NH-12

Climate Change, Heat Waves, and Adaptation

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INTRODUCTION

One of the most important prospective impacts on public health and welfare resulting from human-caused climate change is a rise in the rate of heat-related mortality from an increase in the intensity and frequency of extreme urban heat events. It is central to the EPA's Endangerment Finding from carbon dioxide and other greenhouse gases. According to the 2007 Supreme Court case *Mass. v. EPA*, such a Finding requires that EPA regulate these emissions, presumably to the point of non-endangerment.

From the EPA's Technical Support Document for the Endangerment Finding,

> **Severe heat waves are projected to intensify in magnitude and duration over the portions of the United States where these events already occur**, with potential increases in mortality and morbidity, especially among the elderly, young, and frail.

While the first part of this statement is likely to be true (if for no other reason than urban growth), the second half is more of a hypothesis than a statement of fact. The "potential" only exists in the absence of an adaptive response. In reality, the adaptive response is strong. So strong, in fact, that when faced with increasing heat, the general sensitivity of urban populations tends to decline.

In this way, a changing climate actually spurs the adaptive response and may ultimately lead to a better outcome than had warming not taken place at all.

CASE STUDY: STOCKHOLM, SWEDEN

A paper published last year (Oudin Åström et al., 2013) garnered a lot of attention as it purported to quantify the degree to which climate change was leading to an increase in heat-related deaths in Stockholm, Sweden. The researchers reported that as a result of an increase in the occurrence of extreme heat events across the 20th century, an extra **288** people died during the period 1980-2009 than would have otherwise.

However, while the researchers examined temporal changes in the local climate (with the implication that they were driven by large-scale human greenhouse gas emissions), they did not account for changes in the local population's sensitivity to extreme heat. In fact, across the 20th century, the elevated relative risk of dying from extreme heat dropped from nearly 20% to less than 5%. Factoring in this decline, we found that the overall adaptive response prevented more than **2,304** deaths during the same extreme heat events (Knappenberger et al., 2014) from 1980-2009. The number of deaths averted through adaptation was eight times the number of deaths caused by an increase in the number of heat waves.

The observed decline in the relative risk from extreme-heat events likely results from a combination, among other factors, of improvements in health care, dwellings, behavioral changes, and biophysical adaptation to temperature extremes. Some portion undoubtedly driven by climate change itself. Failure to take into account the strong adaptive response leads to the inaccurate and misleading conclusion that a warming climate leads to increases in heat-related mortality.

TRENDS IN HEAT-RELATED MORTALITY IN THE UNITED STATES

Results similar to those found in Stockholm, Sweden, have been demonstrated in cities across Europe and the United States.

We conducted the first comprehensive efforts to identify trends in heat-related mortality in U.S. urban centers more than a decade ago (e.g., Davis et al., 2003). We identified apparent temperature thresholds in 28 major cities across the country and tracked the daily mortality excess that occurred on days exceeding that threshold during the period 1964 through 1998.

We found that for the large majority of cities, after standardizing for changes in the size and the demographics of the population, that the number of people dying during heat waves was declining. And, perhaps most notably, that this decline was occurring in the face of rising urban afternoon apparent temperature.

Another important finding was that statistically identifiable heat-related mortality was virtually nonexistent in in those cities with the highest summer apparent temperatures (e.g., Phoenix, Dallas, Houston, Tampa, Miami)—an indication that as heat becomes commonplace, the population's sensitivity to it declines, or largely disappears.

Our original research included data through 1998. Since then several studies have been undertaken using more recent data. Notably, Kalkstein et al. (2010) using data through 2004 and more recently Bobb et al. (2014) employing data through 2005 reported that the declines in heat-related mortality first identified in Davis et al. (2003) were continuing.

The Bobb et al. (2014) study was particularly interesting in that it reported the trends in heat-related morality for different age categories, particularly focusing on the elderly population cohort—an age group identified by the EPA as being particularly vulnerable to extreme heat events and a population from which the EPA expects to see future morality increases as a result of human greenhouse gas emissions..

What Bobb et al. (2014) found, was that while there was a greater sensitivity in the elderly populations early in the data period (mid-1980s), by the end of data record (2000s) the sensitivity to extreme heat in the elderly population (>75 years old) had become statistically indistinguishable from that of the general <65 population.

This finding completely undermines the EPA's projections.

Instead of the expectation that global warming should lead to elevated heat-related mortality, particularly among the elderly population, a more accurate assessment of the scientific literature would lead to the opposite conclusion—that an increase in heat exposure may result in a decrease in heat-related mortality brought about by the adoption of a variety of adaptive measures which lessen the sensitivity of extreme heat events.

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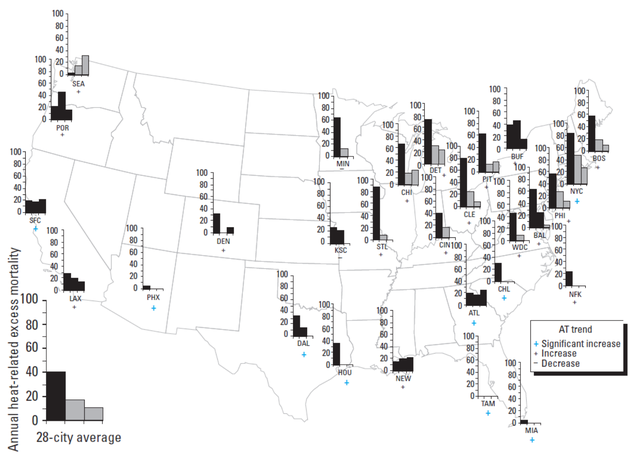
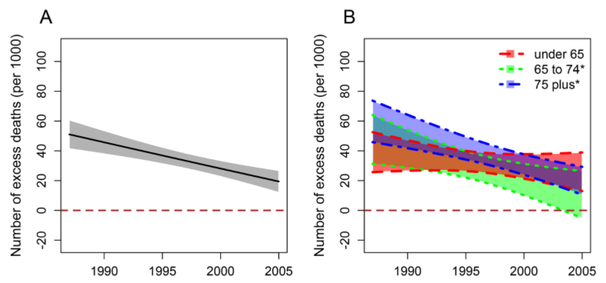
U.S. HEAT-RELATED MORTALITY TRENDS



Annual heat-related mortality rates (excess deaths per standard million population on days in which the decadal-varying threshold apparent temperature (AT) is equaled or exceeded) by city and decade, and long-term trend in summer afternoon apparent temperature (AT). Each histogram bar indicates a different decade: from left to right, 1960s–1970s, 1980–1989, and 1990–1998. Decades without histogram bars exhibit no threshold ATs and no heat-related mortality. Decades with gray bars have mortality rates that are statistically significantly different from the decades indicated by black bars. The average excess deaths across all 28 cities is shown at the lower left. AT trends are indicated beneath each city abbreviation (from Davis et al., 2003).

HEAT-RELATED MORTALITY TRENDS



Temporal trends, from 1987 to 2005, in the excess number of deaths (per 1000 deaths) attributable to each 10°F increase in the same day's summer temperature, nationally in the U.S., (A) on average across age groups, and (B) stratified by age group. Asterisks in the legend denote statistically significant trends (from Bobb et al., 2014).

CONCLUSIONS

The cause of the observed decline in the sensitivity to extreme heat in the face of rising heat is likely found in a collection of adaptations including increased access to air-conditioning, better medical care, improved building design, community response programs, heat watch/warning systems, and biophysical changes. There is no reason to think that such response measures won't continue to exist and be improved upon into the future.

In our recent study summarizing the findings on declining heat-related mortality trends in both the U.S and Europe, we made this observation (Knappenberger et al., 2014):

> "Some portion of this response [the declining sensitivity to excessive heat events] probably reflects the temporal increase in the frequency of extreme-heat events, an increase that elevates public consciousness and spurs adaptive response. In this manner, climate change itself leads to adaptation."

It is insufficient and inappropriate to ignore this effect when compiling and discussing the impacts of climate change. If an increasing frequency of heat events raises public awareness and gives rise to an adaptive response that lowers the population's relative risk due to extreme heat, this must be properly weighed against any increases in mortality that result from a greater number of mortality-inducing heat events.

Our analysis highlights one of the many often overlooked intricacies of the human response to climate change.

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