7.1 THE POTENTIAL OF URBAN HEAT ISLAND MITIGATION TO ALLEVIATE HEAT-RELATED MORTALITY: METHODOLOGICAL OVERVIEW AND PRELIMINARY MODELING RESULTS FOR PHILADELPHIA

David J. Sailor*
Tulane University, New Orleans Louisiana

Laurence S. Kalkstein
University of Delaware

Eva Wong
U.S. Environmental Protection Agency

1. BACKGROUND

Regions of intense urban development are distinct from their non-urban counterparts in several key ways. They are typically characterized by relatively lower albedo, lower vegetative cover/moisture availability, and significantly higher anthropogenic heating. The result of these differences is that cities tend to be warmer than their rural surroundings – a phenomenon widely referred to as the urban heat island (UHI).

The consequences of the UHI include reduced thermal comfort and increased summertime electricity loads, air pollution levels (particularly ozone), and incidence of heat-related illness and mortality.

The causes of urban heat islands suggest possible mechanisms for mitigation. Specifically, there is significant ongoing interest in mitigating urban heat islands through large-scale implementation of programs designed to increase urban albedo, and/or vegetative cover.

In this study we investigate the potential implications of large-scale UHI mitigation on issues related to heat-related illness and mortality for a case study in Philadelphia PA.

2. APPROACH AND METHODS

The general approach for this study involves using a mesoscale atmospheric model to simulate historical weather conditions associated with oppressive air masses. We first establish a base-case control simulation and then model the same conditions using modified surface characteristics associated with various levels of city-wide implementation of UHI mitigation. The modeled differences in urban meteorology are then added to the observational data corresponding to each episode and used in conjunction with models relating oppressive air mass characteristics to health. The results include projections of how large-scale mitigation of the UHI might impact the frequency of oppressive air masses and associated heat-related mortality rates.

2.1 Meteorological Impacts of Heat Island Mitigation

The atmospheric model used in this research is MM5 (v3.4) from the National Center for Atmospheric Research. The study region is Philadelphia PA (Fig. 1) which is modeled using 3 nested grids with grid spacing of 18, 6, and 2 km. The outer domain is approximately 1200 by 1000 km. Land use in the innermost domain has been modified from the original USGS data base to better define the current physical extent of the city. The single urban land use category of the USGS classification scheme has also been further refined to include three general urban categories --- urban core, commercial/industrial, and residential, each with their own distinct surface characteristics taken from the literature (e.g. Sailor 1995). The vertical grid consists of 30 levels.

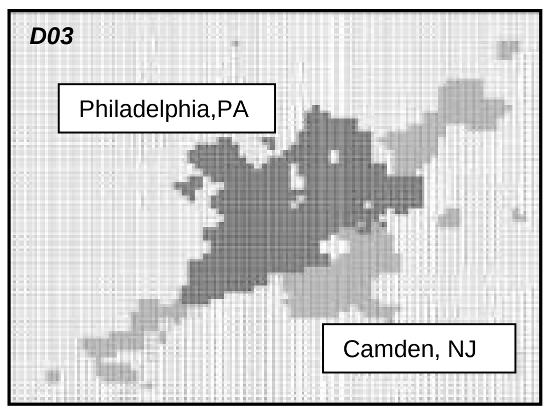

Fig. 1. Spreadsheet representation of Philadelphia's land use for innermost model domain. Shaded regions are urban.

Various 2 to 5 day episodes from the period 1997 to 2001 have been selected to investigate conditions corresponding to oppressive air masses with respect to heat-related mortality. For each episode meteorological simulations are conducted first for the historical land cover (control run) and then for the perturbed land cover associated with a UHI reduction measure. The focus of this paper will be our cursory experiments involving uniform urban albedo increases of 0.10.

To avoid issues of model bias we use model output differences to drive our impact projections. That is, rather than using the directly predicted changes in temperature, dew point, and wind speeds, we calculate the mesoscale-model predicted differences in these variables and add them to the corresponding observational data. Fig. 2 shows a sample of surface air

* Corresponding author address: David J. Sailor, Tulane Univ., Dept. Mech. Engr., New Orleans, LA 70118; e-mail: sailor@tulane.edu

temperature differences resulting from the urban albedo increase of 0.10. This information is then used to drive assessments of potential impacts on oppressive air masses and heat-related mortality, as discussed below.

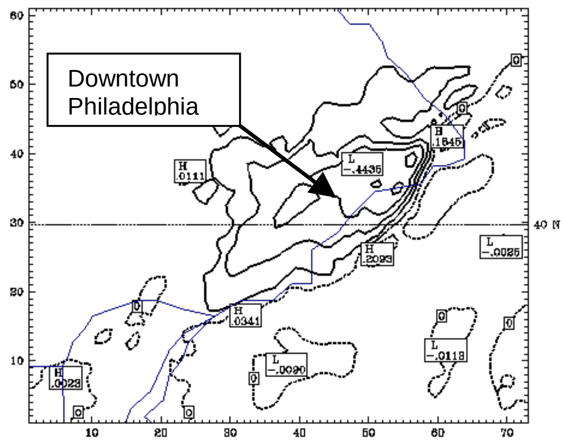

Fig. 2. Contour plot of differences in near-surface air temperatures associated with an urban albedo increase of 0.10. This figure is a snapshot from the July 18, 1999 simulations at 1300 local time.

2.2 Heat-Related Mortality

The analysis approach for heat-related illness/mortality focuses on the determination and evaluation of air masses that lead to dramatic increases in mortality, especially during the summer. We have found that certain oppressive air masses, while relatively uncommon, possess the highest mean mortality and occur on a vast majority of the highest mortality days (Sheridan and Kalkstein, 1998). As not all days within these oppressive air masses are associated with high mortality totals, we have demonstrated the possibility of determining which meteorological (e.g. maximum temperature, dewpoint temperature, windspeed) and non-meteorological (e.g. consecutive days of oppressive air mass, within-season timing) parameters are associated with the highest mortality (Kalkstein, 2001).

In our approach, air masses are identified using a variety of statistical procedures (see Sheridan, 2002). The resulting air mass identification scheme, called the Spatial Synoptic Classification (SSC), places each day within a particular air mass type, and permits identification of those air masses historically associated with elevated human mortality. The specific air mass categories are: dry polar (DP), dry temperate (DM), dry tropical (DT), moist polar (MP), moist moderate (MM), and moist tropical (MT; a particularly oppressive subset of MT, which we have labeled MT+, is most responsible for excess deaths). Heat-health systems developed from this approach are presently being used by the National Weather Service and health department officials in a number of cities.

Using daily mortality data from the National Center for Health Statistics and 50 years of historical weather data we have developed air mass/mortality relationships for Philadelphia. Within each oppressive air mass (for Philadelphia, there are two: DT and MT+) we develop mortality relationships that are typically multiple linear regressions based on meteorological parameters and other factors. The resulting algorithm estimates heat-related deaths for each day; any day with 1 or more estimated deaths is labeled "oppressive". For Philadelphia the MT+ model for estimating heat-related mortality contains the following parameters: number of consecutive days the air mass has been present (direct relationship), maximum temperature (direct relationship), and time of season (whether or not the MT+ day occurs early or late in the warm season; inverse relationship).

The meteorological model output data at hourly resolution are then used to assess the likely change in the number of oppressive air mass days within the modeled urban area between the control runs and the mitigation runs, and also the change in heat-related mortality between the two datasets.

3. RESULTS AND DISCUSSION

For the modest level of urban albedo increase of 0.10 we have found large regions of depressed air temperatures with average daytime depressions of about 0.3 to 0.5 ^{o}C. Due to changes in circulation patterns related to the reduction of the UHI intensity isolated regions on the outskirts of the city typically experience temperature elevations of comparable magnitude but much smaller spatial extent. Corresponding increases in urban dew point temperatures and varying impacts on surface winds are also observed.

When these perturbations to the near-surface weather are used in conjunction with the models of heat-related mortality we find impacts on both the number of oppressive air masses experienced by the city as well as an overall projected decrease in heat-related mortality. The actual impacts vary for the different historical episodes studied. These model results will be presented and discussed in more detail.

Acknowledgement
This work was supported by the U.S. Environmental Protection Agency under Cooperative Agreement X828067.

REFERENCES

Kalkstein, L.S., 2001. Biometeorology - Looking at the Links Between Weather, Climate and Health (A speech given to the Executive Council of the WMO, May 25, 2000), *WMO Bulletin* **50**:1-6.

Sailor, D.J. (1995) "Simulated Urban Climate Response to Modifications in Surface Albedo and Vegetative Cover", *J. Appl. Meteor.*, **34** (7), 1694-1704.

Sheridan, S.C., and L.S. Kalkstein, 1998. Heat Watch-Warning Systems in Urban Areas. *World Resource Review*, **10** (3):375-383.

Sheridan, S.C., 2002. The Redevelopment of a Weather-Type Classification Scheme for North America. *Int. J. Climatology*, **22** (1):18 pp.