.28	-0.03	4.82	8	4	7
1958 Feb 14-17	6.25	5.98	0.27	4.80	9	7	8
1966 Jan 29-31	5.93	5.05	0.88	4.53	10	11	10
1978 Feb 05-07	5.78	6.25	-0.47	4.45	11	5	11
1987 Jan 21-23	5.40	4.93	0.47	4.13	12	12	13
1994 Feb 08-12	5.39	4.81	0.58	4.16	13	13	12
1972 Feb 18-20	4.77	4.19	0.58	3.65	14	16	15
1979 Feb 17-19	4.77	4.42	0.35	3.66	15	15	14
1960 Dec 11-13	4.53	4.47	0.06	3.50	16	14	16
1969 Feb 22-28	4.29	4.01	0.28	3.28	17	17	17
1961 Jan 18-21	4.04	3.47	0.57	3.12	18	23	18
1966 Dec 23-25	3.81	3.79	0.02	2.92	19	20	19
1958 Mar 18-21	3.51	3.92	-0.41	2.71	20	18	20
1969 Feb 08-10	3.51	3.34	0.17	2.71	21	24	21
1967 Feb 05-07	3.50	3.82	-0.32	2.71	22	19	22
1982 Apr 06-07	3.35	3.75	-0.40	2.57	23	21	23
2000 Jan 24-26	2.52	3.14	-0.62	1.93	24	25	24
2000 Dec 30-31	2.37	2.48	-0.11	1.82	25	26	25
1997 Mar 31-01	2.29	2.37	-0.08	1.76	26	27	26
1956 Mar 18-19	1.87	2.23	-0.36	1.45	27	28	27
1987 Feb 22-23	1.46	1.46	0.00	1.13	28	30	28
1995 Feb 02-04	1.43	3.51	-2.08	1.11	29	22	29
1987 Jan 25-26	1.19	1.70	-0.51	0.91	30	29	30



Diff. Stats: New NCDC - Kocin	
Bias	0.15
Mean Abs. Diff.	0.51
Root Mean Sq. Diff.	0.67

Spearmen (rank) and Pearson Correlations			
	New Rank	*Kocin Rank*	*Old Rank*
New Rank	1		
Kocin Rank	0.9537264	1	
Old Rank	0.9977753	0.95773081	1

Fig. 7. Similar to Fig. 6, but the NCDC values are based on mean area and population calculated using the NCDC methodology.

Summary

The Northeast Snowfall Impact Scale (NESIS) is an index developed to characterize and rank Northeast snowstorms. The index is not only based on snowfall amount, but also aerial extent of snowfall and population affected. Thus NESIS is believed to be an effective measure of a storm's societal impacts. NCDC has developed a semi-automated process for calculating NESIS scores on a near real-time basis. The values produced by NCDC are similar to those produced by Kocin, who developed the index. A comparison of the 30 cases from the original Kocin-Uccellini study shows the NCDC NESIS values have a bias of *0.15*, a mean absolute difference of *0.51* and a Spearmen correlation of *0.95*. Since the index is computed with somewhat different methodologies, these differences are to be expected. Plans to produce the NESIS operationally need to consider COOP data availability and further quality control.

References

Kocin, P. J., and L. W. Uccellini, *"A Snowfall Impact Scale Derived from Northeast Storm Snowfall Distributions"*. Bulletin of the American Meteorological Society, Feb 2004.

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