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HEAT WAVES IN A HOT PLACE: EXAMINATION OF INTENSE HEAT EPISODES IN THE PHOENIX ARIZONA METROPOLITAN AREA DURING JULY 2003-2005-2006

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1. INTRODUCTION

Hot summer weather is a fact of life over the lower desert of south-central Arizona, including the Greater Phoenix metropolitan area. Climatologically, July is the hottest month in Phoenix, with a mean high temperature of 42 C (107 F), a mean low temperature of 28 C (83 F), and an average temperature of 35 C (95 F), based on the 1971-2000 period of record (NCDC). Table 1 and 2 indicate Phoenix warmed during the past half century, mainly as a consequence of rapid urbanization (Table 4) and areal expansion, with the strengthening "urban heat island" reflected as a 2-3 C increase in average minimum temperature over the core of the metropolitan area (Green et al, 2000).

Recently, the Phoenix metropolitan area experienced a noticeable increase in the frequency of record-breaking heat events during July. Three of the four hottest calendar months in Phoenix's recorded weather history (1896-2006) occurred during the past five years: July 2003 (hottest), July 2005 (third-hottest) and July 2006 (fourth-hottest). The principal heat events occurred between 11 and 25 July in each of the three years.

This paper provides a quick look at July temperature climatology for Phoenix and for Yuma, Arizona, a much smaller city in extreme southwest Arizona, proposes a "heat wave" definition for the Greater Phoenix metropolitan area, examines the evolution, duration and character of recent July heat waves in Phoenix, highlights specifics regarding each event, and correlates the events with observed large-scale meteorological conditions. A brief description of the current WFO (weather forecast office) Phoenix heat advisory/warning program is also provided

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2. JULY TEMPERATURE CLIMATOLOGY FOR PHOENIX

The 30-year daily high, low, and average temperatures for Phoenix during July for successive 30-year periods are provided in Table 1; decadal average values are provided in Table 2.

Table 1. High, low and average daily temperatures (C) during July for Phoenix, Arizona, during successive 30-year periods.

Years	High	Low	Average
1911-1940	39.7	25.3	32.5
1941-1970	40.2	25.8	33.1
1971-2000	41.1	27.9	34.5

Table 2. Same as Table 2, but for successive 10-year periods as well as for the most recent 6-year period (2001-2006).

Years	High	Low	Average
1941-1950	40.1	25.5	32.8
1951-1960	39.7	25.9	32.8
1961-1970	40.6	25.8	33.2
1971-1980	41.3	27.6	34.4
1981-1990	41.1	28.2	34.6
1991-2000	40.8	27.9	34.4
2001-2006	41.8	29.4	35.6

The biggest decadal change in temperature occurred between 1961-1970 and 1971-1980, when overnight low temperature rose 1.8 C (3.2 F) while average temperature rose 1.2 C (2.2 F). The hottest decade, in terms of average high temperature, occurred during 1971-1980; however, that record is in jeopardy, given how warm the first six years of the current decade have been.

For comparison purposes, Table 3 provides similar information as Table 2, but for Yuma, Arizona. Yuma did not experience a noticeable increase in

temperature between the 1960s and 1970s; in fact, Yuma experienced an increase of only 0.4 C in average minimum temperature between the 1950s and 1990s. However, minimum temperatures have been warmer by slightly more than 1 C so far this decade compared to the 1971-2000 average.

Table 3. Same as Table 2, but for Yuma, Arizona.

Years	High	Low	Average
1941-1950	41.9	24.6	33.2
1951-1960	42.4	26.8	34.6
1961-1970	41.2	26.9	34.0
1971-1980	41.2	26.9	34.1
1981-1990	41.9	27.1	34.5
1991-2000	41.7	27.2	34.4
2001-2006	41.8	28.4	35.1

Table 4 highlights the population for the City of Phoenix, by decade, from 1950 to 2000. Although population growth continued at a dizzying pace since the decade of the 1970s, average daytime highs, nighttime lows, and mean daily temperatures for July haven't changed much since that time.

Table 4. Phoenix population (U.S. Bureau of the Census).

Year	Population	National Rank
1950	106,818	99
1960	405,220	29
1970	581,562	20
1980	789,704	9
1990	983,403	9
2000	1,321,045	6
2005	1,461,575	6

However, the incidence of extreme temperatures, especially record warm minimum temperatures, has significantly increased (Tables 5-8).

Table 5. Frequency of occurrence of minimum temperature at and above 32 C (90F) during July and all 12 months at Phoenix. First occurrence: July 1934. Number of daily record high minimum temperatures per decade (or portion of a decade) for July is provided in parentheses (ties included).

Years	July	All Months
1931-1940	2 (0)	2
1941-1950	0 (0)	0
1951-1960	0 (0)	0
1961-1970	1 (1)	1
1971-1980	6 (5)	11
1981-1990	11 (6)	21
1991-2000	10 (10)	21
2001-2006	32 (21)	38
Total	62	94

Table 6. Frequency of occurrence of minimum temperature at and above 32 C (90F) at Yuma during a. July and b. all 12 months. First occurrence: June 1990. Number of daily record high minimum temperatures per decade (or portion of a decade) for July is provided in parentheses (ties included).

Years	July	All Months
1931-1940	0 (1)	0
1941-1950	0 (0)	0
1951-1960	0 (1)	0
1961-1970	0 (2)	0
1971-1980	0 (6)	0
1981-1990	0 (4)	1
1991-2000	3 (8)	13
2001-2006	5 (27)	6
Total	8	20

Table 7. Frequency of occurrence of maximum temperature at and above 45 C (113 F) at Phoenix during a. July and b. all 12 months. Number of daily record high maximum temperatures per decade (or portion of a decade) for July is provided in parentheses (ties included).

Years	July	All Months
1896-1900	0 (0)	4
1901-1910	7 (3)	12
1911-1920	3 (0)	7
1921-1930	4 (1)	11
1931-1940	18 (4)	32
1941-1950	5 (2)	11
1951-1960	5 (3)	6
1961-1970	5 (0)	21
1971-1980	17 (2)	48
1981-1990	25 (8)	53
1991-2000	15 (6)	35
2001-2006	24 (11)	34
Total	128	274

Table 8. Frequency of occurrence of maximum temperature at and above 45 C (113 F) at Yuma during a. July and b. all 12 months, for the same period of record as Phoenix (Table 6). Number of daily record high maximum temperatures per decade (or portion thereof) for July is provided in parentheses (ties included).

Years	July	All Months
1896-1900	1 (0)	8
1901-1910	3 (1)	7
1911-1920	13 (0)	46
1921-1930	9 (0)	33
1931-1940	30 (3)	58
1941-1950	30 (4)	76
1951-1960	46 (12)	107
1961-1970	17 (1)	50
1971-1980	20 (0)	52
1981-1990	33 (3)	93
1991-2000	35 (5)	78
2001-2006	16 (3)	25
Total	253	633

Average daily temperature, computed by adding the calendar day high and low temperature, then dividing by 2, is a good measure of the persistence of unusually hot conditions. Table 8 shows that the average daily temperature was at or above 37.8 C (100 F) in Phoenix on 136 July days since 1896; by comparison, Yuma experienced 98 calendar days with an average temperature of 37.8 C (100 F) or greater during that time. Although Yuma has a higher frequency of July days with maximum temperature at or above 45 C, Phoenix has a much greater frequency of July days with minimum temperature at or above 32 C, which highlights the much stronger urban heat island in place at Phoenix.

Table 9. Number of July days with average temperature at or above 37.8 C (100 F) in Phoenix.

Period (years)	Days	Peak frequency by year
1896-1970 (75)	21	3 in 1925, 1934 and 1936
1971-1980 (10)	18	5 in 1973
1981-1990 (10)	32	5 in 1985 and 1988
1991-2000 (10)	25	7 in 1998, 5 in 1995, 1996 and 2000
2001-2006 (6)	40	12 in 2006, 8 in 2005, 7 in 2003
Total	136	

Table 10. Same as Table 9, but for Yuma.

Period (years)	Days	Peak frequency by year
1896-1970 (75)	34	6 in 1958, 4 in 1957, 1959, and 1960
1971-1980 (10)	13	5 in 1980, 3 in 1972
1981-1990 (10)	11	3 in 1990, 1989, and 1985
1991-2000 (10)	19	7 in 1998, 5 in 1995
2001-2006 (6)	21	9 in 2006, 4 in 2005, 3 in 2003
Total	98	

Phoenix has experienced 11 July days with an average temperature of 40 C (104 F) or higher. Eight of the eleven days occurred during three months; July 2003, July 2005 and July 2006. By comparison, Yuma, Arizona, experienced 10 calendar days with an average temperature of 40 C (104 F) or higher. Eight of those days occurred during the period 1990-2006, but only 2 occurred during July 2006, and none occurred during July 2003 or July 2005.

Table 11. Days with average temperature of 40 C (104 F) or higher at Phoenix.and Yuma Arizona. Matching dates are in bold type.

Phoenix		Yuma	
Day	Avg T	Day	Avg T
6/26/1990	42 (107)	**7/21/2006**	41 (106)
7/22/2006	41 (106)	7/31/1996	41 (106)
7/15/2003	41 (106)	**6/27/1990**	41 (105)
6/27/1990	41 (106)	7/28/1995	40 (104)
7/17/2005	41 (105)	**7/22/2006**	40 (104)
7/14/2003	41 (105)	8/12/1996	40 (104)
7/16/2003	40 (104)	6/25/1994	40 (104)
6/25/1990	40 (104)	**6/26/1990**	40 (104)
7/21/2006	40 (104)	8/28/1981	40 (104)
7/15/2006	40 (104)	7/31/1957	40 (104)
8/10/2003	40 (104)		

Table 12. Total days with average temperatures at or above given thresholds at Phoenix and Yuma for the period 1896-2006.

Avg T at least:	Phoenix	Yuma
41 C	7	3
40 C	11	10
39 C	55	34
38 C	228	202

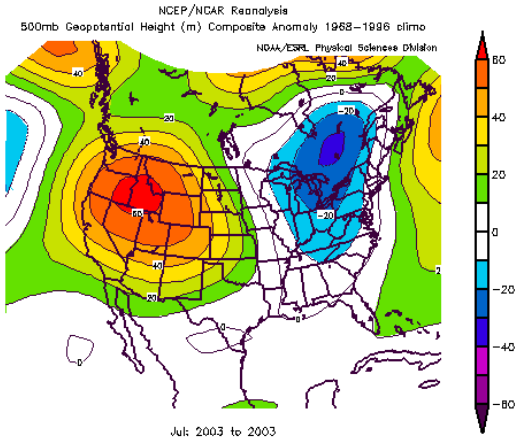
3. HEAT WAVES OF JULY 2003-2005-2006

For purposes of this paper, **a heat wave exists when the average daily temperature reaches or exceeds 38 C (100 F) for at least 3 successive days**. Based on this definition, 25 heat waves affected Phoenix during the period 1896-2006. Seventeen of the 25 heat waves occurred during the month of July, 14 of the 17 July heat waves occurred during the past 20 years (1987-2006), and four of the 17 July heat waves occurred during the past four years (1 in July 2003, 1 in July 2005, and 2 in July 2006).

a. July 2003

July 2003 was the hottest month on record at Phoenix, with an average temperature of 36.4 C (97.6 F). The previous record-holder was July 1989, with an average temperature of 36.3 C (97.4 F). Not surprisingly, 500 hPa heights over the west and southwest United States were well above normal during July 2003 (Figure 2), with a mean 500 hPa height of 5940 gpm over Phoenix (30 gpm above climatology). The greatest positive anomaly, 50-60 gpm, existed over southern Idaho (Figure 1).

Figure 1. 500 hPa geopotential height composite anomaly, based on 1968-1996 climatology, for July 2003 (from NCEP/NCAR Reanalysis).



The potential for a heat wave became evident on or near 8 July, when high pressure aloft rapidly strengthened over the southwest United States: 500 hPa heights over Arizona increased 30-50 gpm between 0000 UTC 8 July and 0000 UTC 9 July. Then, the 500 hPa reflection of the upper high center remained over/near Arizona 9-14 July, with peak intensity near 6000 gpm. During the period 15-17 July, the upper high slowly weakened and drifted toward the northeast (not shown).

An intense heat wave affected Phoenix 12-16 July. The average temperature during this 5-day period, 39.8 C (103.6 F), was the hottest on record for any July heat wave, and second-hottest on record (hottest: 39.8 C (103.7 F) during 24-28 June, 1990). Minimum temperatures remained at or above 33 C (91 F) 12-17 July; daytime highs were 46-47 C (114-117 F) 13-16 July; and average temperatures were 39-41 C (102-106 F). The five consecutive days with average temperature of at least 38 C (100 F) tied the existing longevity record, set in 1989. Phoenix's all-time warmest overnight low, 36 C (96 F), occurred the morning of 15 July (old record was 34 C (93 F)). Although this heat wave was quite severe, it could have been worse: if not for the unexpected arrival

of relatively cool and moist air in the lowest 1.5 km AGL from the Gulf of California on the morning of the 10th, heat wave conditions may have existed for a longer period. In any event, the heat wave of July 2003 ended on 17 July as deep-layered subtropical moisture associated with the remains of former Hurricane Claudette overspread south-central Arizona. The onset of the summer monsoon, defined as the first of three consecutive days with average daily dew point of 13 C (55 F) or higher, occurred on 18 July (average monsoon onset: 7 July).

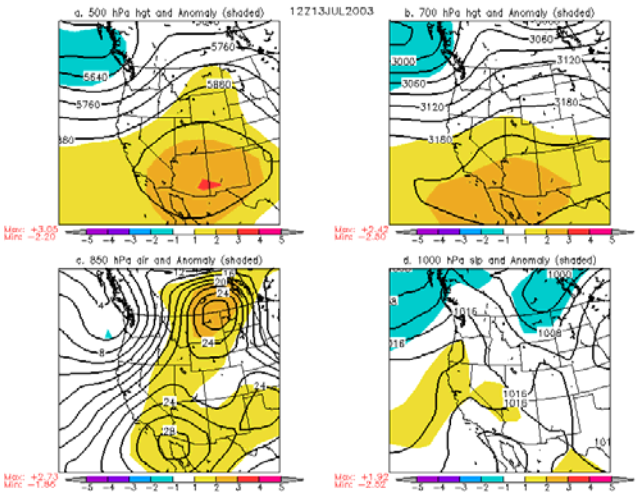
Table 13 provides daily meteorological data for Phoenix during the period 9-17 July 2003.

Table 13. Daily high/low/average temperatures observed at Phoenix Sky Harbor airport before, during and shortly after the heat wave of 12-16 July 2003 (records denoted by an asterisk (*)). T/Td in deg C; height in dam; 500, 700 and 850 hPa data valid at 1200 UTC.

Date	T High	T Low	T Avg	hgt 500	T/Td 850	T/Td 700	Td avg sfc
9	45	29	37	594	28/0	18/-10	4
10	43	28	36	595	32/-4	18/-8	8
11	42	31	37	596	26/10	18/-10	15
12	44	33*	39*	597	27/12	16/-1	13
13	46*	33	39*	597	27/12	18/-1	12
14	47*	34*	41*	596	29/8	18/-1	10
15	46	36*	41*	595	30/10	16/3	11
16	47	33*	40*	593	29/12	16/1	9
17	40	34*	37	592	27/7	16/-2	12
Climo	42	28	35	591	24/	13/	14

How anomalous was this event? The average temperature for the 5-day period 12-16 July was the highest on record for any 5-day period in Phoenix. The average minimum temperature for the period 12-17 July was the warmest for any 6-day period. However, the mean maximum temperature for 12-16 July, 46 C (114.8 F), fell short of what occurred during 5-day periods in June 1990, July 1995, and June 1979. Figure 2 depicts constant pressure anomaly data for 1200 UTC 13 July 2003, day 2 of the 5-day heat wave. A 500 hPa height anomaly of 3 standard deviations above the mean was centered over southeast Arizona and southwest New Mexico. 700 hPa height was in excess of 2 standard deviations above the mean, while 850 hPa temperature was 1-2 standard deviations above the mean.

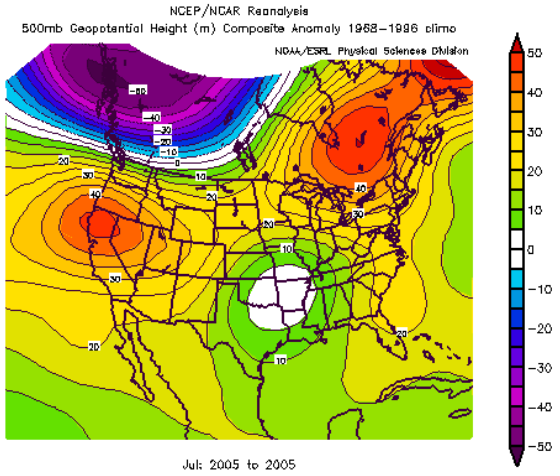
Figure 2. Anomaly charts for 500 hPa height (upper left), 700 hPa height (upper right), 850 hPa temperature (lower left) and 1000 hPa sea level pressure (lower right), valid at 1200 UTC 13 July 2003 (image provided by Grumm and Graham, 2007)



b. July 2005

July 2005 was the third-hottest month on record at Phoenix, with an average temperature of 36.2 C (97.2 F). Above-normal 500 hPa heights occurred over the west and southwest United States during July 2005, with a mean 500 hPa height of 5935 gpm over Phoenix (25 gpm above climatology). The greatest positive height anomaly, 45-50 gpm, was centered over northern California (Figure 3).

Figure 3. 500 hPa geopotential height composite anomaly, based on 1968-1996 climatology, for July 2005 (from NCEP/NCAR Reanalysis).



High pressure aloft began to strengthen over the western United States on 11 July. For the next week, the 500 hPa reflection of the upper ridge meandered over the southwest United States, but was primarily centered north or northeast of Phoenix, keeping Arizona in persistent east to northeast flow aloft. During the period 20-22 July, the upper ridge drifted off to the east, which allowed somewhat cooler and more moist air to advect northward over Arizona. As was the case in 2003, monsoon onset did not occur at Phoenix until 18 July.

By definition, a heat wave affected Phoenix 13-19 July, as daily average temperature reached or exceeded 38 C (100 F) seven consecutive days. The average temperature reached or exceeded 38 C (101 F) six consecutive days, which broke the record of 5 consecutive days set in 1989, and tied during the heat wave of 12-16 July 2003. Even more remarkably, the average temperature reached or exceeded 37 C (99 F) 10 consecutive days (12-21 July). During this heat event, low temperatures remained at or above 33 C (91 F) five days, and at or above 32 C (89 F) 8 consecutive days, while daytime highs reached or exceeded 45 C (113 F) 6 days, and were at or above 43 C (110 F) 11 days.

In terms of public health, the July 2005 heat wave was a high-impact meteorological event for the Greater Phoenix area. Unofficially, in excess of 30 heat-related deaths were reported during and shortly after the event (Arizona Republic, 2007), which made it the second-deadliest weather-related event of 2005 in the United States (Runyan, personal communication, 2006). The persistent nature of this heat wave, coupled with the fact that the atmosphere moistened slowly with time, were two factors that contributed to its overall severity and notoriety.

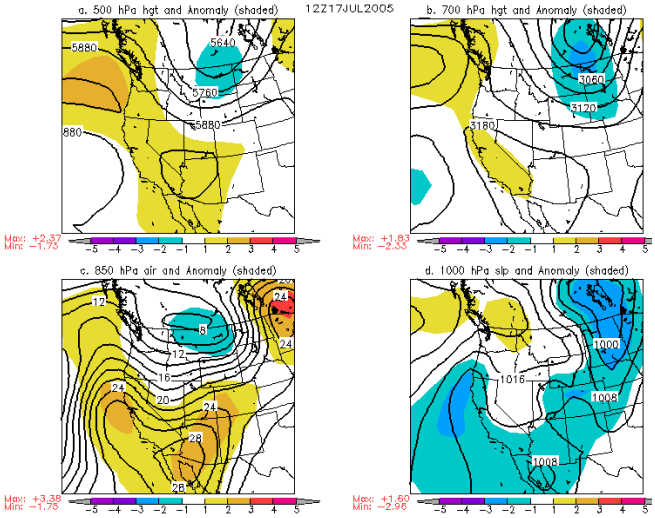
Table 14. Daily high, low and mean temperatures observed at Phoenix Sky Harbor airport before, during and shortly after the heat wave of 13-19 July 2005 (records denoted by an asterisk (*)). T/Td in deg C; height in dam; 500, 700 and 850 hPa data valid at 1200 UTC.

Date	T High	T Low	T Avg	hgt 500	T/Td 850	T/Td 700	Td avg sfc
11	44	28	36	590	27/-3	14/-19	2
12	46*	28	37	595	29/-7	16/-10	-1
13	46*	29	38	595	31/-7	17/-9	2
14	43	33	38	592	28/7	16/-3	9
15	45	32	38	592	28/7	17/-3	11
16	45	33*	39	593	28/8	17/1	11
17	47*	34*	41*	595	29/10	16/4	12
18	45	32	38	595	27/11	17/1	13
19	44	33*	38	592	28/8	17/1	14
20	43	32	37	593	25/12	15/4	15
21	44	33*	38	594	27/13	15/4	16
22	43	28	36	592	28/10	14/7	14
Climo	42	28	35	591	24/	13/	14

How anomalous was this event? In terms of persistent heat, it was unprecedented in Phoenix recorded history: the average daily temperature was at least 38 C (101 F) for six consecutive days. Minimum temperatures were at or above 32 C (89 F) for 8 consecutive days, a new record. The four consecutive days with a maximum temperature of 45 C (113 F) or higher matched what occurred 12-15 July 2003, but was well short of the all-time record of 9 days, set 20-28 June 1990.

Figure 4 depicts constant pressure anomaly data for 1200 UTC 17 July 2005, the hottest day of the heat wave. A 500 hPa height anomaly of 1-2 standard deviations above the mean existed over Arizona; 850 hPa temperature was 2-3 standard deviations above the mean; and 1000 hPa sea level pressure was 1-2 standard deviations below the mean.

Figure 4. Same as Figure 2, except for 1200 UTC 17 July 2005.



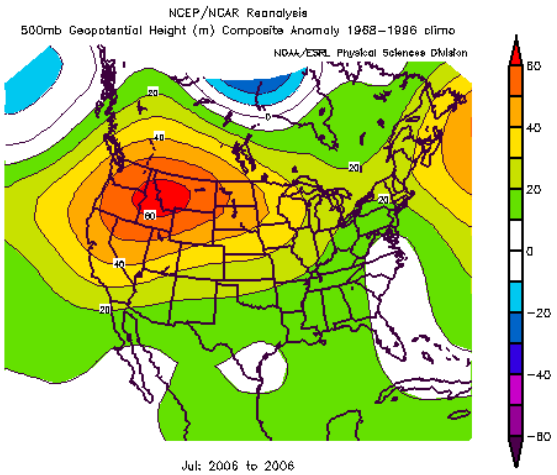
c. July 2006

July 2006 became the fourth-hottest month on record at Phoenix, with an average temperature of 35.8 C (96.5 F). The period 1-24 July was hottest first 24 days of July on record; however, below-normal temperatures occurred 26-31 July in the wake of a significant convective outbreak the evening of 25 July. Yuma, Arizona, was not affected by the convective outbreak on the 25th, and experienced its hottest month on record.

As expected, 500 hPa heights over the west and southwest United States were well above normal during July 2006. The 500 hPa composite anomaly map for July 2006 (Figure 5) appears strikingly similar to the July 2003 map, especially over the western United States (Figure 1). The mean 500 hPa height of 5935 gpm over Phoenix was 25 gpm above climatology. The greatest positive 500 hPa anomaly, 60-70 gpm, existed over central Idaho and western Montana, slightly north of its 2003 position, and was stronger by 10 gpm.

High pressure aloft slowly strengthened over the southwestern United States 11-13 July, with a strong upper high centered near the Four Corners region (the location where Utah, Colorado, New Mexico and Arizona meet) by 14 July. The ridge persisted near or slightly east of the Four Corners region 15-18 July; meanwhile, an upper level disturbance moved west across southern and central Arizona on 16-17 July, bringing isolated thunderstorms over and near Phoenix on 16 July.

Figure 5. Same as Figures 1 and 3, except for July 2006.



The upper ridge strengthened and expanded over the Pacific Northwest during the period 19-22 July, while maintaining its influence over the southwest United States. After that, the ridge slowly weakened, shifted south, and was centered near the Four Corners region by 24 July. A significant low-level moisture increase from the Gulf of California (a “Gulf surge”) occurred the morning of 25 July, and contributed to a widespread thunderstorm outbreak over the Greater Phoenix area that evening.

Two heat waves affected the Phoenix area this month: the first heat wave occurred 11-15 July; the second, and more intense, heat wave occurred 18-24 July. The seven consecutive days with daily average temperature at least 38 C (100 F) during the period 18-24 July broke the record of 6 consecutive days that had been set in July 2005. During these two heat waves, daytime highs reached or exceeded 45 C (113 F) 8 times, while nighttime lows remained at or above 32 C (90 F) 10 times. The second and third warmest daily minimum temperatures ever recorded in Phoenix occurred this month: 35 C (95 F) on 22 July and 34 C (94 F) on 15 July.

The heat waves of July 2006 were significant, especially from a public health standpoint. During July, 45 deaths in Maricopa County (Phoenix is the county seat) were directly caused by heat or heat exposure, while 17 deaths were related, but not directly attributed, to heat or heat exposure (Maricopa County Department of Public Health, 2007, unpublished).

Table 15. Daily high, low and mean temperatures observed at Phoenix Sky Harbor airport before, during and shortly after the heat wave of 11-15 July 2006 (records denoted by an asterisk (*)), T /Td in deg C; height in dam; 500, 700 and 850 hPa data valid at 1200 UTC.

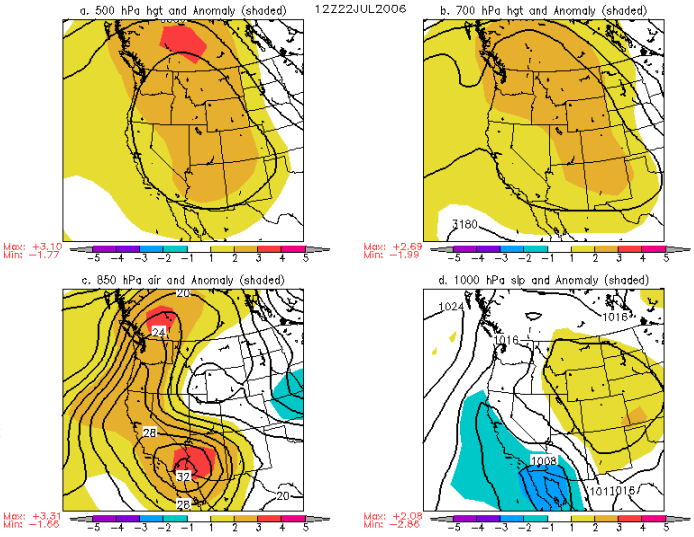
Date	T High	T Low	T Avg	hgt 500	T/Td 850	T/Td 700	Td avg sfc
9	43	31	37	591	26/9	11/5	12
10	42	31	37	589	27/7	13/3	11
11	43	31	38	591	27/6	12/2	8
12	43	33*	38	594	28/8	13/4	12
13	45	34*	39*	595	28/12	13/7	13
14	46	33	39	595	28/10	15/5	12
15	45	34	40	595	28/10	15/6	13
16	43	31	37	593	29/12	17/4	15
Climo	42	28	35	591	24/	13/	

Table 16. Same as Table 15, except for the heat wave of 18-24 July 2006.

Date	T High	T Low	T Avg	hgt 500	T/Td 850	T/Td 700	Td avg sfc
17	41	29	36	592	23/12	13/5	16
18	45	33*	39*	595	26/14	14/7	14
19	44	33*	39	593	25/10	13/3	12
20	42	33	38	594	26/11	13/6	13
21	48*	32	40*	594	30/10	15/1	12
22	47*	35*	41*	594	30/6	16/1	9
23	46*	33*	39*	593	31/6	15/5	11
24	46*	32*	39*	591	29/8	16/3	13
25	42	25	34	590	29/10	16/5	17
Climo	42	28	35	591	24/	13/	14

How anomalous was this heat event? In terms of persistent heat, the event was unprecedented in Phoenix recorded history. The average daily temperature was at least 38 C (101 F) for seven consecutive days, a new record. The four consecutive days with a maximum temperature of 46 C (114 F) or higher tied for second-longest on record (record: 5, June 18-22, 1968). Figure 6 depicts constant pressure anomaly data for 1200 UTC 22 July 2006, the hottest day during the second, more intense heat wave. A 500 hPa height anomaly 2-3 standard deviations above the mean existed over Arizona, while 700 hPa height anomaly 1-2.5 standard deviations above the mean was present. 850 hPa temperature anomaly in excess of 3 standard deviations above the mean covered all of south-central and southwest Arizona, as well as far southeast California. The combination of positive 1000 hPa sea level pressure anomalies over New Mexico and negative 1000 hPa sea level pressure anomalies mainly south and west of Phoenix resulted in more downslope flow over Phoenix, which contributed to the heat wave conditions.

Figure 6. Same as Figures 2 and 4, except for 1200 UTC 22 July 2006.



4. HEAT WARNING PROGRAM AT WFO PHOENIX

Extreme heat poses a significant health risk to segments of the population, especially the elderly and those who work outside or otherwise spend a large portion of the day outdoors, and it is directly or indirectly associated with more deaths than any other meteorological phenomenon in the Phoenix WFO area of responsibility (from Maricopa County Department of Health Services).

Although an extreme version of the mT (moist tropical) air mass, with well-above normal temperature and dew point, is most dangerous to residents in much of the conterminous United States, including major metropolitan centers such as Chicago, Philadelphia, and Atlanta, the most dangerous air mass for the Greater Phoenix area, in terms of its impact on heat-related mortality /morbidity, is an extreme form of dT (dry tropical), with temperatures 1 to 2 standard deviations

above normal coupled with below-average dew point (Kalkstein and Haffer, 2004). This so-called "dry heat" is well-known to residents of the Greater Phoenix metropolitan area; however, even lifelong, well-acclimated residents of south-central Arizona may become dehydrated or suffer other heat-related illnesses under extreme dT conditions.

Since 2001, WFO Phoenix has employed a synoptic-based Heat/Health System, developed at the University of Delaware, to assist in determining the need for issuance of heat advisory, excessive heat watch and excessive heat warning products for the Greater Phoenix area (Kalkstein et al, 1996; Haffer and Skindlov, 2004). The Heat/ Health System ingests digital forecast information generated by WFO Phoenix forecasters, including forecast maximum temperature, hourly temperature, dew point temperature, and percent opaque sky cover; identifies an air mass classification for each of the upcoming two days and determines the number of days in a row that this air mass will have existed; then provides guidance which helps forecasters determine whether a heat advisory, excessive heat watch or warning should be issued or extended.

WFO Phoenix forecasters use a combination of the synoptic-based Heat/Health System and maximum temperature thresholds that closely parallel 1) the 95th percentile and 2) the 99th percentile to determine whether a particular heat-related product should be issued. [For the period 1-15 July, the 95th percentile Tmax for Phoenix is 45 C (113 F) and the 99th percentile Tmax is 46 C (115 F); for 16-29 July, the 95th percentile Tmax is 44 C (112 F) and the 99th percentile maximum temperature is 46 C (114 F)]. In general, if the Heat/Health System indicates the most dangerous air mass exists, and the forecast maximum temperature is at or above the 99th percentile value, an Excessive Heat Warning (day 1) or an Excessive Heat Watch (day 2) is issued. If the Heat/Health System indicates either of the most two dangerous dT air masses exist, and the forecast maximum temperature reaches or exceeds the 95th percentile value, a Heat Advisory is issued.

5. DISCUSSION

Rapid urbanization and expansion of the Greater Phoenix metropolitan area has resulted in localized warming, especially with regard to overnight low temperatures, during the past few decades. Heat wave conditions (at least 3 consecutive days with average temperature at or above 38 C (100 F)) have become more frequent, especially during July.

Table 17. Phoenix heat waves with a duration of at least 4 days, ranked in terms of consecutive days with Tavg at least 38 C (100 F). Periods with average temperature 39-40 C (102.2-104 F) are in bold print.

Period	# of days
8/3-10/1995	8
7/18-24/2006	7
7/13-19/2005	7
8/8-13/2003	6
7/11-15/2006	5
7/12-16/2003	5
7/24-28/2000	5
6/24-28/1990	5
7/4-8/1989	5
7/14-17/1998	4
7/27-30/1995	4
7/2-5/1973	4
7/29 to 8/1/1972	4

The severe heat wave of July 2005 became 'international news', principally by virtue of the reported number of heat-related deaths, and helped increase local awareness of the danger that intense heat poses to the general population, even in a relatively hot and arid location like Phoenix.

6. REFERENCES

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