THE DEVELOPMENT OF HEAT-WARNING SYSTEMS FOR CITIES WORLDWIDE

In Land Minds: 100 Geographic Solutions to Saving Planet Earth, *In Press*

Scott Sheridan, Ph.D.
Department of Geography
Kent State University
Kent, OH 44242
ssherid1@kent.edu

HEAT AS A HAZARD

Natural hazards and their impact upon humans have long been the focus of curiosity by researchers and the general public. Geologic hazards, such as earthquakes and volcanoes, and atmospheric phenomena, such as tornadoes and hurricanes, receive considerable attention, especially in light of the dramatic impact they may have upon the landscape.

In contrast, the awareness of **heat** as an atmospheric hazard has been largely understated over time. This occurs despite the fact that heat is as deadly a phenomenon as all other atmospheric phenomena combined (National Weather Service 2002). For example, over the ten-year period from 1992 to 2001, on average 219 deaths per year were directly attributable to the heat, though with a lack of consensus on the definition of a heat-related death, the actual toll is far higher. While the Galveston hurricane of September 1900 is often cited as the deadliest atmospheric-phenomenon disaster in United States history, claiming 6,000 lives, the hot summer of 1980 is believed to be associated with 10,000 deaths (National Climatic Data Center 2002). Future scenarios suggest that, in a warmer world, heat vulnerability could significantly increase. Worldwide, Tol (2002) estimates that an additional 350,000 people could die from heat-related cardiovascular and respiratory problems per 1°C increase in the global mean temperature.

Yet it is arguable that only after the heat wave of 1995, during which the nation witnessed graphic images of several hundred Chicagoans perishing during a week of punishing heat and humidity, that the will and the resources were galvanized to attempt to mitigate the deadly hazard of excessive summertime heat.

COMBATING HEAT VULNERABILITY

The effort into combating the effects of excessive heat has been forged in two directions: better forecasting methodologies, and better mitigation strategies once oppressive weather has been forecast to occur (e.g. Kalkstein et al. 1996). It is the former in which I have participated, studying the relationship between heat and mortality. My work has been incorporated into improved forecasting systems for several worldwide locations, including Rome, Shanghai, and Toronto, as well as several regions in the US.

The appeal of the heat-health relationship to a geographer is that it is not static. Thresholds of heat vary from place to place, both on the large scale (e.g. Kalkstein and Davis 1989) and the small scale; they depend upon the time of year as well. Understanding heat vulnerability is more than just the ambient afternoon temperature or a "heat index" too: wind desiccates skin more rapidly, less cloud cover heats up buildings faster, and high overnight temperatures do not allow them to cool off.

It is important to assess the heat-health relationship as precisely as possible. Announcing too few warnings would not protect the population, as many hazardous days would be ignored; calling too many days, on the other hand, would result in the population ignoring the warnings.

For all of these reasons, the National Weather Service's official criterion for an excessive heat warning – a heat index above 105°F on two consecutive days – is inadequate. It does not account for whether one is in Duluth or Miami, in May or

August. A more holistic approach, used by many applied climatologists and geographers, is the “synoptic climatological” method. Synoptic climatology’s main goal is to link the atmosphere and a surface “response”, in this case, human health. It does so by categorizing the atmosphere holistically, viewing all components together, rather than independently. This method thus identifies the “air mass” or “weather type” over a particular location at a particular time.

“SYNOPTIC” SYSTEM DEVELOPMENT

By identifying a weather type, one can account for all atmospheric conditions at once, and this is the “umbrella” of conditions to which we respond. The conditions associated with a weather type – temperature, humidity, and so on – vary by location, just as one would expect: a cold front advancing polar air southward never brings temperatures to Miami nearly as cold as those it brings to Minneapolis. The weather types that affect human health actually vary according to location as well. The system I have used in analyzing the heat-health relationship is the Spatial Synoptic Classification (SSC, Sheridan 2002a), which categorizes each day at a location into one of eight weather types. The two most commonly associated with heat-related health problems are, unsurprisingly, the two hottest: Dry Tropical (DT), hot and dry, with little cloud cover; and Moist Tropical Plus (MT+), an oppressively humid weather type with high overnight temperatures.

Up to 25 years of daily mortality data, standardized for population growth and seasonal migration, have been analyzed. As is expected, humans deal worst with conditions that are outside of their accustomed range. Across much of the middle latitudes, both weather types mentioned above occur infrequently, less than one day in ten. Mortality rates on these days generally rise 5 to 10 percent as a result. At locations further from the poles, such as Phoenix and New Orleans, often only the most extreme conditions evoke any response, and these are generally lower in magnitude (Table 1). These mean responses do not capture all the variability observed in the human response. That is, on some oppressive days there is a large increase in mortality; on others, none at all. What causes this variability? In many locations, particularly those farther poleward, seasonality is important. The same weather conditions evoke a stronger response earlier in the season than later in the season, after the population has acclimatized to the summer. The length of time that oppressive conditions have persisted is also crucial – previous forecasting methods never accounted for this obvious factor – the 5^{th} day of a heat wave will be more unbearable than the first, especially inside, where interior temperatures will keep rising each day. Even within a weather type, certain characteristics are important, such as cloud cover and overnight temperatures, as mentioned above.

All of these relationships between mortality, weather, and other parameters are ultimately quantified statistically, and equations are developed that can be used to relate forecast weather conditions to a likelihood of excess mortality occurring, based on past analogous conditions. These relationships appear on interactive websites (Figure 1) for use by the forecaster as well as health and other community officials. Forecasts are automatically produced twice a day based on computer model output, prognosticating two days into the future. The forecasts can also be manually updated, as often as desired, should a forecast change. Utilizing this output, local agencies then have the ultimate decision on whether to call attention to the oppressive conditions. Most agencies have more than one level of advisory. Toronto, for example, has a *heat emergency*, which represents a day whose weather conditions in the past are associated with a greater than 90 percent chance of excess mortality, and a lower-level *heat alert*, where this likelihood exceeds 65 percent. Mitigation strategies vary according to location and type of advisory, but include media announcements, opening of cooling shelters, additional emergency medical services staffing, among other local community action programs.

FUTURE DIRECTIONS

While this work has focused on the metropolitan-area level thus far, much research remains. What makes a particular person vulnerable is not yet fully understood. It has often been surmised that the urban population is more vulnerable, due to the heat island and building type. Interestingly, initial analysis I have performed for the state of Ohio shows the percentage increase in mortality during oppressive heat is similar across rural, suburban, and urban areas (Sheridan 2002b). This suggests that more than the physical location, perhaps other socioeconomic factors are important, as Smoyer (1998) has suggested. As outdoor conditions can only serve as a proxy for the conditions we personally endure on any given hot day, be it indoors or outdoors, with or without a cooling system, vulnerability is an individual-level issue that demands further examination.

REFERENCES

Kalkstein, L.S. and R.E. Davis. 1989. Weather and human mortality: an evaluation of the demographic and interregional response in the United States. *Annals of the Association of American Geographers* 79: 44-64.

Kalkstein, L.S., P.F. Jamason, J.S. Greene, J. Libby, and L. Robinson. 1996. The Philadelphia Hot Weather – Health Watch/Warning System: Development and Application, Summer 1995. *Bulletin of the American Meteorological Society* 77: 1519-1528.

National Climatic Data Center. 2002. Billion-dollar weather disasters, 1980-2002. Website: http://www.ncdc.noaa.gov/ol/reports/billionz.html. Accessed 19 September 2002.

National Weather Service. 2002. Natural hazard statistics. Website: http://www.nws.noaa.gov/om/hazstats.shtml. Accessed 22 September 2002.

Sheridan, S.C. 2002a. The Redevelopment of a Weather-Type Classification Scheme for North America. *International Journal of Climatology* 22: 51-68.

Sheridan, S.C. 2002b. Using a Synoptic Classification Scheme to Assess Rural-Urban Differences in Heat Vulnerability. *Proceedings, 13th Conference on Applied Climatology*: 323-325.

Smoyer, K.E., 1998: Putting risk in its place: methodological considerations for investigating extreme event health risk. *Social Science and Medicine* 47: 1809-1824.

Tol, R.S.J., 2002: Estimates of the Damage Costs of Climate Change: Part I. Benchmark Estimates. *Environmental and Resource Economics* 21: 47-73.

Table 1. Mean mortality response to different weather types by location.

DRY TROPICAL			MOIST TROPICAL PLUS		
Frequency	Excess Mortality	Percentage Increase	Frequency	Excess Mortality	Percentage Increase
CINCINNATI, OHIO, USA (25 years)					
1.9	+4.4	+15.6	6.5	+1.8	+6.4
NEW ORLEANS, LOUISIANA, USA (25 years)					
			2.4	+1.9	+6.2
PHOENIX, ARIZONA, USA (25 years)					
1.3*	+2.7	+6.0			
ROME, ITALY (11 years)					
6.8	+6.2	+12.1	3.9	5.0	+9.8
SHANGHAI, P.R. CHINA (10 years)					
			11.0	42.4	+11.3
TORONTO, ONTARIO, CANADA (17 years)					
3.4	2.4	+7.7	3.9	2.2	+7.1

Frequency is the percentage of days in the period studied that are classified as the weather type (from 15 May – 30 September); **excess mortality** is mean total deaths per day greater than normal; and **percentage increase** represents this increase in mortality as a percentage above mean value. Blank indicates the air mass does not cause an increase in mortality. * "Dry Tropical Plus", defined only for Phoenix, to separate it from the extremely common Dry Tropical weather type.

TORONTO HEAT HEALTH ALERT SYSTEM

Afternoon Forecast
Issued 8/7/2001 15:13:49
Forecast for 8/ 8 - 8/ 9/2001

8/ 8: HEAT EMERGENCY
Conditions oppressive - with a 97% chance of excess mortality

8/ 9: HEAT EMERGENCY
Conditions oppressive - with a 92% chance of excess mortality

DAY				08/08				08/09
HOUR	05	11	17	23	05	11	17	23
TEMPERATURE	23	31	35	29	25	29	31	25
DEW POINT	22	22	23	23	22	23	23	22
CLOUDINESS				4				5
AIR MASS				MT+				MT+
DAY IN ROW				3				4

Forecast data provided by Meteorological Service of Canada - Ontario Region
Click here for the latest 5-day Public Forecast and latest observation at Pearson Airport

SYSTEM LEVELS

HEAT EMERGENCY

The likelihood of weather-related excess mortality occurring exceeds 90 percent.

HEAT ALERT

The likelihood of weather-related excess mortality occurring exceeds 65 percent.

ROUTINE MONITORING

Conditions do not suggest excess mortality is likely.

Figure 1. The Toronto Heat Watch-Warning System webpage.