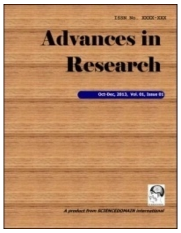

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High Risk Periods in Tornado Outbreaks in Central USA

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

This study provides numerical comparisons of tornado outbreak risks in developed synoptic system along the season and along the time of a day. Time of day yields sharply changing risk along the geographic time (solar time) adjusted to the longitude of location, which makes it equal opportunities to sun energy supply in different locations. As a result of this paper, most dangerous short time interval for each location can be provided in approaching tornado watch situation. Diurnal probability profile of tornado outbreaks in Texas from 1955 through 2012 was investigated and sharply changing diurnal risks were provided based on actual data. Of all 7,997 tornadoes in Texas, about 54% (4352 tornadoes) developed during the high risk spring season. In the spring season 55% (2,392 tornadoes) occurred during the high risk time window (geographically adjusted time 3:31PM to 8:30PM). Those patterns remain absolutely the same for neighboring states. These data assure us to make extra warnings in many practical situations of approaching dangerous front that depends on a time of event.

Keywords: Kolmogorov-zurbenko fourier transform; tornadoes; geographic time; solar time; spectral analysis; diurnal risk; probabilistic intensity.

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1. INTRODUCTION

During the past decades, there have been numerous studies in this country aimed at assessing the tornado formation and/or tornado evolution for selected tornadoes [1-6]. These studies have individually assessed the tornadogenesis process of specific tornadoes. For example, based on an integrated analysis of the progression of wind, rain, and thermodynamic fields in the parent supercell, Kosiba and his colleagues [2] reconstructed the tornadogenesis process occurring on 5 June 2009 in Goshen County, Wyoming.

For the most part, the techniques used to deduce the tornadogenesis in these studies were applying the local Doppler Radar data to various analysis algorithm, such as diabatic Lagrangian method, Kinematic or thermodynamic analysis in each case respectively. These studies provided with the detailed estimations for each unique tornado. However, its holistic features relevant to tornado occurrence are missing. Does tornado occur at any time anywhere with equal probability? What are their diurnal pattern of likelihood and their periodicity if they exist?

To study its diurnal feature of tornado onset, the Kolmogorov-Zurbenko periodogram (KZP) algorithm is an ideal approach to employ [7]. It is known as a useful tool for time series analysis and has been widely used for meteorological air quality time series analysis [8-10], especially in separation of high-resolution wavelets from noisy background [11-13]. By applying the hourly tornado data over 58 years in Texas to KZ algorithm and generalized additive models fit, we therefore investigated the tornado periodicity and the diurnal likelihood of tornado onset in Texas, in different season and by different F-scale respectively.

2. BACKGROUNDS AND DATA SOURCE

2.1 Data Source

The hourly tornado dataset is derived from merging an hourly sequential data series with the “All Tornadoes” data (1950 – 2012) from the Storm Prediction Center, NOAA’s National Weather Service (http://www.spc.noaa.gov/wcm/#data). National Weather Service provides comma separated value (.csv) files for tornado, hail, and damaging wind data as compiled from NWS Storm Data. Tornado reports exist back to 1950 while hail and damaging wind reports date from 1955. Therefore we extracted hourly tornado data from 1955 through 2012 for Texas in this study.

2.2 The Tornado F-scales

The F scale was named for Professor Ted Fujita at University of Chicago in 1971. It has been used as a measure of damage intensity by tornado [14]. It grades tornadoes from F0 through F5 (Table 1) based on the wind speed, with the higher wind speed causing more severe damage.

Table 1. F-scale tornadoes

F-scale	**F0**	**F1**	**F2**	**F3**	**F4**	**F5**
Wind speed (miles/hour)	40-72	73-112	113-157	158-205	206-260	261-318

2.3 The Likelihood of Tornado Risks

2.3.1 Probability of tornado onset

Let all the number of tornadoes that occurred in Texas from 1955 through 2012 be a unit. Then at each diurnal hour-point, the proportion of tornadoes of each category (such as F-scale, season) during the study period is defined as probability of tornado onset.

2.3.2 Relative tornado intensity

Let all the number of tornadoes in each category (such as F-scale, season) occurred in Texas from 1955 through 2012 be a unit. Then at each diurnal hour-point within each category, the proportion of tornadoes occurred in Texas from 1955 through 2012 is defined as relative tornado intensity.

2.4 Description of Tornado Outbreaks from 1955 through 2012 in Texas

A total of 7997 tornadoes with valid date and location of occurrence (5 tornadoes were removed due to lack of geographic location information) in Texas from 1955 through 2012 were identified. Distribution of yearly tornado onsets displayed a violent turbulence in the number of annual tornadoes across the years studied (Fig. 1A). For most of the years (45 out of 58), the number of tornado onsets was between 100 and 200. The years in which number of tornado occurrence exceeding 200 fell in 1967 (n=232), 1982 (n=206) and 1995 (n=235). On the contrary, the number of tornado occurrence was only 56 in 1956. Like the yearly pattern, the number of hourly tornado counts dramatically jumped up-and-down, with the highest number of 13 tornadoes developed within the same hour in Texas (Fig. 1B). In general, when tornado occurred, about 50% of the tornadoes (3985 out of 7997), had developed as single tornado within the same hour; On the other hand, another 50% of tornadoes had developed as multiple tornadoes within the same hour (Table 2). Among the multiple tornado onsets, about a quarter of them evolved as two tornadoes in the same hour. Furthermore, 11 tornadoes evolved simultaneously within the same hour twice in 1967 and once in 2006; during 6:31PM and 7:30PM (adjusted time) on December 14, 1971, 13 tornadoes occurred in Texas. Our goal was to look for any predictable patterns behind these unpredictable tornado onsets.

Table 2. Tornado Multiplicity in the Same Hour

Multiple tornadoes at same time (hour)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**11**	**13**
Frequency	3985	927	346	123	56	23	16	2	4	3	1
# of tornadoes	3985	1854	1038	492	280	138	112	16	36	33	13
Percent (%)	49.83	23.18	12.98	6.15	3.50	1.73	1.40	0.20	0.45	0.41	0.16

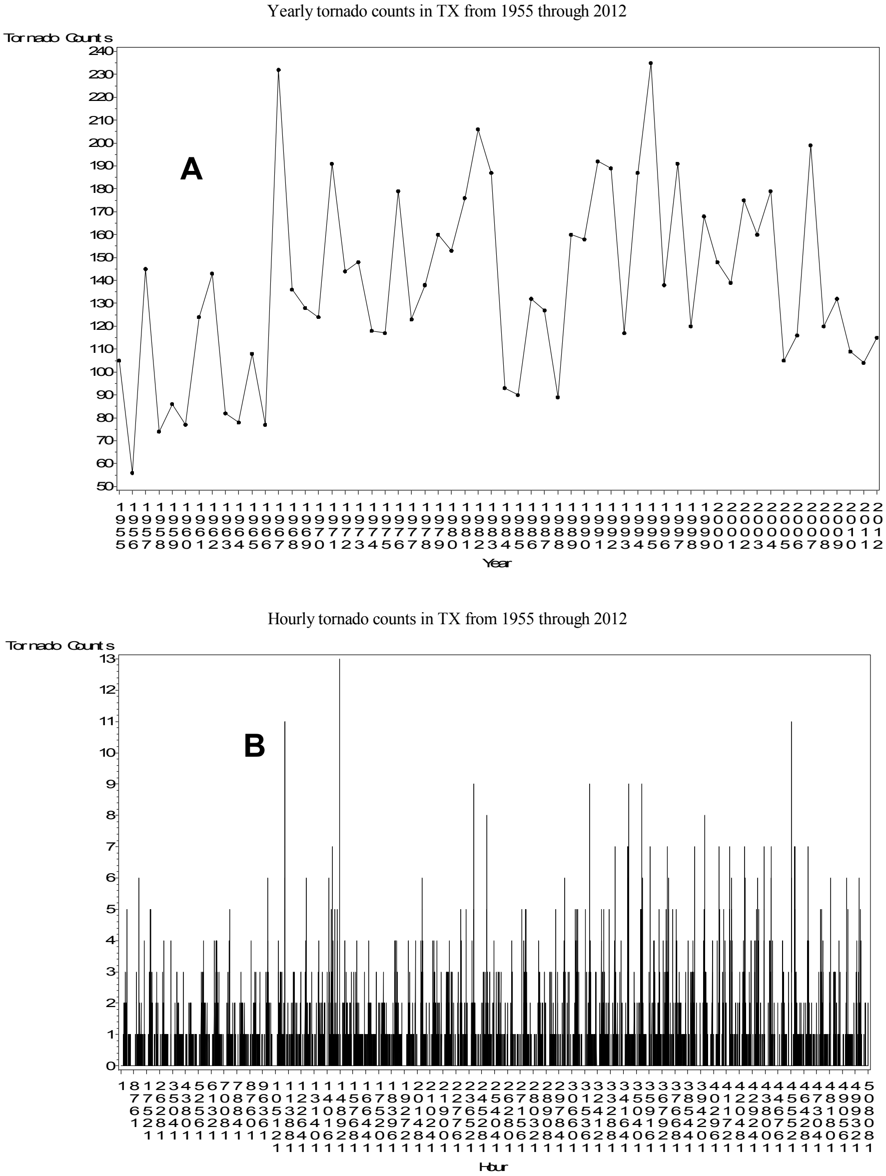

Fig. 1. Temporal series distribution of tornado occurrence in Texas from 1955-2012 (unadjusted local time)
A. annual time series trends; B. hourly tornado onsets

3. SPECTRA ANALYSIS OF THE HOURLY TORNADO SERIES

The spectra is an important diagnostic tool to uncover any periodicity and dominant frequency of the data if they exist. A highly distinguished algorithm of such diagnostic techniques is provided in Kolmogorov-Zurbenko Periodogram (KZP) R-software. KZP is a member of Kolmogorov-Zurbenko (KZ) statistics, derived from KZ filter [13]. According to Eskridge and Zurbenko [15], KZ filter has unique power to distinguish signals and smooth out noises with high resolution while applied in non-equally spaced or missing data environment. Assume time series {X(t)}, t= 0, 1, …, N-1, then KZP is defined as:

$f_N(\lambda) = (1/T)*\mathrm{SUM}(|\mathrm{KZFT}_{m,k,\lambda}[X(t)]|^2)$,

where $\mathrm{KZFT}_{m,k,\lambda}[X(t)] = \mathrm{SUM}[(a_s^{m,k}/m^k)*X(t+s)*e^{-i\lambda S}$

The steps of performing KZP algorithm are summarized as:

1) Input time series {X(t)}, t = 0, 1, 2, …, N-1
2) Choose the parameters m, k, smoothing method and smoothing level. The default smoothing level is 5% for DZ method
3) Choose the sampling frequency rate within the interest band. The default frequencies are defined as $2\pi i/m$,i = 0, 1, …, m-1
4) Perform the KZP to estimate the spectrum

We applied KZP algorithm to recover the periodicity of tornado occurrence in Texas. The output periodogram peaked at frequency of 0.000114, 0.000228 and 0.041667 cycles/hour; it corresponds to 8760-hour, 4380-hour and 24-hour period respectively (Fig. 2). Most likely, this periodicity corresponds to sun energy influence.

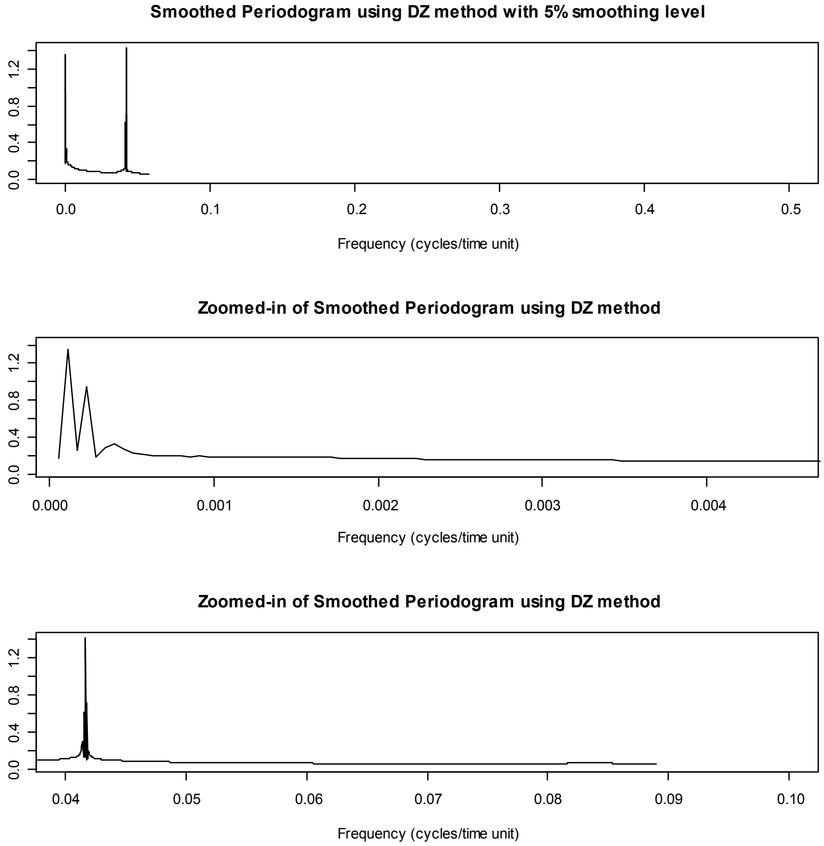

Fig. 2. Spectra of hourly tornado onset data (unadjusted local time)
A, 5% DZ method smoothed periodogram; B, zoom-in display of the spectrum distribution

4. TIMING ATTEMPT AND NECESSITY OF GEOGRAPHIC TIME

4.1 Uniformity of "Winter" Time to "Daylight Saving Time"

Although daylight saving time (DST) has been used in the United States since World War II, it was not enforced by federal law until 1966; it was left free for local option from 1945 to 1966. From 1955, most places including TX did observe DST from the last Sunday in April to the last Sunday in October. Effective in 1967, federal law mandated that DST start on the last Sunday in April and end on the last Sunday in October. Beginning March 11, 2007, DST was extended nation widely, from the second Sunday in March to the first Sunday in November. In this study, we keep the "Daylight Saving Time", also known as "summer" time as it is, but adjust the "winter" time to DST time for all the years studied accordingly.

4.2 Synchronization of Local Time to Geographic Time

As the second largest state, Texas is pretty spread out, occupying about 7% of the total water and land area of the US. It covers about 12 longitudinal zones, starting from -93° to -105°, this corresponds to about 1 hour time lag. To see if there exist a timing shift of tornado occurrence, we grouped Texas as "East" region (-93 ° to -99 °) and "West" region (-99° to -105°). While comparing the diurnal pattern of tornado onsets in east-region to that in west-region, the overall timing of the tornado onsets in east-region is about 1 hour earlier than that in west-region (Fig. 3). In east-region, the frequency curve summited at 5:00PM, whereas it summited at 6:00PM in west-region. This timing shift feature demonstrated that tornadoes occurred in "East" developed earlier than that in "West", while referenced to the local time in Texas. It is obvious that its sole administrative time (Central Time Zone) acquires some non objectivities in analyzing tornado onset. We also looked at the timing of tornado development in Florida which is located in East Time Zone. Diurnal distribution of tornado occurrence displayed a 2 to 3 hours leading time compared to that in Texas (data not reported here). Furthermore, we compared frequencies of tornado onsets in different states locating in the same time zone, including Texas, Oklahoma and Kansas (Fig. 4). Relative tornado intensity peaked at the same time point (6:00PM) in all the three states. Unlike tornadoes occurring in different time zones or distant areas within the same zones, tornadoes developed in areas located in the same longitudinal zone, followed the same timing pattern.

Given the substantial timing shift in tornado development in different longitudinal zone, its sole local time is not good enough to apply in our analysis. We therefore introduced an area-specific time measure - geographic time (GT) as the simplest possible correction to administrative local/regional time, by adjusting the local time based on a precise reference (-100 degree line).

To get the geographic time (GT) at different areas in Texas, set the time-longitude constant
c = 24*60/360 = 4 minutes/degree.

Let the longitude -100 degree line (located in the middle area of Texas) be the baseline, and its adjustable degree ad = 0, its adjustable time at = 4*ad = 0.

Its geographic time GT_0 = local time (LT) - 4*ad = LT - 0 = LT;
For all the other areas in Texas, their geographic time:

GT_i = LT – at_i= LT - 4*ad_i = LT + 4*(100 - longitude), depends where it is located.

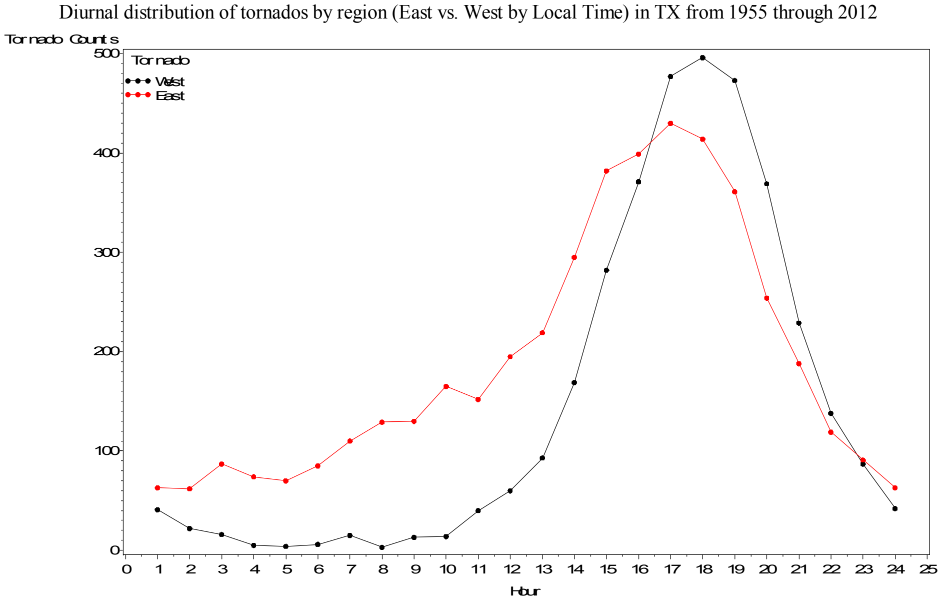

Fig. 3. Frequency of tornado onsets at each diurnal hour-point in east and west region in Texas (unadjusted local time)

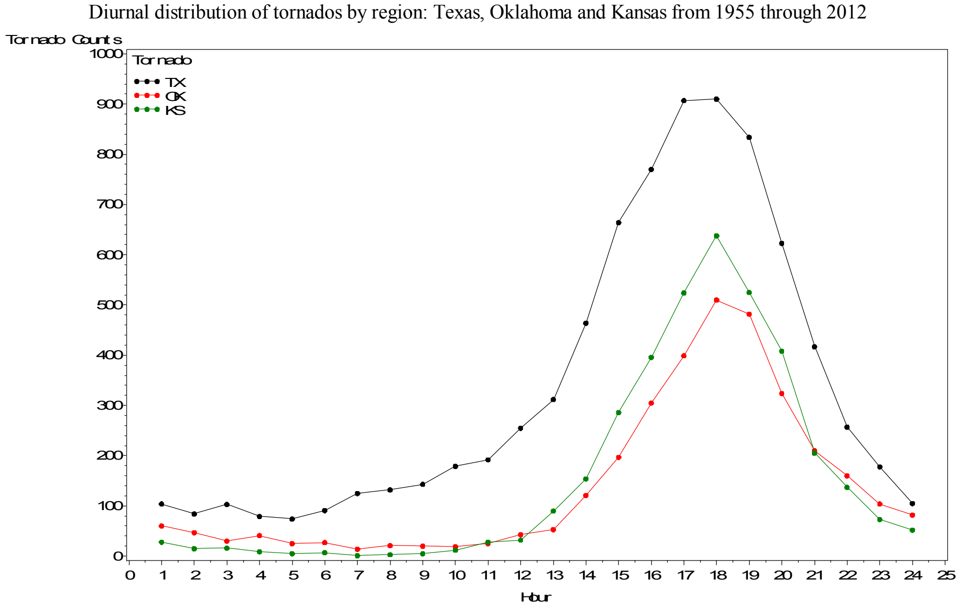

Fig. 4. Diurnal frequency of tornado onsets in Texas, Oklahoma and Kansas (unadjusted local time)

We generated the area specific GT time through longitude adjustment of local time from the approximate midpoint in Texas in this study. This not only “corrected” timing shift (resulted from administrative time), but also provided the simplest connection to administrative time.

However, Patterns of risks would remain the same anywhere else far away from Texas. If it would be necessary to do this adjustment there, it will be better to do it by referencing the moment of which the sun crossing meridian at any arbitrary location. It will provide a uniform adjustment everywhere to facilitate tornado risk analysis properly.

After geographic time synchronization, we measured the relative tornado intensity in east- and west-region in Texas (Fig. 5). The timing shift of tornado onsets between east- and west-region was obviously ameliorated.

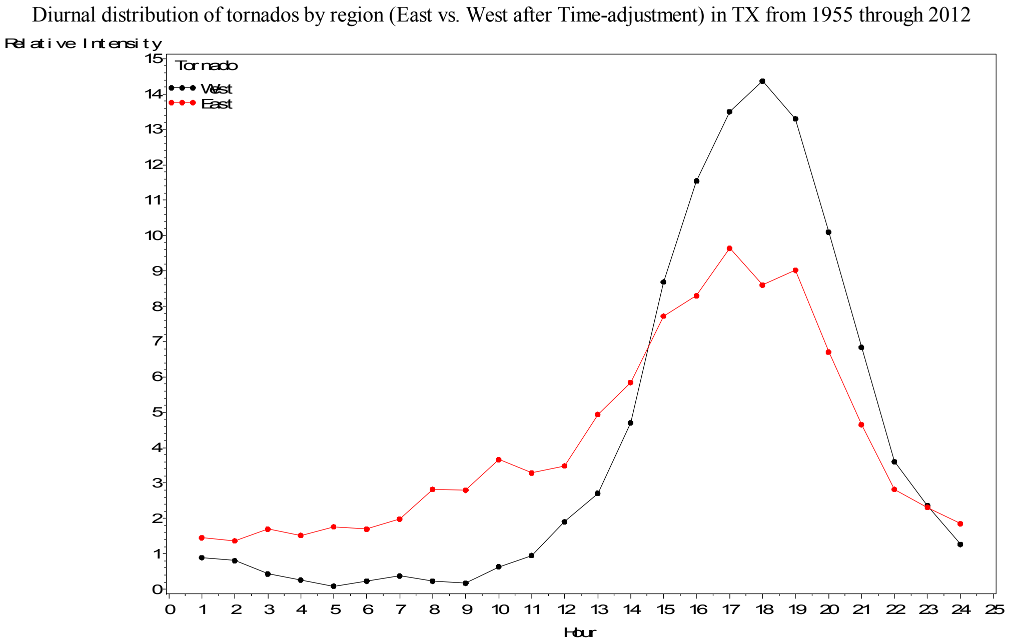
Diurnal distribution of tornados by region (East vs. West after Time-adjustment) in TX from 1955 through 2012

Fig. 5. Relative intensity of tornado occurrence in east- and west-region of Texas (geographically adjusted GT time)

5. RISKS OF TORNADO ONSETS

5.1 Diurnal Risks of Tornado Onsets

Fig. 6 displayed an impressive relationship between tornado onsets and geographic hour-point; this typical periodicity is strongly supported by spectra analysis. All the three states, Texas, Oklahoma and Kansas showed a similar risk pattern of tornado onsets. While under the ‘right’ condition, within a 5-hour time window in the late afternoon (3:30PM through 8:30PM), risks of tornado occurrence were 50.8%, 60.9% and 68.3% in Texas, Oklahoma and Kansas respectively; when looking at a 3-hour interval from 4:30PM through 7:30PM, the risk was still 33.1%, 41.9% and 46.2% respectively. Our results are consistent with the “hourly tornado occurrence”, reported by NOAA [16] and National Weather Service Weather Forecast Office [17] respectively. However, they used local time in their reports.

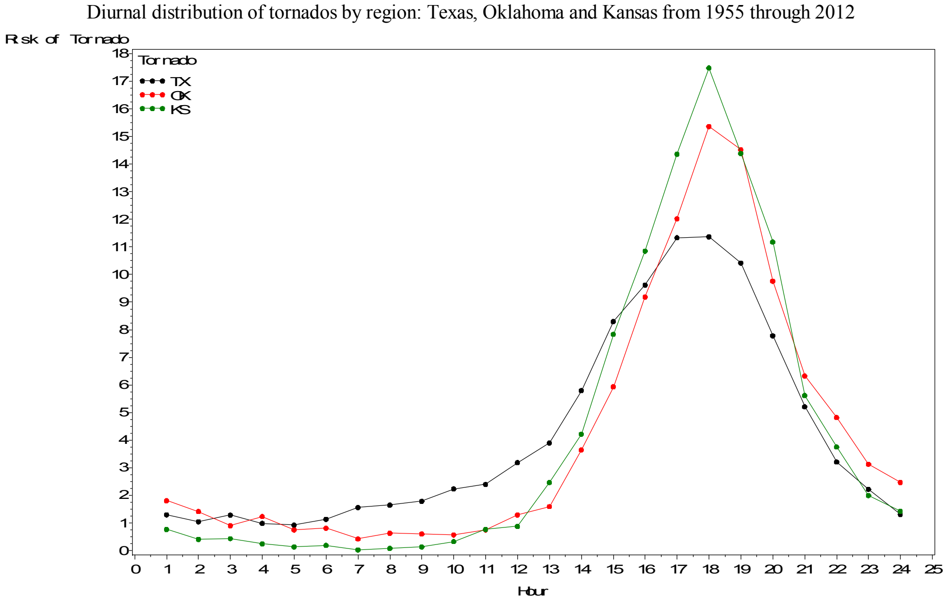
Diurnal distribution of tornados by region: Texas, Oklahoma and Kansas from 1955 through 2012

Fig. 6. Overall risk distribution of tornado onsets by hour in Texas, Oklahoma and Kansas (geographically adjusted GT time)

5.2 Non-parametric Model Fit of the Relationship between Tornado Onset and Diurnal Hour

Considering the conditions of developing a tornado includes many climate factors, a parametric model might force the fitted relationship away from its natural path at critical points. Fortunately, by relaxing the usual assumption of linearity, Generalized Additive Models (GAM) enables to uncover structures in the relationship between response variable and predictor variables that might otherwise be missed. We applied a GAM spline algorithm to investigate the diurnal profile of tornado occurrence in Texas.

Given the 24-hour period of tornado onset in Texas, we then looked for any significant association between tornado occurrence and diurnal “hour” time points. We rolled up any tornadoes occurred from 1955 through 2012 in Texas to the “hour” point level, then applied the GAM model fit. For the smoothing effect in the model, Table 3 displayed a chi-squared test, showing that diurnal hour highly associated with tornado occurrence in Texas; this fitted GAM could explain 99.8% deviation regarding to tornado onset in Texas. We can get a sense of the fit by simply visualizing Fig. 5. We noted the number of tornadoes climbing up abruptly after 2:00PM, and in addition, the tapering off after 6:00PM (Fig. 7).

Table 3. Generalized additive model analysis

Smoothing Model Analysis Approximate Analysis of smooth terms					
Source	**DF**	**Chi-Square**	**Pr > ChiSq**	**R-squared**	**Deviance**
Spline(hour)	8.21684	2788.4493	<.0001	0.996	99.8%

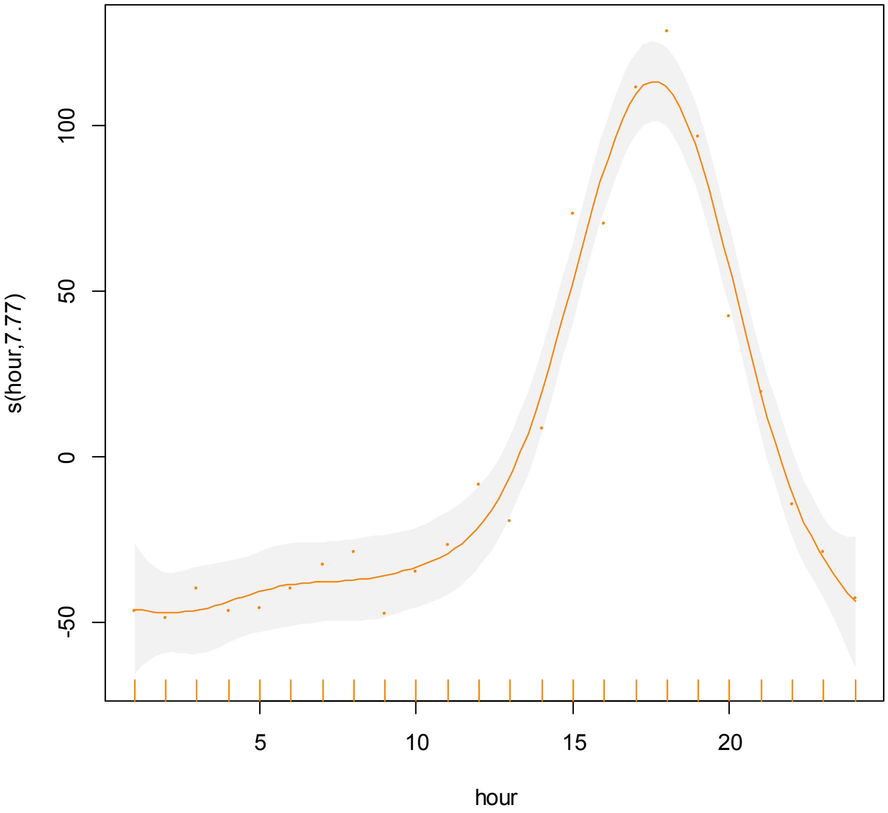

Fig. 7. Graphical display of the GAM fit (geographically adjusted GT time)

6. COMPARISONS OF TORNADO RISKS IN TX

6.1 Seasonal Profile

Although tornadoes occurred at any time anywhere of the world, tornadoes developed in Texas from 1955 through 2012 displayed a clear seasonality and/or diurnal hour-preference. The probability of developing tornadoes was dramatically high in the late afternoon in spring and summer (Fig. 8, 9 and Table 4). More than half tornadoes (54.4%, 4352 out of 7997) occurred in March, April and May, but only 6.7% (523 out of 7997) tornadoes happened to occur in winter time (December, January and February). The diurnal pattern of tornado occurrence demonstrated a clear discrepancy in different season. The majority of tornadoes developed in the late afternoon, peaking at the evening hours between 4:30PM and 7:30PM in spring. During this 3-hour spike interval, more than one third of spring tornadoes evolved. Tornadoes developed in summer displayed an expanded, but relative flat peak hours, ranging from 2:30PM through 8:30PM; unlike that in spring or summer, tornadoes occurred in autumn and winter did not show impressive peak hours. Whereas while looking at the relative intensity of tornado onsets (Fig. 9), it displayed a late afternoon 'rush hour' of tornado onsets for all the four seasons. Of course, it was much more explicit in spring and summer than that in autumn or winter.

Table 4. Tornado onsets in Texas from 1955 through 2012 by season and hour

Hour	Time Span	Spring	Summer	Autumn	Winter	Total
1	0:31AM - 1:30AM	59	12	19	7	97
2	1:31AM - 2:30AM	55	12	15	8	90
3	2:31AM - 3:30AM	57	8	22	5	92
4	3:31AM - 3:30AM	35	3	24	16	78
5	4:31AM - 5:30AM	41	9	20	13	83
6	5:31AM - 6:30AM	39	11	29	6	85
7	6:31AM - 7:30AM	60	13	25	5	103
8	7:31AM - 8:30AM	55	24	44	13	136
9	8:31AM - 9:30AM	49	30	34	20	133
10	9:31AM - 10:30AM	63	46	58	21	188
11	10:31AM - 11:30AM	74	46	48	14	182
12	11:31AM - 12:30PM	106	40	56	22	224
13	12:31PM - 13:30PM	152	82	60	24	318
14	13:31PM - 14:30PM	229	110	63	26	428
15	14:31PM - 15:30PM	335	196	85	35	651
16	15:31PM - 16:30PM	452	195	96	33	776
17	16:31PM - 17:30PM	509	240	111	45	905
18	17:31PM - 18:30PM	533	213	107	35	888
19	18:31PM - 19:30PM	492	226	90	62	870
20	19:31PM - 20:30PM	406	162	53	33	654
21	20:31PM - 21:30PM	255	125	46	22	448
22	21:31PM - 22:30PM	139	71	30	13	253
23	22:31PM - 22:30PM	97	43	24	23	187
24	23:31PM - 0:30AM	60	17	29	22	128
Total		**4,352**	**1,934**	**1,188**	**523**	**7,997**

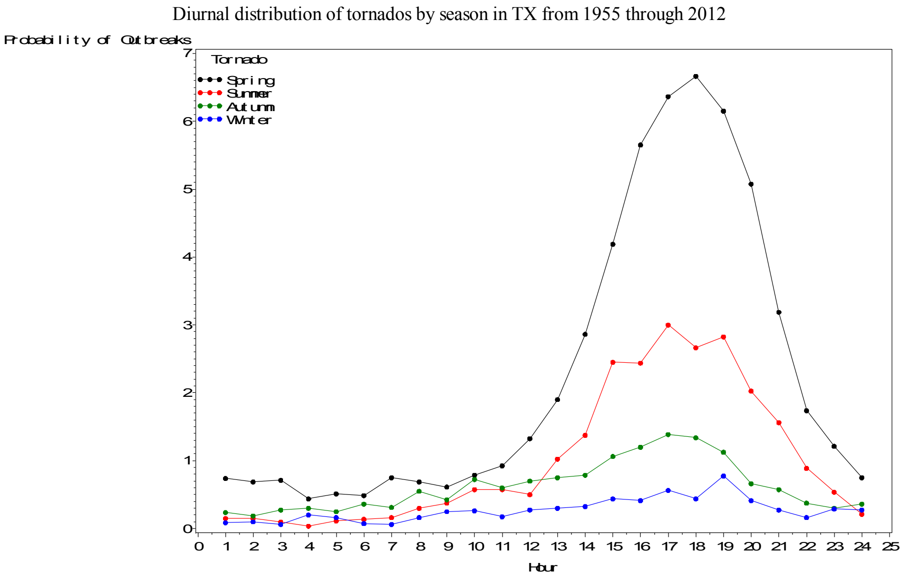

Fig. 8. Probability of Tornado onsets in Texas from 1955 to 2012 by season and hour (geographically adjusted GT time)

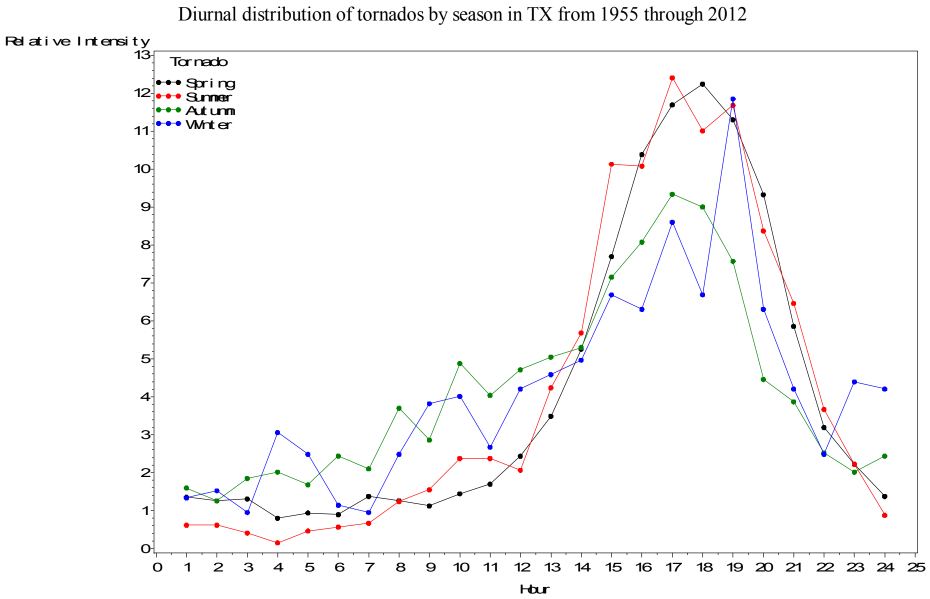

Fig. 9. Relative intensity of tornado occurrence by season from 1955 to 2012 in Texas (geographically adjusted GT time)

6.2 F-scale Profile

We were also interested in the risk pattern of different scale of tornadoes. As shown in Fig. 10 and Table 5, probabilities to develop lower F scale tornadoes were high, but probabilities of developing higher F scale tornadoes (F3, F4 and F5) were low. Of all 7997 tornadoes, 51.8% were F0 tornadoes, only 0.6% were F4 or F5 tornadoes. Diurnal patterns of outbreaks were similar for F0, F1 and F2 tornadoes; all three types of low F scale tornadoes displayed the late afternoon peak between 4:00PM and 7:00PM, although probability curve for F2 was not summited as F0 or F1; and these late afternoon spikes were more impressive while looking at their relative intensity curve (Fig. 11). Even probability curve for F4 or F5 was flat due to very few tornadoes, their relative intensity curve also substantially jumped up at the afternoon hours. For each F scale, about 50% of tornadoes developed during 3:30PM through 7:30PM time window.

Table 5. Tornado distribution by F Scale

F Scale	F0	F1	F2	F3	F4 or F5	Unknown
Tornado Count	4,142	2,200	1,119	286	48	202
Tornado %	51.79	27.51	14.00	3.58	0.60	2.53

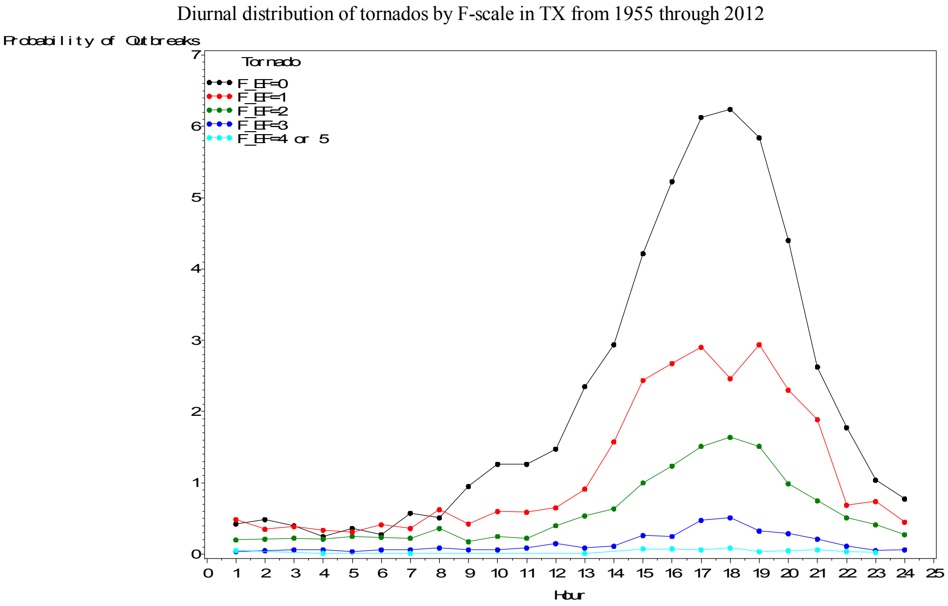

Fig. 10. Probability of Tornado onsets in Texas from 1955 to 2012 by F-scale (geographically adjusted GT time)

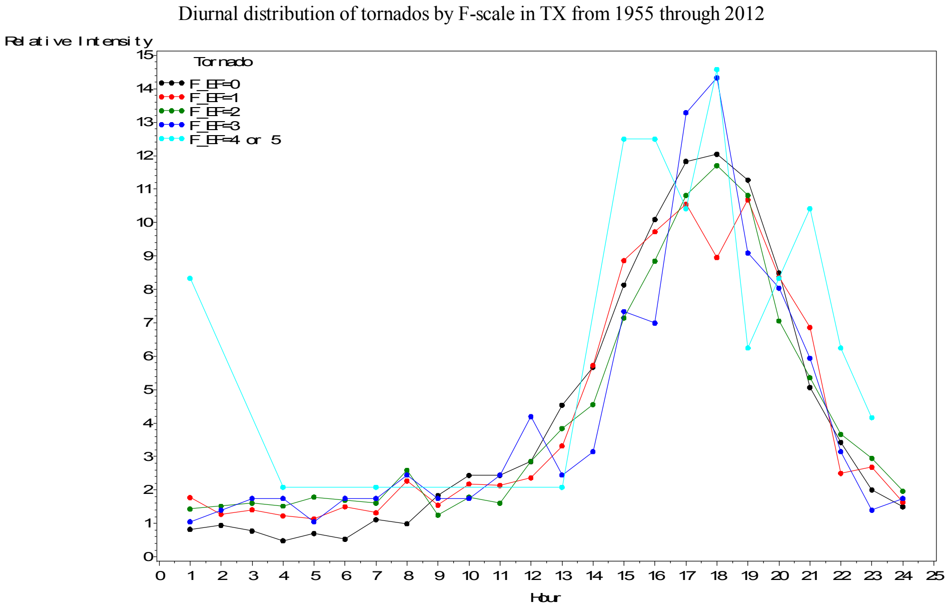

Fig. 11. Relative intensity of Tornado onsets in Texas from 1955 to 2012 by F-scale (geographically adjusted GT time)

7. CONCLUSION

As a member of KZ statistics, KZP is distinguished with its substantial power to construct a periodic signal from noisy environment. KZP algorithm packed in KZFT package in R software provides the technique to recover the periodicity of tornado onset in Texas.

We observed an obvious 24-hour period of tornado onsets by applying KZP to the data for Texas from 1955 through 2012, and in addition, this is also evidenced by the fact that under 'right' conditions, there were substantial high probabilities to develop tornadoes around 5:00PM and 6:00PM, especially in the spring and summer. Both probability of tornado onsets and relative intensity of tornado occurrence in this study suggest that the same dangerous synoptic system moving across the space provides the areas reaching at 5 - 8 PM with a 10 times greater risk in tornado onsets than areas at other time window of the day. Very helpfully, César explained dynamic structure of single tornado in his recent study [18]. That dynamic structure assumes strong energy supply from a Sun radiation for proper heating of atmosphere. Strongest sun radiation is at geographic noon time and effect for heating is coming with some delay. We are determining that delay statistically and the most efficient effect is turning out to be at 5 - 8 PM of geographic time of location. Many other synoptic factors should satisfy to create tornado, but that time interval appears the most dangerous under other proper conditions. Statistical evidence provided in current paper is making this fact beyond reasonable doubts. Given the high probability of developing tornadoes late afternoon in Texas, in case a tornado warning is issued to a certain area in the afternoon, people living there must respond to it seriously, especially in spring and summer time. This could be used as tornado warning guidelines for public health, to eliminate casualties and lost.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCE

1. Ziegler CL. A Diabatic Lagrangian Technique for the Analysis of Convective Storms. Part II: Application to a Radar-Observed Storm. J Atmos Oceanic Technol. 2013;30:2266–2280. doi: http://dx.doi.org/10.1175/JTECH-D-13-00036.1
2. Kosiba K, Wurman J, Richardson Y, Markowski P, Robinson P, Marquis J. Genesis of the Goshen County, Wyoming, Tornado on 5 June 2009 during VORTEX2. Mon Wea Rev. 2013;141:1157–1181. doi: http://dx.doi.org/10.1175/MWR-D-12-00056.1
3. Skinner PS, Weiss CC, Schroeder JL, Wicker LJ, Biggerstaff MI. Observations of the surface boundary structure within the 23 May 2007 Perryton, Texas, Supercell. Mon Wea Rev. 2011;139:3730–3749. doi: http://dx.doi.org/10.1175/MWR-D-10-05078.1
4. Frame J, Markowski P, Richardson Y, Straka JM, Wurman J. Polarimetric and Dual-Doppler Radar Observations of the Lipscomb County, Texas, Supercell Thunderstorm on 23 May 2002. Mon Wea Rev. 2009;137:544–561. doi: http://dx.doi.org/10.1175/2008MWR2425.1
5. Rasmussen EN, Straka JM. Evolution of Low-Level Angular Momentum in the 2 June 1995 Dimmitt, Texas, Tornado Cyclone. J Atmos Sci. 2007;64:1365–1378. doi: http://dx.doi.org/10.1175/JAS3829.1

6. Dunn LB, Vasiloff SV. Tornadogenesis and Operational Considerations of the 11 August 1999 Salt Lake City Tornado as Seen from Two Different Doppler Radars. Wea. Forecasting. 2001;16:377–398.
   doi: http://dx.doi.org/10.1175/1520-0434(2001)016<0377:TAOCOT>2.0.CO;2
7. Yang W, Zurbenko IG. "Kolmogorov-ZurbenkoFil- ters", Wiley Interdisciplinary Reviews. Computational Sta- tistics. 2010;2(3):340-351. doi: 10.1002/wics.71.
8. Yang W, Zurbenko I, Nonstationarity. Wiley Interdisciplinary Reviews - Computational Statistics. 2010;2(1):107-15.
9. Wise EK, Comrie AC. Extending the Kolmogorov-Zurbenko filter: Application to ozone, particulate matter and meteorological trends. Journal of the Air & Waste Management Association; 2005.
10. Papanastasiou DK, Poupkou A, Katragkou E, et al. An Assessment of the Efficiency of Dust Regional Modelling to Predict Saharan Dust Transport Episodes. Advances in Meteorology; 2010.
11. Zurbenko I, Luo M. Restoration of Time-spatial Scales in Global Temperature Data. American Journal of Climate Change. 2012;1(3):154-163.
    doi: 10.4236/ajcc.2012.13013.
12. Zurbenko I, Potrzeba A, Tides in the Atmosphere, Air Quality. Atmosphere and Health; 2011. DOI: 10.1007/s11869-011-0143-6.
13. Kolmogorov–Zurbenko filter.
    Website: http://en.wikipedia.org/wiki/Kolmogorov%E2%80%93Zurbenko_filter
14. Tornado Facts. Website: http://tornado-facts.com/the-tornado-scale/
15. Eskridge RE, Ku JY, Porter PS, Rao ST, Zurbenko IG. Separating different scales of motion in time series of meteorological variables. Bull Amer Meteorolog Soc. 1998;78:1473-1483.
16. National Climatic Data Center. National Oceanic and Atmospheric Administration. U.S. Tornado Climatology: Historical Records and Trends.
    Available: http://www.ncdc.noaa.gov/climate-information/extreme-events/us-tornado-climatology/trends
17. National Weather Service Weather Forecast Office, Wichita, Kansas. Historical Kansas Tornado Statistics 1950-2009.
    Available: http://www.crh.noaa.gov/ict/?n=kstorfacts
18. César MB. Hurricanes and Cyclones Kinematics and Thermodynamics based on Clausius-Clapeyron Relation Derived in 1832. International Journal of Physical Sciences. 2013;8(23):1284-1290. doi: 10.5897/IJPS2013.36.

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