Identifying and Ranking Multi-Day Severe Weather Outbreaks

Chad M. Shafer[1] and Charles A. Doswell III[2]

[1] Department of Earth Sciences, University of South Alabama, Mobile, AL

[2] CIMMS, University of Oklahoma, Norman, OK

Objectives

•Identify severe weather outbreaks using kernel density estimation (KDE; Bowman and Azzalini 1997), as developed by Shafer and Doswell (2011), without a time constraint on the severe reports considered (e.g., 24 hours, as in Doswell et al. 2006; Shafer and Doswell 2010, 2011)

•Rank the qualifying cases using multivariate linear-weighted indices, based on preconceived notions regarding the severity of outbreaks

•Evaluate climatological characteristics and uncertainty associated with multi-day outbreaks and rankings

Data and Methods

•Severe reports from the Storm Prediction Center severe weather database (Schaeffer and Edwards 1999) are collected from 1960 to 2011.

•KDE with a Gaussian kernel function and a tunable bandwidth (120 km herein) is used to approximate a probability density function (PDF) associated with the severe reports. The PDF is determined by computing the distance between each report and the grid point of interest. The domain is a 1º latitude-longitude grid encompassing the conterminous United States.

•Severe reports are assessed for 6-h periods, with subsequent periods including the final three hours of the previous period. Using threshold values of the PDF, a KDE region is identified for a particular severe weather event for each 6-h period. Any KDE region that intersects a previous period's contiguous region is identified as part of the same event (case ID = YYYYMMDD_startUTC_clusterID; e.g., 19990503_30_1_2 = cluster 2 starting at 0600 UTC 4 May 1999; see examples in Fig. 6). The reports in each KDE region are collected (duplicates excluded), and each type of report is quantified, detrended if necessary, and standardized as in Shafer and Doswell (2011; see also Table 1 and Fig. 3). All events with total report numbers or report densities below the mean values of the events for the particular year are excluded.

•The remaining events are ranked using a multivariate linear-weighted index (as in Shafer and Doswell 2011 – see also Fig. 3). Several indices are developed to quantify the variability among the rankings (e.g., Figs. 1, 2, and 7). Results consistently indicate long-duration major tornado outbreaks are ranked highest (Figs. 4 and 5; Tables 2 and 3).

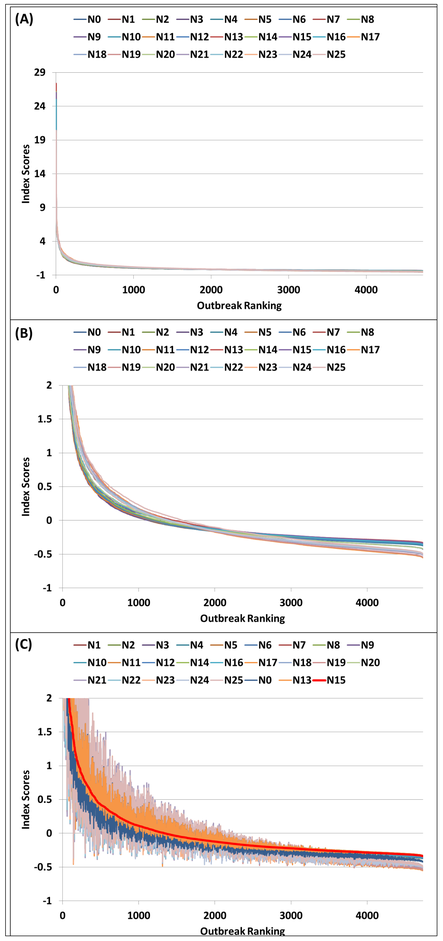

Figure 1: (a) Scores for each linear-weighted multivariate index (legend) as a function of outbreak ranking for each index. (b) As in (a), zoomed in to scores between -1 and 2. (c) As in (b), except scores for each index are indicated as a function of the outbreak rankings for the N15 index.

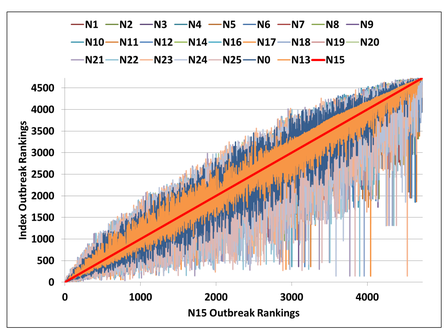

Figure 2: Rankings of the outbreaks for each linear-weighted multivariate index (y-axis) as a function of the outbreak's N15 ranking (from lowest rank number to highest rank number; *x*-axis).

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Table 1: Variables used for ranking the severe weather outbreaks in this study.

Variable	*Abbreviations used in subsequent tables*
Total number of severe reports*	ALL
Total number of tornadoes*	TORN
Total number of hail reports*	HAIL
Total number of wind reports*	WIND
Total number of significant hail reports*	SIGH
Total number of significant wind reports*	SIGW
Total number of significant tornadoes*	SIGT
Total number of violent tornadoes*	VIOT
Number of long-track tornadoes	LTT
Number of killer tornadoes	KT
Destruction Potential Index	DPI
Total path length	TPL
Fatalities	FTL
Report density*	DEN

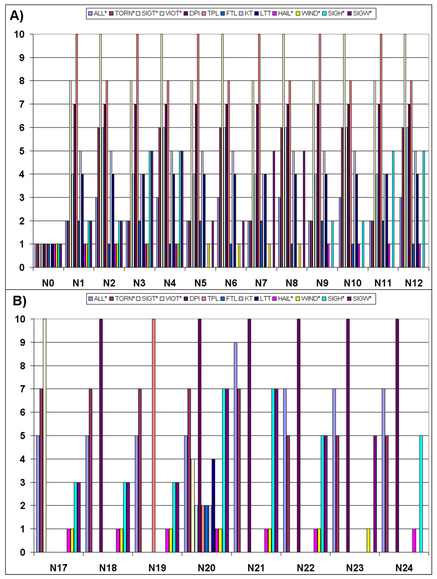

Figure 3: Weights for the variables listed in Table 1 for each index. An asterisk (*) indicates that the variable was detrended. Report density (DEN) was given a weight of 3 for each index. N13-N16 and N25 (not shown) are "maximum indices". N13 is the maximum score of N1, N5, and N9; N14 is the maximum of N2, N6, and N10; etc. N25 is the maximum of N22, N23, and N24.

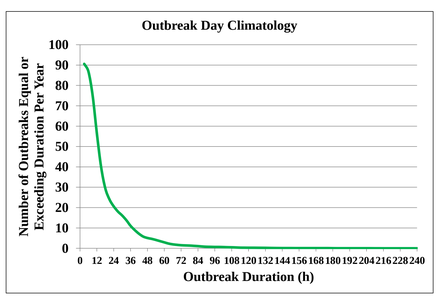

Figure 4: Average number of outbreak events per year, as identified by the KDE technique (4731 events in the period 1960–2011), equal to or exceeding a threshold duration in hours (*x*-axis).

	N0		N13		N14		N15		N16		N25	
20110426_15_1_1	18.83	20110426_15_1_1	27.38	20110426_15_1_1	26.15	20110426_15_1_1	26.03	20110426_15_1_1	25.01	20110426_15_1_1	20.42
19740403_12_1_1	16.53	19740403_12_1_1	21.44	19740403_12_1_1	20.33	19740403_12_1_1	20.60	19740403_12_1_1	19.52	20110521_18_1_2	12.59
20110521_18_1_2	11.28	20110521_18_1_2	11.79	20110521_18_1_2	11.77	20110521_18_1_2	12.20	20110521_18_1_2	12.13	20030429_18_1_2	12.40
20030429_18_1_2	10.88	20030429_18_1_2	10.88	20030429_18_1_2	10.70	20030429_18_1_2	10.67	20030429_18_1_2	10.88	19740403_12_1_1	11.32
19650411_15_1_1	7.90	19650411_15_1_1	9.33	19650411_15_1_1	8.88	19650411_15_1_1	8.92	19650411_15_1_1	8.14	20040520_21_1_3	9.86
20040520_21_1_3	7.00	20110414_15_1_1	8.36	20110414_15_1_1	8.18	20110414_15_1_1	8.03	20110414_15_1_1	7.89	20080522_15_1_1	7.32
19920615_15_1_2	6.01	19921121_18_1_1	8.26	19921121_18_1_1	8.04	19921121_18_1_1	7.77	19921121_18_1_1	7.61	20040529_18_1_1	6.85
20040529_18_1_1	5.43	20040520_21_1_3	7.00	20080204_24_1_1	6.53	19990503_21_1_4	6.29	19990503_21_1_4	6.35	19920615_15_1_2	6.78
19990503_21_1_4	5.35	20080204_24_1_1	6.55	19990503_21_1_4	6.52	19920615_15_1_2	6.28	20080522_15_1_1	6.34	20050602_18_1_3	6.42
20110414_15_1_1	5.32	20021109_24_1_2	6.36	19920615_15_1_2	6.24	20080204_24_1_1	6.27	19920615_15_1_2	6.29	19960419_21_1_1	6.26
20030507_18_1_2	5.00	19990503_21_1_4	6.23	20080522_15_1_1	6.20	20080522_15_1_1	6.24	20080204_24_1_1	6.28	19940424_33_1_1	5.68
19921121_18_1_1	4.96	20060310_24_1_3	6.18	20021109_24_1_2	6.09	20060310_24_1_3	6.13	20040520_21_1_3	5.98	20030507_18_1_2	5.58
20080522_15_1_1	4.92	20080522_15_1_1	6.09	20060310_24_1_3	5.92	20021109_24_1_2	6.10	20060310_24_1_3	5.89	19930606_24_1_1	5.49
20021109_24_1_2	4.76	19920615_15_1_2	6.01	19730526_15_1_2	5.73	20040520_21_1_3	5.84	20021109_24_1_2	5.87	20110612_33_1_2	5.46
20060310_24_1_3	4.64	19730526_15_1_2	5.76	20040520_21_1_3	5.62	20030507_18_1_2	5.53	20030507_18_1_2	5.64	20110414_15_1_1	5.45
19960419_21_1_1	4.62	19850531_18_1_1	5.53	20030507_18_1_2	5.59	19730526_15_1_2	5.49	19730526_15_1_2	5.47	19950515_18_1_2	5.37
19930606_24_1_1	4.62	20030507_18_1_2	5.44	19850531_18_1_1	5.20	19850531_18_1_1	5.30	20100616_12_1_1	5.13	19950605_15_1_2	5.25
20080204_24_1_1	4.61	20040529_18_1_1	5.43	20100616_12_1_1	5.01	20100616_12_1_1	4.96	19850531_18_1_1	5.00	19990503_21_1_4	5.15
20050602_18_1_3	4.55	19900312_21_1_1	5.02	19900312_21_1_1	4.98	19900312_21_1_1	4.80	20040529_18_1_1	4.90	19960525_15_1_1	5.02
20100616_12_1_1	4.38	19910425_21_1_2	4.67	19970228_18_1_1	4.93	20040529_18_1_1	4.78	19900312_21_1_1	4.79	20100616_12_1_1	5.00
19730526_15_1_2	4.28	19970228_18_1_1	4.62	19910425_21_1_2	4.73	19930606_24_1_1	4.68	19930606_24_1_1	4.75	20100423_15_1_1	4.83
19950515_18_1_2	4.21	19960419_21_1_1	4.62	19930606_24_1_1	4.72	19970228_18_1_1	4.67	19910425_21_1_2	4.72	19650411_15_1_1	4.73
19940424_33_1_1	4.17	19930606_24_1_1	4.62	20070504_18_1_2	4.70	19910425_21_1_2	4.66	19970228_18_1_1	4.66	19980529_24_1_3	4.68
19950605_15_1_2	4.13	20070504_18_1_2	4.60	20040529_18_1_1	4.68	20070504_18_1_2	4.53	19960419_21_1_1	4.58	19921121_18_1_1	4.59
20110612_33_1_2	4.02	20050602_18_1_3	4.55	19990120_33_1_1	4.49	19600505_18_1_2	4.36	20070504_18_1_2	4.55	20060310_24_1_3	4.48

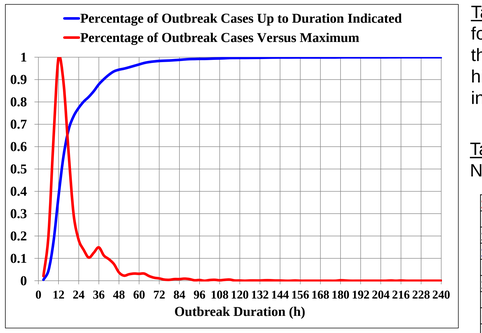

Figure 5: Percentage of cases with a given duration (*x*-axis) versus the duration with the maximum number of cases (red curve), and percentage of cases with durations less than or equal to the given duration (blue curve).

Table 2 (above): The top 25 severe weather outbreaks for the N0, N13, N14, N15, N16, and N25 indices, and their associated index scores. Some cases are highlighted for convenience. Case IDs are described in the text.

Table 3: The top 25 severe weather outbreaks for the N15 index, and their associated durations (h).

20110426_15_1_1	66	20021109_24_1_2	72
19740403_12_1_1	42	20040520_21_1_3	186
20110521_18_1_2	138	20030507_18_1_2	111
20030429_18_1_2	216	19730526_15_1_2	90
19650411_15_1_1	33	19850531_18_1_1	18
20110414_15_1_1	66	20100616_12_1_1	150
19921121_18_1_1	48	19900312_21_1_1	63
19990503_21_1_4	111	20040529_18_1_1	132
19920615_15_1_2	141	19930606_24_1_1	90
20080204_24_1_1	57	19970228_18_1_1	78
20080522_15_1_1	144	19910425_21_1_2	45
20060310_24_1_3	84	20070504_18_1_2	93
		19600505_18_1_2	45

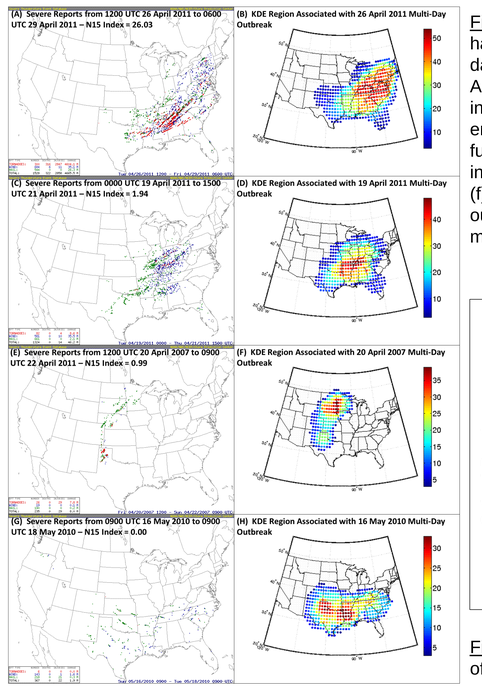

Figure 6 (left): (a) Severe reports (tornadoes in red; hail in green; wind in blue) for the 26 April 2011 multi-day outbreak. (b) KDE region associated with the 26 April 2011 multi-day outbreak. Each filled grid point indicates the time (in hrs) that grid point was encompassed by a KDE-derived probability density function magnitude exceeding $5*10^{-6}$ km^{-2}. (c)-(d) As in (a)-(b), for the 19 April 2011 multi-day outbreak. (e)-(f) As in (a)-(b), for the 20 April 2007 multi-day outbreak. (g)-(h) As in (a)-(b), for the 16 May 2010 multi-day outbreak.

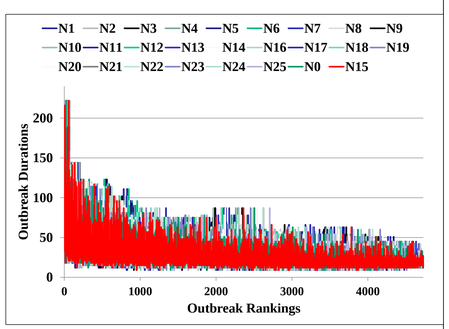

Figure 7: Duration of each outbreak (h) as a function of outbreak ranking for each of the 26 indices tested.