The Development of an Evaporative Cooler Warning System for Phoenix, Arizona

Adam J Kalkstein
Laurence S. Kalkstein
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INTRODUCTION

Previous research has linked oppressive meteorological conditions to excessive mortality in numerous cities around the world. As a result, Heat-Health Watch/Warning systems, based on a synoptic methodology, have been implemented in places determined to be particularly prone to heat-related mortality such as Rome, Italy, Shanghai, China, Philadelphia, PA, and numerous other cities (Kalkstein 2004, Tan et al. 2004, Ebi et al. 2003, Fano et al. 2001). These watch/warning systems are based upon the occurrence of certain air masses that have historically been associated with elevated mortality levels. It is advantageous to use air masses in this type of heat-health research since it considers the entire "umbrella" of air over a region, rather than a single meteorological variable such as the heat index. For example, the National Weather Service has long considered a 105°F heat index as an arbitrary threshold to issue a "heat warning". However, the Heat-Health Watch/Warning systems discussed here consider numerous meteorological, seasonal, and social factors, and are based upon actual human health responses.

Through the watch/warning systems, it is possible to predict the likelihood of excess mortality given the synoptic conditions present at certain cities. Furthermore, it has been shown that elevated mortality is not solely based upon the overlying air mass itself. For example, the number of consecutive days an oppressive air mass is present has been shown to elevate mortality. In addition, the time of year the event occurs has a significant impact, and people are often more prone to heat-related mortality early in the summer season when their bodies aren't acclimatized to the heat (Kalkstein, 1995).

Unlike most cities, however, Phoenix, Arizona experiences a noticeable shift in summer climate, as the hot, dry conditions present in June and July become more humid in August as the summer monsoon begins to take effect. It is possible that the changes in climate might affect humans' responses to oppressive heat in the Phoenix Metropolitan Area. Furthermore, there has been anecdotal evidence suggesting that minorities in Phoenix, who often use evaporative coolers throughout the summer, are more vulnerable to heat-related mortality. It has been hypothesized that evaporative coolers, which cool homes by evaporating water into the atmosphere, lose their effectiveness as moisture begins to build.

This study will examine the impact of Phoenix's changing summer climate on human health and will be offered to the Phoenix office of the National Weather Service to possibly improve upon the Heat-Health Watch/Warning system currently in place. The overall goal is to develop an "evaporative cooler" warning system that runs parallel to the present heat-health warning system in Phoenix. Thus, the segment of the population that relies on evaporative coolers for the modification of indoor climate can be warned when these coolers loose effectiveness, as determined by increases in heat-related mortality associated with outdoor humidity increases.

Daily mortality data, broken down by race, will be examined along with surface meteorological conditions such as air mass, temperature, and dew point throughout the summer months. The racial breakdown will serve as surrogate data for the impoverished portion of the Phoenix population. It is assumed that blacks, Hispanics, and Indians have less access to air conditioning and depend more on evaporative coolers for primary indoor climate modification than do whites. In addition, if a late-season increase in summer heat-related mortality is occurring in Phoenix, it will provide circumstantial evidence that the use of evaporative coolers throughout the monsoon season might be detrimental to human health.

DATA

Several sets of data are necessary for completion of this study:

(1) Daily mortality data for the Phoenix Metropolitan Area were assembled from 1975 through 1998. Only the summer months of June, July, and August were examined. Furthermore, the data were broken down into several categories depending on race: white, black, Mexican hispanic, non-Mexican hispanic, non-black and non-hispanic minority, and other. For this study, all categories other than white were classifies as minority. It is important to note that the mortality data were standardized to control for increasing population throughout the time period (Fig. 1). A linear trend line was fitted through these annual data, and variations from the mean daily mortality were established for each day evaluated. For example, if 40 people died on a summer day in 1980, and the mean daily mortality for that year is approximately 32, the standardized mortality value was +8. If 40 people died in 1990, and the mean daily mortality for that year is approximately 43, the standardized mortality value for that year was -3.

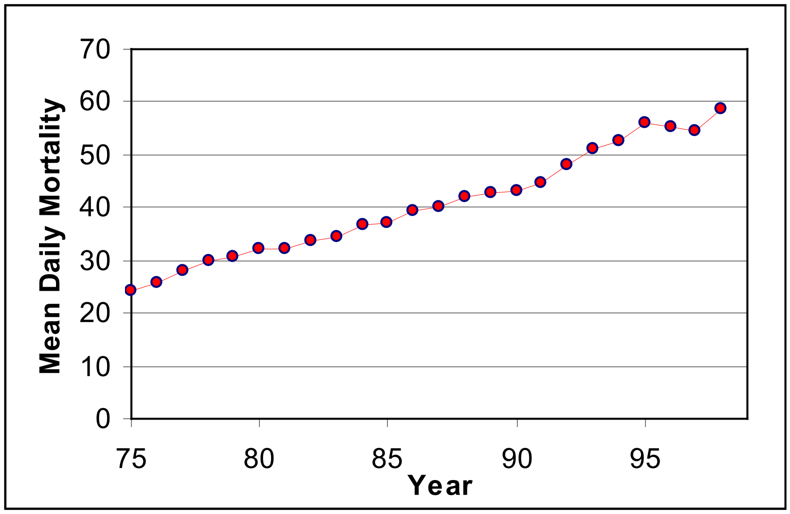

Fig. 1. Average daily summer mortality levels in Phoenix (1975-1998)

(2) A daily air mass calendar was used to classify each day from June 1 through August 31, 1975-1998 into one of 8 air mass types: dry tropical, dry moderate, dry polar, moist tropical, moist tropical plus (a moist tropical day with especially high temperature and dew point levels), moist moderate, moist polar, or transition. The air mass classification scheme used in this study is modified from the Spatial Synoptic Classification (SSC) developed by Sheridan (2002). However, since the majority of days in Phoenix throughout the summer consist of dry tropical air, three subsets of this air mass were classified based upon both temperature and dew point conditions: DT1, DT2, and DT1/2 with DT2 having the hottest, driest conditions, DT1having slightly cooler but more humid conditions, and DT1/2 residing somewhere in between.

(3) The surface meteorological data necessary for this study consist of average daily surface temperature and average daily surface dew point measured at Sky Harbor Airport.

The three datasets resulted in an S-mode matrix consisting of 2,208 rows (92 days per year x 24 years) and 5 columns (total daily minority mortality, total daily White mortality, air mass type, average daily temperature, and average daily dew point).

ANALYSIS AND RESULTS

To better understand what synoptic conditions result in elevated mortality levels in Phoenix, average daily mortality was calculated for each air mass type (Fig. 2). It was determined that DT2, the hottest dry tropical air mass with afternoon temperatures often rising to above 110°F, was associated with the highest daily mortality levels. In fact, daily mortality for minorities on DT2 days was nearly 30% above the long-term summer mean. For whites, average mortality levels on DT2 days were approximately 13% above average. Both DT1 and DT1/2 were also associated with elevated mortality, but less than with DT2. Surprisingly, mortality levels among minorities seemed to be more highly affected by air mass type compared to white mortality levels.

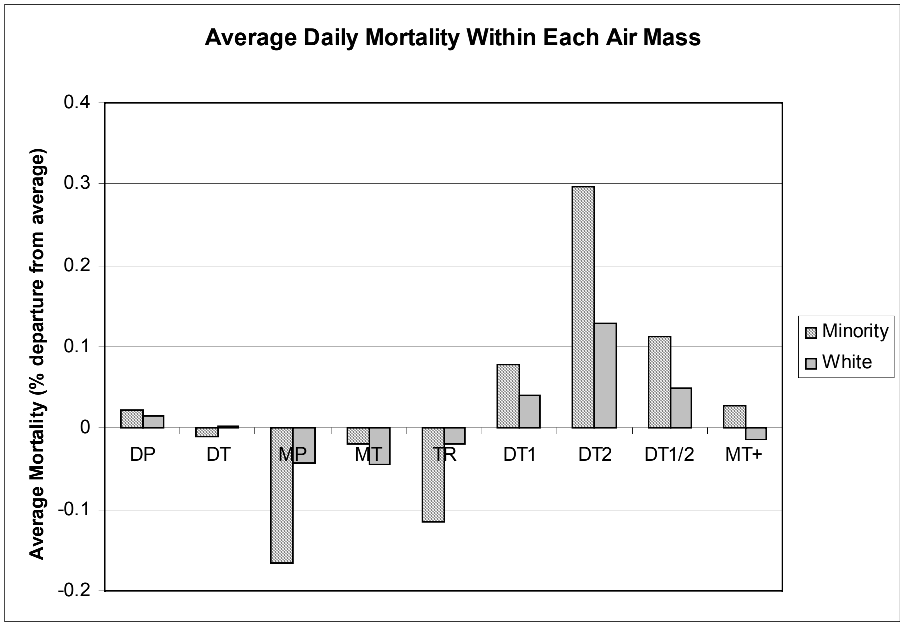

Fig. 2. Average daily summer mortality associated with each air mass

(% departure from long-term average)

To examine if summer heat-related mortality trends in Phoenix resemble those in other cities (ex. higher earlier in the season), average mortality was examined under numerous meteorological conditions for June, July, and August. Best results were obtained utilizing a one-day lag between the offending meteorological conditions and the mortality response. It was found that among whites, oppressive conditions resulted in higher numbers of excess deaths in June, and decreased gradually throughout the rest of the summer (Fig. 3). This pattern is very similar to those found in other cities around the world. However, the seasonal trend for minorities varied greatly from that of whites. Among minorities, oppressive conditions often led to increased mortality in both June and August, but seemed to have little impact in July. In fact, on August days with average temperatures above 36°C, mortality among minorities was over 13% above the long-term summer average. This can possibly be explained by the unique meteorology

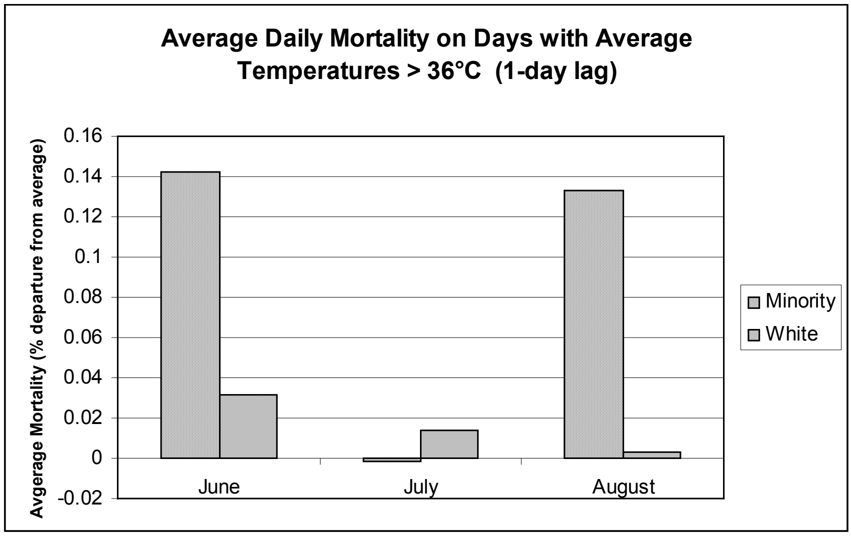

Fig.3. Average mortality on days with average temperatures above 36°C

of Phoenix. During the first very hot days of June, populations are highly vulnerable to heat. As the summer continues, there is a level of acclimatization, and, of course, many of the susceptibles were already killed off through the "harvesting" effect. The most likely explanation for the minority increase in August is the onset of the Arizona monsoon season and the corresponding ineffectiveness of evaporative coolers during that time.

A more specific temperature evaluation was undertaken to determine the precise thermal conditions when mortality began to increase. Thus, threshold conditions at which human health is adversely affected by weather were determined. For whites, it was discovered that days with average temperatures above 37°C often result in a spike in excess mortality levels (Fig. 4). However, for minorities, a sharp increase in mortality seemed to occur on days with average temperatures exceeding 36°C. The spike for

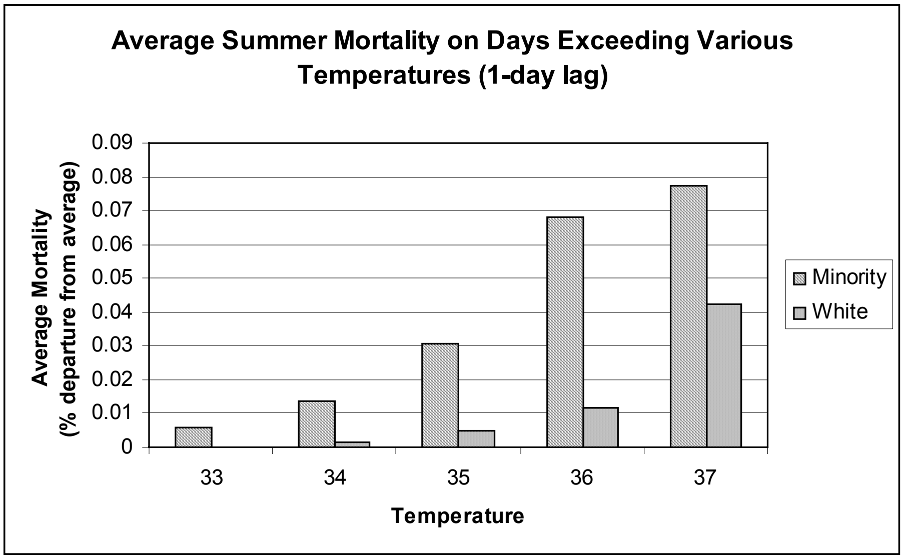

Fig. 4. Average daily mortality on days with various average daily temperatures

minorities was much greater than that for whites.

Dew point was also examined, and minorities appear to be much more susceptible to increases in dew point levels compared to whites. Figure 5 illustrates average daily mortality levels for which temperatures are greater than 37°C and certain dew point thresholds are met. For example, on days with average daily temperatures greater than 37°C and with average dew point temperatures greater than 14°C, minorities experienced mortality levels 22% above average. However, on days with average temperatures greater than 37 °C and dew points above 12°C, minority mortality was only 12% above average. Clearly, for minorities, human health is adversely affected when average dew points exceed 12°C on the hottest days in Phoenix. Whites experienced a much smaller increase in mortality as a result of high dew point temperatures, with the notable exception of only the hottest and most humid days in which average daily temperatures exceed 37°C and dew points exceed 17°C, something that rarely happens.

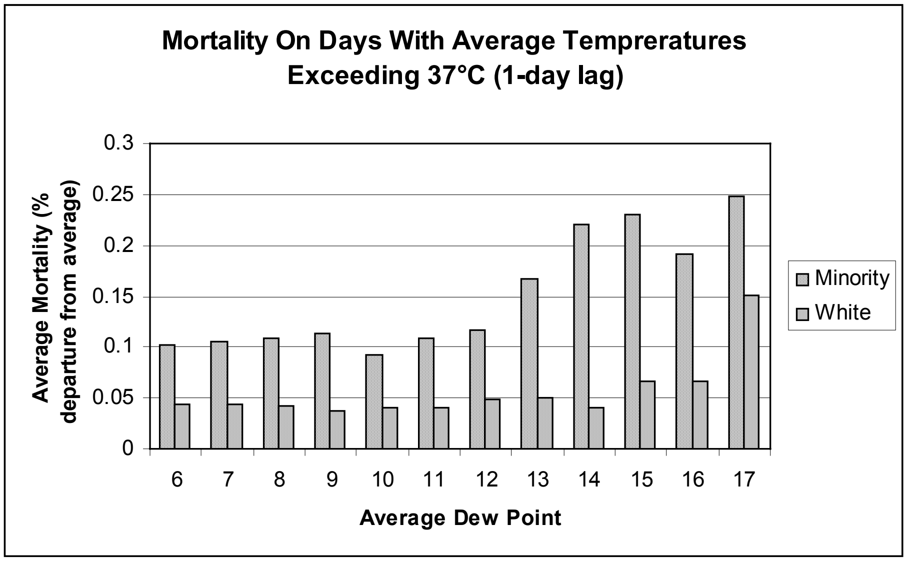

Fig. 5. Average daily mortality on days with average daily temperatures exceeding 37°C

Once again, the mortality spikes for minorities were significantly greater than those for whites.

CONCLUSIONS

This research indicates that, similar to other cities examined around the world, various thresholds exist beyond which human health is adversely affected. First, three distinct air mass types were identified that are associated with elevated mortality levels, especially among minorities: DT1, DT2, and DT1/2. Furthermore, both temperature and dew point thresholds were found that seem to increase human mortality. Most interesting, however, is the apparent susceptibility of minorities to oppressive climatic conditions, especially elevated dew point temperatures. Heat-related mortality among minorities seems to not only spike early in the summer, but also late in the summer during the monsoon season. This late season spike in heat-related mortality is something not observed in any other city for which Heat-Health Watch/Warning systems have been developed. Furthermore, on hot, summer days, minorities seem to be especially susceptible to elevated dew point temperatures.

A possible explanation to the unusual reaction of minorities to elevated dew point levels is the common use of evaporative coolers among minorities in the Phoenix Metropolitan Area. It is clear that evaporative coolers, which depend upon the effectiveness of evaporating water to cool home interiors, become less useful when dew point temperatures increase. The observed spike in mortality corresponding to elevated dew point temperatures might be a direct result of the decrease in evaporative cooler efficiency.

The research presented here will be essential in the development of an evaporative cooler warning system for Phoenix and Maricopa County. It is expected that those thresholds leading to increased minority mortality during hot, humid conditions will be used to create "evaporative cooler warnings" on summer days when it is predicted conditions will exist that will hinder the effectiveness of evaporative coolers. Hopefully, these warnings will allow portions of the population that depend upon evaporative coolers to seek air conditioned shelter when oppressive conditions exist, potentially saving lives.

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