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Climatology

AN EVALUATION OF HEAT WAVE OCCURRENCE IN NEW JERSEY

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ABSTRACT

Dates of the start of the first heat wave at 20 New Jersey sites are correlated with mean summer temperatures to determine if early heat waves are precursors to hotter summers. Mean summer temperatures and mean dates of occurrence of the first heat wave from 1914 - 1948 are also correlated to determine if warmer sites experience heat waves earlier in the year than cooler sites. Mean number of heat waves per year, percentage of seasons with heat waves, and probabilities of occurrence of heat waves are computed for each site to determine a heat wave climatology for New Jersey. The frequency distribution of heat waves at each site is compared to the Poisson distribution using chi-square analysis.

1. INTRODUCTION

An assertion often made during late spring or early summer is that the severity of the upcoming summer can be predicted by the earliness of the first heat wave. It is believed that the earlier the first heat wave, the hotter the summer. This paper will investigate this hypothesis. A heat wave may be defined as three or more consecutive days with temperatures of 90°F (32.2°C) or higher (3). The incursion of hot maritime (sub) tropical air into northeastern United States in summer causes rather frequent occurrences of up to three consecutive days of such temperatures. A more rigorous definition of a heat wave, defined as four or more consecutive days of temperatures at or above 90°F will be used in this study. A heat wave ends when the temperature fails to reach 90°F on a particular day. This paper will also investigate whether sites with higher summer mean temperatures experience earlier heat waves. Finally, an assessment will be made of the frequency of occurrence of heat waves in New Jersey using the Poisson distribution model.

2. METHODOLOGY

In order to test the hypothesis that the earlier the first heat wave, the hotter the summer, Pearson correlation coefficients were computed between the date of the first heat wave and the mean summer temperature (June, July and August) for each of the 20 sites throughout New Jersey (Fig. 1) for the period between 1914-1948. Dates of the first day of the first heat waves are assigned numerical values for purposes of correlation. Considering the climatology of heat waves in New Jersey, May 1 was assigned a value of one, June 1 a value of 32, and so on through September.

To test whether warmer sites experienced earlier first heat waves, the mean summer temperature for each site during the period and the mean date of occurrence of the first heat wave for each site were correlated. Cape May and Atlantic City had too few years with heat and were not used. A significant negative correlation would mean sites with higher mean temperatures experience heat waves earlier than cooler sites.

The frequency of occurrence of heat waves in New Jersey was evaluated using the Poisson distribution model. The frequencies of heat waves were tabulated by site and compared to the predicted Poisson frequencies using a chi-square analysis.

Six of the 20 sites had data for all 35 years, while three stations had less than 30 years of data, including Clayton which had 20 years of data.

Years without heat waves were omitted, and correlation coefficients were calculated for only the years in which heat waves occurred. Also, mean dates of occurrence of first heat waves were based only on years when heat waves occurred. Since Cape May and Atlantic City had only one and four years respectively with heat waves, their mean dates of occurrence of first heat waves were considered unreliable.

3. RESULTS

Correlation coefficients between dates of onset of first heat waves and mean summer temperatures for each site are given in Table 1. A correlation coefficient was not computed for Cape May, since only one recorded heat wave occurred there during the period of this study. Since the number of heat waves in Atlantic City was low, the value of its correlation coefficients is, although high, not significant. In fact, none of the correlation coefficients in Table 1 are significant at the 95 percent confidence level. The highest correlation coefficients for 18 sites, excluding Atlantic City, was -.3795 at Newton, where there were 17 heat wave years during the period. These results show that the date of occurrence of the warm season's first heat wave is not a good indicator of the severity of the upcoming summer. However, 17 of 19 correlation coefficients were negative. Although no statistically significant relationship existed for each site, this indicated a tendency for early heat waves to be associated with warmer summers when considering the whole state. Mean summer temperatures and mean dates of occurrence of the first heat wave from 1914-1948 are given in Table 1. The correlation coefficient for these data, omitting Cape May and Atlantic City, was -.5135, and is significant at the 95 percent confidence level. The significant negative correlation coefficient indicates that higher mean summer temperatures generally correspond to earlier mean dates of occurrence of first heat waves, and that warmer stations tend to experience heat waves earlier in the year than cooler stations.

The probability of occurrence of heat waves per season for each of the 20 sites was calculated using the Poisson Probability equation:

$$P(x) = \frac{\mu^x e^{-\mu}}{x!} \qquad (1)$$

where x is the number of occurrences in a season and μ is the mean number per year. Results are given in Table 2 along with the distribution of the number of occurrences of heat waves per season by station. Note that 65 percent of the sites have $<$ 10 percent chance of experiencing four or more heat waves in a single season, and that 75 percent of the sites have $>$ 25 percent chance of experiencing two heat waves in a season. Only four sites had $<$ 50 percent chance of experiencing any heat waves per season and were the three coastal sites and Dover, a higher elevation station. These sites also had the lowest mean number of heat waves per year and the lowest percentage of seasons with heat waves (Table 1). Tables 1 and 2 show that the heat waves are least frequent at coastal sites. They are slightly more frequent at the northern elevated sites of Dover and Newton, and still more frequent at sites that are inland but within 10 miles of the Atlantic coast. At southern and central inland sites, heat waves are very common occurrences. The tables do not clearly show an urban heat island effect. Although Elizabeth ranked fifth in percentage of heat waves, fourth in mean number of heat waves per year, and fourth in probability of at least one heat wave in a year, Trenton and Jersey City were similar in these three categories to the near-coastal sites of Tuckerton and Lakewood. This is likely due to the fact that urban effects are more of a factor with minimum temperatures.

The chi-square comparison of actual and Poisson distribution showed no significant difference between the two for any site except Bridgeton. Generally, the probabilities of occurrence of heat waves by season of the sites in this study fit the Poisson probabilities.

4. CONCLUSIONS

Pearson correlation coefficients between dates of first occurrence of heat waves and mean summer temperatures at individual stations show no statistical relationship. Thus, the severity of the upcoming summer is not indicated by the earliness of the first heat wave.

However, the negative sign for 17 of the 19 r values is a possible indicator that stations tend to experience earlier occurrences of first heat waves in warmer than normal summers. The significant correlation coefficient between the mean summer temperatures and the mean dates of occurrence of first heat waves by site show, as expected, that the time of heat wave onset is a function of local climatology.

Tables 1 and 2 show that heat waves in New Jersey are rare only along the Atlantic Coast and in northern higher elevations. In the southern and central inland regions, heat waves occur almost annually and often more than once.

The frequencies of occurrence of heat waves at sites in New Jersey generally fit the Poisson predicted frequencies.

SITE	DATE	# HEAT WAVE YEARS	YEARS DATA	% SEASONS W/HEAT WAVES	MEAN HEAT WAVES/YR	MEAN TEMP (°F)	
Atlantic City	7/17	4	35	11.4	.114	71.4	-.6991
Belvidere	7/4	27	35	77.1	1.83	71.9	.0457
Bridgeton	7/10	31	32	96.9	2.34	74.1	-.2074
Burlington	6/30	30	33	90.9	2.76	74.1	-.2965
Cape May	8/26	1	25	4.0	.040	71.8	
Clayton	7/13	17	20	85.0	1.85	73.1	.0626
Dover	7/22	13	31	41.9	.484	69.6	-.0198
Elizabeth	7/1	28	33	84.8	2.21	73.0	-.2177
Flemington	7/4	29	35	82.9	2.31	72.9	-.2550
Hightstown	7/7	23	28	82.1	1.57	71.9	-.1344
Indian Mills	7/4	30	35	85.7	2.03	72.2	-.2489
Jersey City	7/18	24	33	72.7	1.03	73.3	-.2982
Lakewood	7/8	26	35	74.3	1.09	71.7	-.1181
New Brunswick	7/7	24	34	70.6	1.24	72.1	-.3032
Newton	7/18	17	30	56.7	.833	69.9	-.3795
Phillipsburg	7/11	25	34	73.6	1.26	71.5	-.3154
Sandy Hook	7/20	10	34	29.4	.294	72.0	-.0980
Somerville	7/12	23	31	74.2	1.45	71.7	-.3446
Trenton	7/10	24	35	68.6	1.09	72.8	-.0841
Tuckerton	7/4	20	30	66.7	1.07	72.2	-.3403

Table 1. Mean start of first heat wave for each site, number of summers with at least one heat wave (heat wave years), number of years of data, percentage of seasons with heat waves (at least one), mean number of heat waves per year, mean summer temperatures, and correlation coefficients between dates of onset of first heat waves and mean summer temperatures for each site, 1914-1948.

SITE	NUMBER OF OCCURRENCES							
	0	1	2	3	4	5	6	7
Atlantic City	.886(31)	.114(4)	.000(0)					
Belvidere	.171(6)	.286(10)	.257(9)	.171(6)	.086(3)	.029(1)	.000(0)	
Bridgeton	.094(3)	.219(7)	.250(8)	.219(7)	.125(4)	.063(2)	.031(1)	.000(0)
Burlington	.061(2)	.182(6)	.242(8)	.212(7)	.152(5)	.091(3)	.030(1)	.030(1)
Cape May	.960(24)	.040(1)	.000(0)					
Clayton	.150(3)	.300(6)	.250(5)	.150(3)	.100(2)	.050(1)	.000(0)	
Dover	.594(19)	.281(9)	.065(2)	.032(1)	.000(0)			
Elizabeth	.114(4)	.229(8)	.257(9)	.200(7)	.114(4)	.057(2)	.029(1)	.000(0)
Flemington	.086(3)	.235(8)	.265(9)	.206(7)	.118(4)	.059(2)	.029(1)	.000(0)
Hightstown	.222(6)	.333(9)	.259(7)	.148(4)	.037(1)	.000(0)		
Indian Mills	.152(5)	.273(9)	.273(9)	.182(6)	.091(3)	.030(1)	.000(0)	
Jersey City	.364(12)	.364(12)	.182(6)	.061(2)	.030(1)	.000(0)		
Lakewood	.333(12)	.361(13)	.194(7)	.083(3)	.028(1)	.000(0)		
New Brunswick	.294(10)	.353(12)	.235(8)	.088(3)	.029(1)	.000(0)		
Newton	.433(13)	.367(11)	.167(5)	.033(1)	.000(0)			
Phillipsburg	.294(10)	.353(12)	.235(8)	.088(3)	.029(1)	.000(0)		
Sandy Hook	.758(25)	.212(7)	.030(1)	.000(0)				
Somerville	.226(7)	.355(11)	.258(8)	.129(4)	.032(1)	.000(0)		
Trenton	.333(12)	.361(13)	.194(7)	.083(3)	.028(1)	.000(0)		
Tuckerton	.333(10)	.367(11)	.200(6)	.067(2)	.033(1)	.000(0)		

Table 2. Probability of occurrences of heat waves per season and number of seasons with a given number of heat waves (in parenthesis) by station based on the Poisson distribution.

Figure 1. Location of stations used in this study.

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REFERENCES AND FOOTNOTES

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3. Huschke, R.E., ed., 1959: Glossary of Meteorology, American Meteorological Society, Boston, Mass.

4. Addess, S.R. and M.D. Shulman, 1966: A synoptic analysis of freezing precipitation for New Jersey. Bulletin of the New Jersey Academy of Science, 11, No. 2.

5. Marvin, C.F., dir., 1916-1940: Climatological Data, New Jersey Section, Trenton, N.J.

6. Moore, W.L., dir., 1911-1915: Climatological Service, District No. 1, North Atlantic States, Washington, D.C.

7. White, A.E., 1941-1948: Climatological Data, New Jersey Section, Trenton, N.J.