Impacts and Responses to the 1995 Heat Wave: A Call to Action

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ABSTRACT

The short but intense heat wave in mid-July 1995 caused 830 deaths nationally, with 525 of these deaths in Chicago. Many of the dead were elderly, and the event raised great concern over why it happened. Assessment of causes for the heat wave–related deaths in Chicago revealed many factors were at fault, including an inadequate local heat wave warning system, power failures, questionable death assessments, inadequate ambulance service and hospital facilities, the heat island, an aging population, and the inability of many persons to properly ventilate their residences due to fear of crime or a lack of resources for fans or air conditioning. Heat-related deaths appear to be on the increase in the United States. Heat-related deaths greatly exceed those caused by other life-threatening weather conditions. Analysis of the impacts and responses to this heat wave reveals a need to 1) define the heat island conditions during heat waves for all major cities as a means to improve forecasts of threatening conditions, 2) develop a nationally uniform means for classifying heat-related deaths, 3) improve warning systems that are designed around local conditions of large cities, and 4) increase research on the meteorological and climatological aspects of heat stress and heat waves.

1. Introduction

The meteorological and climatological aspects of the severe 5-day heat wave over the central United States during mid-July 1995 have been defined (Kunkel et al. 1996). Of more than 800 deaths nationally as a result of the heat wave, 525 deaths were in Chicago, an event appropriately labeled, "a citywide tragedy" (*Chicago Tribune,* 17 July 1995). This paper focuses on the impacts and responses to the heat wave, but even more importantly, the study reveals the need for investigations of hot weather conditions in American cities where heat-related deaths appear to be increasing over time. Information about this 1995 event has relevance for improved forecasting of extreme heat conditions, for defining areas for future atmospheric research, and for assessing potential impacts of global warming.

2. Impacts

a. Assessing weather-related deaths

Wide-ranging impacts of weather include economic and environmental effects in addition to effects on human health. People die as a result of a wide variety of weather hazards, an issue of deep public concern. In fact, protection of life and property has long been a primary goal of the National Weather Service, and this function helps justify much weather research done in the United States. The importance of the 1995 heat wave and the large loss of life incurred as a result has been defined within the context of the national loss of life due to all forms of weather.

This assessment of weather-related deaths in the United States revealed three prevailing themes.

- Most people do not understand the relative danger of various weather conditions.

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- Statistics for weather-related deaths are often unreliable.
- Much weather-related loss of life is concentrated in a few events.

Many people have incorrect perceptions of weather dangers and are unaware of the relative differences of weather threats to human life. For example, they are awed by the threat of tornadoes and plan accordingly on how to respond (e.g., tornado-planning week each spring), but they fail to realize that lightning or winter storms are greater threats. Further, the nation has no organized program or special weeks dedicated to alerting citizens about lightning or winter storm dangers.

One reason for this situation is that data on many weather-related deaths are inexact and often underestimate the true number of deaths. This is particularly true for lives lost due to heat waves (Ellis 1972) and cold waves (Changnon 1979). These multiday events make it more difficult to attribute the loss of life due to temperature extremes since affected individuals also often suffer from other health problems.

A few weather catastrophes typically cause most deaths. For example, Illinois has had 1061 tornado deaths since 1916, and 57% of these deaths (606) occurred in one hour on 18 March 1925 (Changnon 1982). Among those weather phenomena causing deaths, only lightning has an event distribution that is not highly skewed, killing between 65 and 140 persons a year and seldom more than 4 persons on any one day and usually at widely scattered locations. Some deaths assigned to weather events are due to direct physical damage due to falling or blown objects or to lightning strikes. Deaths in vehicular accidents during inclement weather are typically assigned to the type of weather extreme in progress (heavy rain, fog, or winter storm). Drownings during floods are usually considered as weather-related, as are heart attacks due to strenuous activities in winter storms. In general, weather-related deaths either have a clear physical linkage or are attributed to activities leading to death during an extreme event.

Table 1 presents annual averages and extreme values for U.S. deaths due to various weather events. Averages are based on data from different base periods and from different sources, so these values should be considered as only relative measures, but values likely bracket true averages.

Annual averages of most weather conditions (heavy rains/floods, lightning, tornadoes, hurricanes, and winter storms) range between 60 and 200 deaths per year, but their extremes vary widely, with 6000 deaths being the peak value caused by the famed Galveston hurricane in September 1900. Others have cited as many as 12 000 deaths at Galveston (Rappaport and Ferandez-Pastagas 1995). Importantly, both averages and extremes of heat wave deaths easily exceed those

TABLE 1. Number of deaths attributed to weather in the United States.

Condition	Annual average	Maximum events[1]	Date
Tornadoes	82[2]–130[3]	739	3/25
		322	4/74
Heavy rains/floods	100[3]–160[4]	2200	5/99
		732	3/13
Hurricanes	38[12]–63[3]	6000	9/00
		1836[8]	9/28
Hail	1[5]	22	5/81
Wind storms	60[6]–115[3]	105[6]	12/72
Lightning	100[3]–156[12]	unknown	
Winter storms and cold	130[3]–200[7]	500	12/83
		270[7]	3/92
Heat waves	1000[9]	> 10 000[10]	1980
		> 9500[11]	1901

[1]Extremes are from Munich Reinsurance (1993), except where noted.
[2]See Ferguson and Ostby 1991.
[3]Adapted to current population based on population ratios in White and Haas (1975).
[4]See Wood 1989.
[5]See Changnon et al. 1977.
[6]See Brinkmann 1975.
[7]See Ludlum 1994.
[8]*USA Today,* 19 July 1995.
[9]*Chicago Tribune,* 26 July 1995.
[10]See U.S. Senate Special Committee on Aging 1983.
[11]*Champaign-Urbana News-Gazette,* 17 July 1995.
[12]See Wood 1993.

associated with any other weather condition. Annual U.S. heat-related death values in recent years range from a low of 148 deaths to highs in excess of 10 000 deaths (*Chicago Sun Times,* 12 July 1995).

Ironically, heat-related death statistics are more difficult to assess than those related to other weather conditions. Because here is no federal definition of a "heat death," medical examiners have different ways of defining heat deaths. Everyone records "heat stroke" as a cause of death, but differences occur when those dying due to heart attacks or stroke do so during heat waves. In these situations, heat is sometimes considered a prime cause of death, or heat may be listed as only a contributing factor, with stroke or heart failure listed as the primary cause of death. In some cases, some health examiners list heat as a secondary factor causing death. To address this dilemma, another approach used for estimating heat-related deaths is to compare the number of deaths during a heat wave with the number of deaths during the same period in years with near-average temperatures (U.S. Senate Special Committee on Aging 1983).

More than 70% of heat-related deaths occur in persons aged 65 or older (Avery 1985). Health effects of a heat wave result from high temperatures, high moisture levels, lack of air movement, and radiation (Steadman 1979a,b). A relative humidity of 40% with a dry-bulb temperature of 30°C results in an apparent temperature of 30°C, but the same dry bulb with 70% relative humidity produces an apparent temperature of 35°C. If wind speed exceeded 8 m s^{-1}, the apparent temperature would drop to 34°C. The temperature/moisture–wind/radiation relationship developed by Steadman produces an *apparent temperature,* reflecting the ability of the human body to dissipate heat. Apparent temperature has become widely used as the "heat stress index" or more simply, the "heat index." Wind movement is a minor factor in summer (Avery 1985), with temperature and moisture conditions being the most critical factors. Prolonged heat waves can also become an air quality problem affecting health, particularly as ozone concentrations increase. However, Kalkstein (1995) has shown that heat is a much greater factor causing human deaths than is accompanying air pollution.

The problem of clearly identifying heat deaths has led to major underestimates of heat deaths (U.S. Senate Special Committee on Aging 1983). Ellis's studies (1972) found that actual heat-related deaths are generally 10 times the number recorded. For example, during the 1988 heat wave, the county health examiner in Chicago identified 77 heat deaths by mid-August, noting that "lots of other people had heart attacks" (*Chicago Tribune,* 18 August 1988). In August 1988 the examiner identified 55 deaths as heat related, but the "excess deaths," the number above the August average, was 232 (Whitman 1995). Some reports consider the excess deaths during heat waves as the most correct measure of heat-related deaths (Avery 1988).

Ellis (1972) also identified more than 500 heat-related deaths per year in 1952, 1953, 1954, 1955, and 1966. Avery (1985) found 6700 deaths due to heat in 1966, and 9500 heat-related deaths were reported during the 1901 heat wave (Table 1). During the July 1936 heat wave, considered one of the worst on record in the nation, 3900 people died over an 8-day period (*Chicago Tribune,* 16 July 1936). A Congressional investigation found that the 1980 heat wave produced more than 10 000 deaths (U.S. Senate Special Committee on Aging 1983). Heat waves accompanying the 1988 drought caused between 5000 and 10 000 deaths (Riebsame et al. 1991). As shown in Table 1, the national average of deaths attributed to heat is estimated to be 1000 deaths (*Chicago Tribune,* 26 July 1995).

b. The 1995 heat wave

In mid-July 1995, a 5-day heat wave struck the Midwest killing an estimated 718 persons in 10 states (Table 2). This event joins the ranks of heat waves in recent years (1988, 1980, and 1966) with excessive numbers of heat-related deaths in the Midwest. Deaths in the Midwest during July 1995 were 87% of the national total and were concentrated in Illinois and Wisconsin, as shown in Table 2. These high state totals were due to an excessive number of deaths in two large cities, Chicago and Milwaukee. Deaths due to

TABLE 2. Number of heat-related deaths in the Midwest for 10–31 July 1995. Source: *Chicago Tribune,* 31 July 1995.

State	Deaths	State	Deaths
Illinois	581	Indiana	3
Missouri	31	Ohio	6
Wisconsin	85	Michigan	6
Minnesota	1	Kentucky	2
Iowa	3		

the heat were reported to be 550 in Chicago and 60 in Milwaukee (*Wisconsin State Journal,* 19 July 1995), 86% of the Midwestern total. Most of these deaths occurred in a 4-day period, 13–16 July 1995.

Table 3 shows the temporal evolution of reported heat deaths during the July heat wave in Chicago, the Midwest, and the nation. Values are those reported by the news media and do not reflect the exact date of death, but rather the date when totals were presented by local officials and filtered through the media. For example, on 16 July, Chicago examiners reported 116 heat-related deaths but also that 270 bodies were waiting to be examined (*Chicago Tribune,* 16 July 1995). Also presented in Table 3 are the later official values from the Chicago Department of Public Health. These show the buildup in the heat-related deaths was at a much higher rate than actually reported at the time. The official number of heat-related deaths on 15 July was 186, the 1-day maximum for the heat wave (Centers for Disease Control and Prevention 1995). Chicago medical examiners worked overtime to perform autopsies but could not keep up during the latter stages of the heat wave. Hospitals and ambulance services were overwhelmed. This 1- to 2-day delay in reported deaths in Chicago is reflected in the numbers for the Midwest and the nation since Chicago deaths were a significant portion of both totals.

Examination of values in Table 3 and actual date of death data reveals a rapid upsurge in deaths from 14 to 20 July, with nearly a doubling in Chicago between 16 and 17 July when medical examiners were finally able to complete autopsies of waiting corpses. A few persons also died due to delayed heat effects from 21 July to 2 August, which ended further reporting of the deaths assessed as due to the mid-July heat wave. Recall that the heat wave at Chicago lasted from 11 July to the late afternoon on 15 July (Kunkel et al. 1996). Most deaths in Chicago occurred during 13–16 July when apparent temperatures during daytime exceeded 40°C and nocturnal temperatures remained above 30°C, suggesting a critical "threshold" for heat deaths in Chicago. Also, as in previous heat waves, deaths began one or two days after the heat wave began (11 July).

The official count of heat-related deaths in 1995 at Chicago was 525 (Table 3), a number less than the media count of 550. Assessment of excess deaths, the number during 13–31 July above the July average deaths, was 733, nearly 200 more than officially declared as heat related. This points again to the problem of assigning cause of death due to heat effects.

It is interesting to compare Chicago heat deaths of 1995 with those in the period defined as the most extreme on record, 8–15 July 1936 (Table 1; Kunkel et al. 1996). During 8–15 July 1936, maximum daily dry-bulb temperatures in Chicago's non-lake-effect area were 38°C or higher every day and averaged 41°C, and the daily minimums averaged 24°C, 5–6 degrees higher than suburban temperatures every day. As a result of this 8-day period in 1936, the Chicago coroner identified 297 heat-related deaths (*Chicago Tribune,* 16 July 1936), roughly half those occurring in July 1995. The heat wave in late June 1931, ranked as the worst of this century based on the apparent temperature of 36.1°C over four days (Table 1; Kunkel et al. 1996), led to 169 heat-related deaths in Chicago. The question becomes, what caused the big difference in deaths between the severe heat waves of the 1930s and that in 1995? Possible explanations include 1) changes in social conditions (e.g., older people in the 1930s were less afraid of crime and were able to leave doors and windows open or to sleep safely out-

TABLE 3. The evolution of reported heat deaths in Chicago, the Midwest, and the nation during July 1995.

Date	Media[1] Chicago	City agency[2]	Midwest[1]	Nation[1]
14 July	0	4	14	30
15 July	60	58	81	92
16 July	116	244	175	222
17 July	179	449	302	367
18 July	376	480	555	656
20 July	456	498	637	741
30 July	530	523	711	816
2 August	550	525	718	830

[1]Sources: *Chicago Tribune, Chicago Sun Times, USA Today,* and *New York Times* for July and August 1995.

[2]Chicago Department of Public Health report (Whitman 1995).

doors,[1] and more older persons in the 1930s lived with families that cared for them, whereas in 1995 more of the elderly live alone), 2) effect of an increased population at risk between 1936 and 1995, or 3) differences in record keeping on the cause of death. The Chicago metropolitan population grew from 4.0 million in 1940 to 5.4 million in 1990, but the population in the inner city (where most deaths occurred in all years) has not increased at a similar rate, being only 20% greater in 1995 than in 1936. The effect of air conditioning should lead to decreased deaths since 1936, but most 1995 deaths occurred in homes without air conditioning or where residents did not operate air conditioning or fans because they were unable to afford them (*New York Times,* 20 July 1995).

Another demographic factor that changed from 1936 to 1995 relates to the human age distribution. It has shifted, with more elderly per capita in 1995 than 60 years ago. In the July 1995 heat wave, 73% of the heat-related deaths were persons 65 or older (Whitman 1995). Since the elderly are those most prone to heat stress, this ongoing shift in age could help explain the greater frequency of deaths in 1995. Also important at Chicago was race. Non-Hispanic African Americans were 1.9 times more likely to die from the heat as non-Hispanic whites, and this difference was evident in all ages over 55 (Mayor's Commission on Extreme Weather Conditions 1995). Thus, shifts in ethnicity of urban populations is another factor. Collectively, these social-demographic factors (increasing population, a generally older population, a fear of crime, changing ethnicity, and reduced home/apartment ventilation) would indicate ever greater likelihood of heat deaths in large urban areas.

The 581 heat wave–related deaths during 1995 in Illinois were also compared with casualties for other weather hazards in Illinois, and averages and extremes appear in Table 4. Studies were based on different base periods, a factor influencing averages and extremes cited in Table 4. Comparison of average values reveals that the frequency of heat deaths far surpasses those of any other weather condition. Although 581 deaths due to the 1995 heat wave are the record highest heat-related loss of life during the last 35 years, the total does not quite match the 606 deaths due to the "Tri-State Tornado" of 18 March 1925 (Changnon and Semonin 1966). The regional enormity of the deaths caused by the 1995 heat wave is obvious.

The 1995 heat wave also caused many other types of impacts. For example, energy use vastly increased, reaching an all-time record high on 14 July in Chicago of 19 200 MW (*Chicago Sun Times,* 20 July 1995). A densely populated northern section of Chicago experienced a massive power failure during peak stress times, with power lost to more than 40 000 persons overnight on 14 July, and 8500 people still without power on 15 July (*Champaign–Urbana News-Gazette,* 16 July 1995). Interestingly, no one claimed that this loss of power and air conditioning was a cause of heat-related deaths. The local power company also used "rolling blackouts" in certain western rural suburban communities to help sustain power to southside communities. Demands for power often exceeded capabilities of local power companies elsewhere in the Midwest. The heat wave led to increases in electric bills, a problem for low-income families. In general, regional power companies experienced increased revenues but face potential financial liability for the

TABLE 4. Weather-related deaths in Illinois.

Event	Annual average	Event extremes of record	Period
Tornado	5[1]	606	1915–1990
Lightning	6[2]	11	1914–1947
Winter storms/cold	4[3]	28	1901–1967
Winds	1[4]	4	1950–1957
Heavy rains/flood	4	18	1914–1947
Heat	74	581	1960–1995
Hail	0	1	1914–1947

[1]See Changnon 1982.
[2]See Changnon 1964.
[3]See Changnon 1969.
[4]See Changnon 1980.

[1]A local headline during the 1934 heat wave said, "96° Plus Humidity Empties Flats; No One Sleeps at Home; Parks and Shorelines Full" (*Chicago Tribune,* 20 July 1934).

power failures and brownouts. For example, a group in Chicago, including several businesses damaged by the prolonged power outage, filed a class action suit against the local power company.

Highways and railroads were damaged due to heat-induced heaving and buckling of roadway joints and rails. A freight train wreck in Ohio on 14 July was due to heat-induced movement of rails. Reports from many companies also indicated that work efficiency was greatly reduced and shopping declined dramatically.

A major problem in Chicago was an insufficient number of ambulances to handle the crisis as thousands were taken to local hospitals during 13–16 July (*Chicago Sun Times,* 20 July 1995). In many cases, fire trucks were used as substitute ambulances. Chicago-area hospitals immediately became overloaded and were unable to handle the caseload of heat-related illnesses plus the dead and dying (*Chicago Sun Times,* 20 July 1995).

The heat wave also affected livestock. On 14 July, 850 cows in Wisconsin dairy herds died, major flocks of poultry were killed, and milk production declined by 25% (*Wisconsin State Journal,* 15 July 1995).

Any weather condition produces winners and losers (Changnon 1979), and the extreme heat of 1995 was no exception. Among the many winners were tourism in Wisconsin, manufacture and sale of air conditioners, and public swimming pools. During and after the heat wave, Wisconsin experienced a 10% increase in tourists (*Wisconsin State Journal,* 29 July 1995). Sales of air conditioners in the Midwest were up 52% over 1994, and the nation's prime manufacturer of air conditioners was operating three shifts a day to try to keep up with the demand (*Chicago Tribune,* 26 July 1995). As expected, record attendance was reported at public swimming pools.

c. Responses

Responses to the heat wave were extensive, particularly those relating to numerous deaths in Chicago. Shortly after the heat wave, assessments of the problem's magnitude and its causes began, including politically inspired debates as to who and what were at fault. Several factors were cited as "the cause of the unusually high death loss."

Uniqueness of the weather was a commonly cited factor, as was the failure of Chicago government officials to declare a heat emergency until 15 July, four days into the heat wave. Without advance warning, very few Chicagoans ever used the city's five cooling centers, places established with air-conditioning and facilities for persons to come and relax and rest. This belated declaration of a heat emergency was seen as a major factor leading to the excessive number of heat deaths (*Champaign–Urbana News-Gazette,* 18 July 1995). Another related factor to consider was the heat wave forecasts. The National Weather Service (NWS) issued timely warnings about the impending heat wave on 5 July (*Chicago Sun Times,* 5 July 1995), and on 8 July a newspaper article announced,

> "A heat wave is brewing for Chicago—a suffocating air mass, hottest of the season—a massive ridge of high pressure is stalling over the Midwest, a superheated dome of dry, sinking air with the mercury to go above 100°F by Tuesday [July 11, the first day of the heat wave] or Wednesday [July 12]" (*Chicago Sun Times,* 8 July 1995).

The NWS began an investigation of the adequacy of their forecasts in August, but it appears that forecasting of the heat wave conditions was correct and the onset was recognized several days in advance.

Closely tied to the unique weather conditions is Chicago's heat island, which exacerbated the heat problem. Urban heat islands exhibit much less nocturnal cooling than occurs in rural areas. Hence, large cities do not cool off at night during heat waves like rural areas do, and this can be a critical difference in the amount of heat stress within the inner city. The heat island was cited as an important factor in the deaths at Chicago (*New York Times,* 20 July 1995). Temperature forecasts made for Chicago are for O'Hare Airport, a suburban location with a lesser heat island than the inner city of Chicago.

During heat waves, it is extremely important to delineate the magnitude and dimensions of an urban heat island in preparing warnings for future heat conditions in inner cities. Past studies of conditions in Chicago defined average temperature and moisture conditions of the Chicago heat island in relation to nearby rural conditions (Ackerman 1985, 1987). The key question for forecasters was whether these average heat island–rural differences in temperature and moisture are similar to or quite different than conditions during heat waves.

Table 5 presents mean maximum and mean minimum temperatures determined for the four most severe heat waves during 1901–1995 (27–30 June 1931; 21–24 July 1934; 11–14 July 1936; and 12–15 July

1995). Values are for the inner-city station, the near-lake station in Chicago, a suburban station, and a rural station west of Chicago. Comparison of these values reveals three key points: 1) the near-lake station has a mean maximum > 3.7°C lower than all others, 2) the inner-city maximum is nearly identical to those at the suburban and rural stations, and 3) the inner-city and lakefront mean minimums are comparable (no lake effect at night) and are 2.0°–2.5°C higher than the rural and suburban minimums. These findings for heat waves indicate that the urban heat island during midday is insignificant (with city values near the lake greatly reduced by the lake effect), but the urban heat island at night is sizable during severe heat waves. Urban–rural differences in maximum temperatures in the four heat waves was only 0.1°C compared to a summer average difference of 1.7°C (Ackerman 1985). The urban–rural difference in minimum values for the heat waves was 1.9°C, a value similar to but also less than the summer average difference of 2.7°C (Ackerman 1985). A comparable analysis of moisture could not be accomplished because of the lack of quality urban and rural measurements in the 1930s. Kunkel et al. (1996) found that urban–rural dewpoint temperature differences during the 1995 heat wave were different than those under average summer conditions.

TABLE 5. The mean maximum and mean temperatures for stations in and around Chicago, as determined from city's four worst heat waves during 1901–1995.

Location	Mean maximum °C	Mean minimum °C	Range, °C
Inner city[1]	38.9	24.5	14.4
Near lake[2]	35.2	25.1	10.1
Suburb[3]	38.9	22.5	16.4
Rural[4]	38.8	22.6	16.2

[1]Values for Chicago Midway station except Cicero values for the 1934 heat wave.
[2]Values for Chicago University station except in 1995 when Meigs Field values used.
[3]Values for Aurora station, located 65 km west of Chicago.
[4]Values for Sycamore station for the 1930s and for DeKalb (9 km from Sycamore) for 1995. Both stations are 105 km west of Chicago.

The key finding suggested by the Chicago data is that temperature and moisture conditions associated with the heat island should be determined and incorporated in preparing high temperature forecasts. They are currently issued for O'Hare Airport, which is not representative of the city's heat island. Further, results suggest that heat island conditions during heat waves are probably different for other large cities due to varying local effects (Kalkstein and Davis 1989), a subject warranting further investigation.

City officials received extensive criticism for not issuing a heat emergency warning until 15 July (final day of the heat wave). The city's heat emergency plan called for declaring a heat emergency when air or apparent temperatures were expected to exceed 40.5°C for two consecutive days, and the apparent temperatures exceeded this threshold on 13 and 14 July. During the middle of the heat wave (13 July), Chicago Mayor R. Daley stated, "It's hot. It's very hot. We all have our little problems, but let's not blow it out of proportion" (*USA Today,* 19 July 1995).

This failure to recognize the growing problem and to declare an emergency in timely fashion led the City Council to hold hearings. Mayor Daley, after admitting that "the city could have done better" (*Chicago Tribune,* 19 July 1995), criticized power companies for their power outages as a cause of many deaths and further claimed the death tally had been incorrectly inflated by the county medical examiner, who Daley claimed counted heat deaths that should have been assigned to other illnesses (*Chicago Tribune,* 20 July 1995). This charge was refuted by the county medical examiner and by the investigators from the Centers for Disease Control and Prevention (1995). The medical examiner had a definitive set of criteria for classifying heat deaths, and these criteria had been in use since 1978. These criteria included: 1) measured body temperature of 105°F or above, 2) evidence of high environmental temperature noted at the time a body was discovered, or 3) a decomposed body, last seen alive at the time of a heat wave (Mayor's Commission on Extreme Weather Conditions 1995). The Chicago medical examiner reported that the 1995 heat deaths were an "Act of God" (*Chicago Tribune,* 20 July 1995), interestingly the same explanation offered by a religious leader for the many deaths during the 1936 heat wave (*Chicago Tribune,* 13 July 1936).

Some city officials claimed that many who perished during the heat wave would have died soon anyway, which was refuted by the Chicago health examiner (*Chicago Tribune,* 25 July 1995). Kalkstein's (1995) study of "displaced deaths," the time displacement of imminent deaths caused by heat, at St. Louis, revealed that 81% would not have occurred shortly after the heat wave and that only 19% were imminent at the time of the heat wave.

As a result of debates over who and what were at fault, Mayor Daley appointed a Commission on Extreme Weather Conditions to ascertain what went wrong and what should be done in the future (*Chicago Tribune,* 20 July 1995). The mayor presented a new "heat warning plan" on 20 July (*Chicago Tribune,* 21 July 1995). The new, more comprehensive plan had three phases, each based on NWS forecasts of different temperature levels expected at O'Hare Airport: heat watch (heat index ≥ 90°F), heat warning (heat index ≥ 90°F for three days), and heat emergency (heat index ≥ 105°F). The Chicago Health Department receives the forecasts and declares the category and alerts all other city agencies. The city also established a "weather center" so that the NWS can quickly feed heat wave information or any form of weather hazard warnings for wide dissemination to appropriate elements of city government.

Responses at the state level in Illinois are of interest. On 17 July, Governor Edgar of Illinois declared Cook County a "disaster area" and requested federal aid. Several Chicago-area state senators called for legislative hearings to investigate problems in Chicago, including lack of warning by the city. The Illinois Commerce Commission announced it would hold inquiries into the questionable performance of the Chicago-area power company.

At the federal level, the major response was President Clinton's announcement that the federal government would provide $100 million for emergency funds for the Low Income Home Energy Assistance Program to help people meet payments on power bills in 19 states. Amounts awarded to each state were based on 1) the number of cooling degree days above average for 9–15 July, and 2) the amount of low-income housing in the state. Illinois received the most funding, $15.7 million, and the 10 Midwestern states with 87% of the heat deaths received 73% of the funding. The National Oceanic and Atmospheric Administration also launched an investigation of the performance of the NWS during the heat wave. The U.S. Department of Health and Human Services performed a special investigation of the heat wave (Centers for Disease Control and Prevention 1995).

3. Summary and recommendations

The loss of human life by hot spells in summer exceeds that caused by all other weather events in the United States combined, including lightning, rainstorms–floods, hurricanes, and tornadoes. *Thus, the short-term extremes of summer weather conditions are the most severe weather events affecting human life in the United States.*

The primary victims of the 1995 heat wave, as in past heat waves, were older persons in large cities within the heart of the urban heat island. Urban areas, particularly older U.S. cities, are particularly vulnerable to heat waves. Many older citizens in low-income areas have no air conditioning or cannot afford to operate systems, and they fear use of open-window ventilation at night because of high crime rates in their neighborhoods. Many people have also forgotten how to "live and function" with high temperatures and need continuing education and reminders when heat waves approach. This is particularly true in more northerly cities of the nation where extreme heat is not common.

The nation needs a national system to collect data on heat deaths and a standard, widely accepted definition of what constitutes a heat death. Uncertainties over heat-related deaths have clouded the issue and limited actions to address the problem. Society needs a definitive means for assessing and classifying heat-related deaths.

With the ever-growing populations of elderly persons in the nation and with heat-related deaths in the thousands in recent years (1980, 1988, and 1995), it is fairly obvious that heat-related deaths are on the increase and will continue to increase if action is not taken. Clearly, there is a need for definitive community warning systems tied to weather forecasts of excessive heat issued by the NWS. It is important that a knowledgeable meteorologist be involved who can help explain to the local decision maker the forecast and danger it represents. Forecasts and warning systems need to be integrated at the local level with special warning systems established similar to one in Philadelphia (Kalkstein 1995). This 1995 event demonstrates once again that decision makers cannot make good choices with inadequate weather information and/or their decision models involving weather data are flawed, often lacking proper calibration to the local scene and/or updating to address everchanging physical and social conditions (Riebsame et al. 1991).

Another major problem illustrated in the heat wave, as in the questionable responses to the 1988 drought (Riebsame et al. 1991), is the lack of experience because these extreme events are widely spaced in time. Thus, they rarely occur twice in the career of an emergency response decision maker. This too is a challenge to atmospheric scientists who better understand this problem. This point illustrates the importance of a knowledgeable meteorologist to interface with local decision makers.

The 1995 event should help focus scientific attention on addressing the heat death problem through accurate forecasting, adequate local information dissemination systems, response capabilities, and careful definition of heat death thresholds for major cities. This study has shown that the Chicago heat island during major heat waves differs markedly from the average heat island conditions. It appears that the forecast of heat wave conditions at Chicago, and at other cities, needs to include the heat island values apt to occur, not just the local airport values. Furthermore, the "correct" forecast of apparent temperature for Chicago and its heat island area likely differs from the correct threshold forecasts for Philadelphia, Atlanta, or other cities. Kalkstein and Davis (1989) have shown that these death thresholds vary between cities. This results from differences in regional physical features (valleys, mountains, lakes, etc.), climatic conditions, and in configurations of individual urban areas. These local effects need to be integrated into the forecasts.

Heat stress is a national problem, heat-related deaths are preventable, and atmospheric research focused on the problem is needed. Understanding relationships of stressful weather conditions with ever-changing social conditions, coupled with knowledge of the difficulty in assessing heat-caused deaths, and recognizing the need to have heat warnings designed for a particular place and time, are offered as important objectives for the atmospheric sciences and the nation.

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