5B.1 THE DEVELOPMENT OF A SYNOPTIC-BASED HEAT-HEALTH ALERT SYSTEM FOR TORONTO

Wesley P. Kent and Scott C. Sheridan *
Department of Geography, Kent State University, Kent, OH 44242

Laurence S. Kalkstein
Department of Geography, University of Delaware, Newark, DE 19716

1. INTRODUCTION

Since 1999, the city of Toronto has utilized a heat warning system in an attempt to mitigate the effects of excessive summer heat. The system was originally based upon evaluation of the Humidex, an apparent temperature that accounts for temperature and humidity in one variable. When the temperature was forecast to exceed 30°C and the Humidex was forecast to exceed 40°C on two consecutive days, a heat alert was called to advise the public of precautions to take during the oppressively hot weather. These thresholds set were Canada-wide and did not account for Toronto's local climate.

Through a grant from Toronto Atmospheric Fund and Toronto Public Health, researchers at the University of Delaware and Kent State University were contracted to develop a state-of-the-art heat-health alert system. This new Toronto Heat Health Alert (THHA) system is based upon the "synoptic methodology", a method used in several cities worldwide, including Rome, Shanghai, Dayton/Cincinnati, Phoenix, and New Orleans. By analyzing Toronto's past weather variability and health response together, the system is thus developed to account for Toronto's local response to weather variability. This new system debuted in summer 2001.

2. DATA

The premise behind the new Toronto Heat-Health Alert (THHA) system is one of local acclimatization, that is, people in different locations respond differently to extreme weather conditions. Any system that forecasts such conditions should thus account for the local population. For this purpose, 17 years of mortality data and 46 years of weather data have been analyzed for the city of Toronto. Although the THHA has been extended to run beginning May 1, all analyses are performed solely on the period May 15 to September 30.

Weather conditions are incorporated into the system by the use of synoptic categories, or "weather types". With the categorization into weather types, one can account for more than just Humidex: temperature, moisture, cloud cover, and wind are among the parameters included in determining the weather type. The Spatial Synoptic Classification (SSC, Sheridan 2002) is the specific categorization method used; eight weather types are identified for the Toronto area (Table 1).

* *Corresponding author address*: Scott C. Sheridan, Department of Geography, Kent State University, Kent, OH 44242 USA; e-mail: ssherid1@kent.edu

Table 1. Mean frequency (May 15-September 30) and character (July only) of the eight SSC weather-types (see Sheridan 2002 for more information) for Toronto.

Weather Type	Freq. (%)	T 17h (°C)	T 5h (°C)	Td 17h (°C)	CC 17h (/10)
Dry Polar	18	22	11	9	3
Dry Moderate	28	26	14	12	4
Dry Tropical	3	33	20	16	3
Moist Polar	9	18	14	13	8
Moist Moderate	17	23	18	17	8
Moist Tropical	12	28	19	19	6
Moist Trop. Plus	4	30	22	21	5
Transition	10	24	17	15	6

The mortality data span 1981-1997 for the entire city of Toronto. All deaths are counted, as mortality from numerous causes has been observed to increase during oppressive weather (Sheridan and Kalkstein 1998). The data have been standardized to account for the increase in deaths over the 17 years due to changing demographics. While summer mortality overall is lower than other months, there was no observable seasonal trend within the May 15 – September 30 period; hence, no intraseasonal adjustments were made.

3. ANALYSIS

Two weather types are associated with statistically significantly higher levels of mortality: Dry Tropical (DT) and Moist Tropical Plus (MT+). Both are associated with approximately 4 deaths greater than the mean. Similarly, Figure 2 depicts the likelihood that the occurrence of a particular weather type is associated with increased mortality. Once again, DT and MT+ are the only two weather types statistically significantly above 50%.

Dry Tropical (DT) air is associated with hot and dry conditions. It appears in Toronto usually with strong westerly flow, especially above the surface, which can advect significant amounts of continental air to the region. Subsiding air is also typical of Dry Tropical conditions, as the sinking motion contributes to a lack of cloud cover as well as the drier conditions.

Moist Tropical Plus (MT+) air is hot and oppressively humid. It reaches Toronto via the south, around the Bermuda High, with a strong southerly flow bringing significant moisture from the Gulf of Mexico.

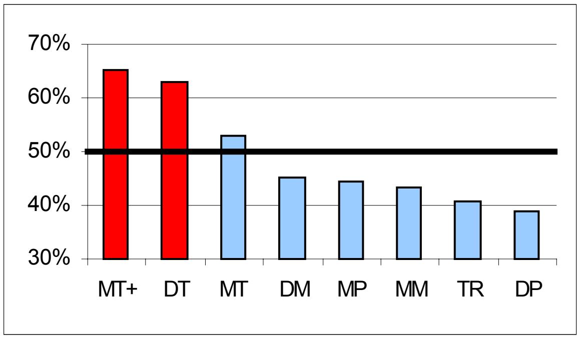

Figure 1. Mean likelihood of excess mortality (percentage) by weather type, Toronto.

Both weather types occur with very high overnight temperatures, not permitting buildings to cool off. They are also the least common weather types, together comprising approximately 7 percent of all summer days. DT peaks in late spring and early summer, when the westerlies are still strong; MT+ peaks in mid- to late-summer, when the Bermuda High is most established and land and water temperatures are warmest.

While both weather types are associated with increased levels of mortality on average, there is still considerable variability within each weather type. For instance, when oppressive conditions occur on consecutive days, mortality is more likely to increase. Also, similar conditions occurring earlier in the summer, before the population has had a chance to acclimatize, are more likely to be oppressive.

To evaluate these other factors, stepwise linear regression was performed for each of the two "oppressive" weather types, comparing mortality with these other factors.

Dry Tropical. For DT overall, there is a 63% chance that excess mortality will occur. The algorithm predicting likelihood of excess morality with DT is

$$likelihood(DT) = \frac{e^{(-9.821-0.043TS+.487H)}}{1+e^{(-9.821-0.043TS+.487H)}},$$

where *TS* is time of season (1 = May 15, 2 = May 16, etc.) and *H* is mean Humidex. One can interpret the equations by noting that as the season progresses, the chance of excess mortality decreases, if atmospheric conditions are constant. Within the test period, this algorithm correctly predicted excess mortality on 81% of DT days, and identified 89% of the DT days during which excess mortality actually occurred.

Moist Tropical Plus. For MT+ overall, there is a 65% chance that excess mortality will occur. The algorithm predicting likelihood of excess morality with MT+ is

$$likelihood(MT+) = \frac{e^{-9.167+0.794SQ+.290T_{17}}}{1+e^{-9.167+0.794SQ+.290T_{17}}},$$

where *SQ* is the day in sequence of an offensive air mass and T_{17} is the 5 PM temperature. This equation suggests that the MT+ weather type is much more offensive as it persists. As a result, the excessively hot temperatures that are needed to lead to excess mortality on the first day are not as important on subsequent days. Within the test period, this algorithm correctly predicted excess mortality on 71% of MT+ days, and identified 87% of the MT+ days during which excess mortality actually occurred.

4. FORECASTING

These relationships have been entered into a web-based tool that ingests weather forecast data and calculates the likelihood that excess mortality will occur. Twice a day, at 3 am and 3 pm, Environment Canada forecasters send information to the website, which then produces the forecasts. Should forecast conditions change, the system may be updated at any moment.

Through consultations with Toronto Public Health, the THHA system suggests a heat emergency if forecast conditions suggest a greater than 90 percent likelihood of excess mortality, a heat alert if excess mortality is 65 to 90 percent likely, and routine monitoring otherwise. Based on the period 1953-1998, on average 1.4 heat emergencies and 4.2 heat alerts would have occurred had the system been in place. Year-to-year variability is significant, however, as several years in the past would have had no emergencies or alerts, while in 1991, 19 would have been recommended.

While the system makes the recommendation for an emergency or alert, the ultimate decision on whether to actually issue an advisory is up to Toronto Public Health.

5. SUMMER 2001

Although the summer of 2001 was not particularly hot overall, there were above-normal numbers of alerts and emergencies recommended by the system. Five emergencies were recommended: June 15, and August 6 through 9. This four consecutive-day stretch was only matched in length three times in the 46 years of available data. Five heat alerts were also recommended: June 19 and 29, July 23 and 24, and August 5. Good forecasting led to most of these occurrences being forecasted at least 24 to 36 hours in advance.

REFERENCES

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

Sheridan, S.C., and L.S. Kalkstein, 1998: Health watch/warning systems in urban areas. World Resource Review, 10, 375-383.