Extreme heat and health: understanding exposures, behaviors and vulnerability

by

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Dedication

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To my loving husband, my beautiful daughters Arielle and Jeannelyn.
My mom, Terrie; my Dad, Joseph; my 'other mom' Granny P, and my 'other Dad' Henderson; My awesome little brother Troy, and my grandparents that are living – James & Effie, and my grandparents who have passed away – Andrew & Jessie Kate, who have certainly lived through the ‘heat’, and was the motivation for this work. I hope that this work will help seniors, like them, live longer and healthier lives.

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I know you will always be there in spirit always …

Table of Contents

List of Tables

List of Figures

List of Appendices

ABSTRACT

The increase in the frequency of heat waves and hot weather can negatively impact the health of the elderly. Each part of this dissertation, while unique in structure, works to better understand and quantify the structural, environmental and behavioral factors that can influence heat related health concerns, specifically for elderly populations, as a result of the expected change in our climate.

The first part of the dissertation examined the strength of the influence of structure and the surrounding environment on indoor temperatures in the homes of an elderly population. A mathematical model, using environmental and home-specific characteristics, was created to predict indoor temperature. Home type, access to air conditioning and the external construction material of the home were all found to be significant.

Part two of the dissertation examined behaviors the elderly used to adapt to hot indoor temperatures during the summertime. Elderly volunteers recorded in a daily activity log how they stayed cool, using any of the following eight heat-adaptive behaviors: opening windows/doors, turning fans or the air conditioner on, changing clothes, taking a shower, going to the basement and/or the porch/yard, or leaving the house. It was found that fewer adaptive behaviors were used by the elderly at higher indoor temperatures.

The results of part one and two of this dissertation helped to quantify indoor temperature exposure and adaptive behavior use in the home. Part three of this dissertation examined another data source that could be used to quantify ambient temperature exposure while identifying urban neighborhood hot spots. Land surface temperatures were derived from Landsat TM-5 satellite images and compared with air surface temperatures collected by a ground based temperature monitoring network. The satellite derived land surface temperatures were not strongly correlated with the surface air temperatures collected on the ground.

Overall, results suggest that structural and behavioral vulnerability to heat should be integrated into existing public health interventions or programming, especially those directed at the elderly population. For satellite data sources to be useful in public health practice, both significant advances in data availability and training for public health practitioners on using remote sensing data are essential.

Chapter 1
Introduction

1.1 Background and Motivation for Research

In the United States, an average of 688 persons succumb to heat-related deaths per year (Portier and Tart 2009). The definition of a heat wave can vary, but in general, heat waves can be regarded as an extended period of unusually high atmosphere-related heat stress that can have adverse health consequences for an affected population. (Robinson 2000) These periods of high temperatures, can also increase mortality and morbidity due to other illnesses.(Kilbourne 1986) Heat stroke, heat syncope, heat stress and heat cramps are illnesses that can be generally attributed to prolonged exposure to high temperatures. Heat waves have been the cause of many deaths, most notably the heat wave in France in 2003 causing over 14,000 deaths in a 20 day period, and in the United States, the heat wave in Chicago in 1995.(Semenza, Rubin et al. 1996; Bouchama, Dehbi et al. 2007)

Heat related health impacts can be exacerbated by many factors – environmental, structural and personal. From an environmental standpoint, urban areas have been shown to be warmer than surrounding rural areas.(Voogt and Oke 1998) The temperature differential between cities and surrounding areas can be attributed to many factors, such as increased area to absorb the sun’s energy, impermeability of surfaces (percent surface imperviousness), amount of vegetation, transportation emissions and the land-use geography of the city. (Stefanov and Brazel 2007) Structurally, the type of home (building structure), lack of access to an air conditioned environment, living in homes with high thermal mass and no ventilation, and living on the upper floors of high rise buildings have also been identified as key risk factors. (Hajat, O'Conner et al. 2010) Individual factors, such as age (the elderly and infants), low socioeconomic status, being non-White, low education levels and pre-existing medical conditions (cardiovascular, respiratory) have shown a greater vulnerability to heat. (Basu 2009)

The Intergovernmental Panel on Climate Change (IPCC) projects that the number of heat waves will continue to increase.(Solomon, Qin et al. 2007) Consequently, preparation, as well as the perception of heat being a risk is critical for public health practitioners to understand and use in their work with vulnerable populations. A survey conducted of seventy (70) United States communities found that most are not prepared to prevent the effects of hot weather on the health of residents and several are not taking measures to reduce heat exposures.(O'Neill, Jackman et al. 2010) Additionally, based on interviews of elderly people in two United Kingdom cities about their perceived vulnerability to heat, many did not regard heat as a significant problem and felt that “common sense” strategies were an adequate response and prevention largely unnecessary. Elderly people's perception of heat risk and the lack of knowledge about heat risk among social contacts are important factors that could add to the vulnerability of elderly in the face of heat events.(Wolf, Adger et al. 2010)

Several recommendations to help the United States adapt to climate change adaptation were presented as a part of an Interagency Working Group on Climate Change and Health, convened by *Environmental Health Perspectives* journal and the National

Institute of Environmental Health Sciences. Some of the recommendations included setting policies that specifically establish heat warning systems and taking steps to increase public awareness of consequences of heat exposure, as well as enhancing the awareness of climate change and health among public health and medical practitioners.(Samet 2010) It is believed that the public health community can draw attention to climate change's human health consequences with simple clear messages, can help ameliorate this public health challenge through encouraging individual adaptation and creating policies around climate change mitigation (i.e. reducing green house gas emissions). (Akerlof, DeBono et al. 2010) In future years, with a larger relatively older U.S. population, the overall vulnerability to health risks will increase, depending on how effective we are, as researchers, in identifying, implementing and monitoring certain adaptive behaviors. (Ebi, Mills et al. 2006)

While preparing for heat is typically not a high priority for any public health department, the change in the general climate will drive increased adaptation efforts, especially for the Detroit-area. There have been a few epidemiological studies that have examined the effect of heat on rates of heat related mortality at certain temperature thresholds, as well as understanding those that could be vulnerable to heat in Detroit and/or Wayne County. (O'Neill, Zanobetti et al. 2003; O'Neill, Zanobetti et al. 2005; Medina-Ramon, Zanobetti et al. 2006; Kalkstein and Greene 2007) However, projections show that these events could triple in number to about 30-50 days per year during which temperatures will likely go above 97 degrees for at least half of the 50 days. These changes likely will lead to increased heat related deaths among the elderly, the very young and those with underlying medical conditions.(2010) The heightened awareness and necessity for creating adaptation plans contributed to the state of Michigan being one of the award recipients of a three-year's worth of funding (over $5.25 million split amongst health departments nationwide) to support departmental efforts to address the public health challenges of climate change and develop strategies and projects to protect those communities.

1.2 Research Objectives and Hypothesis

The objective of this research were to provide evidence that can be used by local public health departments to better understand heat risks, as well as prevent heat related morbidity and mortality. My dissertation is composed of three chapters (chapters 2 – 4) as shown in Figure 1. Chapter 2 explored how different characteristics – housing and meteorological characteristics – could be used in a mathematical model to predict temperatures inside the homes of elderly residents of the city of Detroit during the summer. This mathematical model, using actual indoor temperature data from the field allowed us to determine what homes might be more sensitive to drastic increases in indoor temperature. On the basis of the literature, our hypothesis suggests that the following home types would be more prone to high summertime temperatures: high rise apartment type homes, homes made of brick, homes with no air conditioning, homes surrounded predominantly by concrete as well as homes that were built before the year 1940. Additionally, we hypothesized that the prediction capacity of our simple mathematical model would at least achieve a correlation of 0.75 between the modeled and actual indoor temperatures.

The study described in Chapter 3 explored the behaviors (opening windows/doors, turning fans or the air conditioner on, changing clothes, taking a shower, going to the basement, the porch/yard, or leaving the house) used by elderly residents to adapt to hot indoor temperatures. The behavior frequency and the use of behaviors stratified by indoor temperatures, outdoor temperatures, home type (high rise apartment, two-family flat, single family home), and the lack of green space or 'surface imperviousness' at the home, were calculated. We hypothesized that the elderly will engage most frequently in the behaviors that require less human activity, such as 'turning on fans or the air conditioner''. We hypothesized that the elderly would engage in more adaptive behaviors, overall, in the following scenarios: when indoor temperatures exceed 80 degrees Fahrenheit (°F) indoors; when outdoor temperatures exceed 90°F; if the residence was a high rise apartment, and if they lived in an area without a lot of grass, trees and other green covering (i.e. highly impervious area). Understanding the behaviors of the elderly provides critical insight into what types of education and training that might be necessary to protect our seniors that are vulnerable to heat.

The study described in Chapter 4 of the dissertation examined if satellite derived land surface temperatures can help predict areas of high temperatures on the ground. Land surface temperatures derived from this satellite data were validated by temperatures collected from a ground-based temperature monitoring network. This validation exercise was a method of ground-truthing the satellite data source. We hypothesized that the satellite derived land surface temperatures would provide an accurate measure of ground level temperatures, and could be used as a proxy for estimating air temperature near the ground. This data source, combined with socio-demographic and other environmental parameters could provide the necessary inputs to produce vulnerability maps, a visual overlay of data that can provide an understanding of specific geographic locations that have overlapping factors of vulnerability to heat related health concerns.

All three specific aims, while unique in structure, work to better understand and quantify the structural, environmental and behavioral factors that can impact the heat related health concerns, specifically for elderly populations, as a result of the expected change in our climate extreme temperatures.

1.3 Organization

This dissertation is organized into 5 chapters. This chapter (Chapter 1) describes the background, motivation, objectives and hypothesis. The methods and expected results for Chapters 2 – 3 are described in Figure 1.

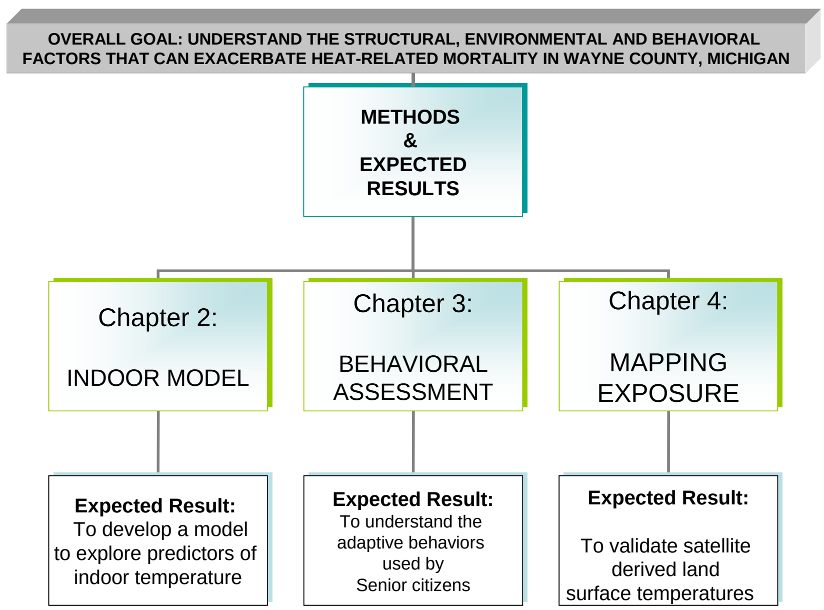

Figure 1-1: Summary of the methods and expected results in Chapters 2 – 4 of the dissertation

Chapter 5 summarizes the findings, strengths, limitations, and implications for public health practice. Chapters 2 – 4 have been written and have been or will be submitted to journals as manuscripts. In addition to the work presented here, a paper that we previously published (in collaboration with other researchers) was part of the motivation for this research and is located in Appendix 1.

Each aim is structured to answer a unique set of research questions, utilizing new, innovative methods, compared to previous studies. The breadth and variety of topics explored in this dissertation can provide springboard for future research, as well as practical results that can be utilized by public health practitioners to minimize heat related morbidity and mortality.

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Chapter 2
Climate change and health: A study of indoor heat exposure in vulnerable populations in Detroit, Michigan

2.1 Abstract

Background: Climate change is increasing heat waves and hot weather in many urban environments. Older people are more vulnerable to heat exposure but spend most of their time indoors. Few published studies have addressed indoor heat exposure in residences occupied by an elderly population.

Objectives: To explore the relationship between outdoor and indoor temperatures in homes occupied by the elderly and determine other predictors of indoor temperature.

Methods: We collected hourly indoor temperature measurements of 30 different homes; outdoor temperature; and solar radiation data during summer 2009 in Detroit, MI. We used mixed linear regression to model indoor temperatures' responsiveness to weather, housing and environmental characteristics, and evaluated our ability to predict indoor heat exposures based on outdoor conditions.

Results: Average maximum indoor temperature for all locations was 34.85°C, 0.83° F higher than average maximum outdoor temperature. Indoor temperatures of single family homes constructed of vinyl paneling or wood siding were more sensitive than brick homes to outdoor temperature changes and internal heat gains. Outdoor temperature, solar radiation and dewpoint temperature predicted 38% of the variability of indoor temperatures.

Conclusions: Indoor exposures to heat in Detroit exceed the comfort range among elderly occupants, and can be predicted using outdoor temperatures, characteristics of the housing stock and surroundings to improve heat exposure

assessment for epidemiological investigations. Weatherizing homes and modifying home surroundings could mitigate indoor heat exposure among the elderly.

2.2 Key words

vulnerable, heat, indoor heat exposure, building characteristics, climate change, elderly, epidemiology, built environment

2.3 Abbreviations and definitions

C: Equivalent thermal heat capacity, i.e. the capacity of a building to store heat that depends on the type of construction (units: Mega Joule/ degrees Celcius, MJ/˚C)

Dewpoint Temperature: the temperature at which air becomes saturated and produces dew; another way of specifying humidity

High rise buildings: Buildings with more than 5 floors

$h_0 + f_{open}*h_v$: Overall heat loss coefficient from window closing and opening, and heat loss to ventilation (unit: Watt/ degrees Celcius, W/˚C)

NIST: National Institute of Standards and Technology

Prevailing surroundings: The dominant type of surroundings in the four cardinal directions of the home

R_{oin} : Energy due to internal heat sources like cooking, lighting, etc. (unit: Watt, W)

RMSE Root mean squared error

$S_{absorption(t)}$: Apparent surface area of the house collecting solar energy (unit: square meters, m^2)

Sensitivity: The magnitude of change of the home's hourly indoor temperature, given changes in the predictor variables

$Solar_{(t)}$: Amount of global horizontal solar radiation reaching the earth's surface (unit: Mega Joule/meter^2, MJ/m^2)

$Solar_{(avg)}$: daily average amount of global horizontal solar radiation reaching the earth's surface (unit: Mega Joule/meter^2, MJ/m^2)

$T_{in(t)}$: Observed value of indoor temperature at current time t (unit: degrees Celcius, ˚C)

$T_{in(t-\Delta t)}$: Observed hourly value for indoor temperature at lagged interval to current temperature at time t(unit: degrees Celcius, ˚C)

$T_{in(t)} - T_{in(t-\Delta t)}$: The change in indoor temperature, i.e., previous hour minus the current hour's indoor temperature over a time interval of one hour (units: degrees Celcius, ˚C)

Δt: Time interval of one hour (hours, h)

T_{out}: Observed hourly outdoor temperature at current time t(unit: degrees Celcius, ˚C)

$T_{out(t)} - T_{in(t)}$: Difference between current outdoor temperature and current inside temperature (units: degrees Celcius, ˚C)

2.4 Background

Heat exposure caused more than eight thousand deaths in the United States from 1979-2003, more than the combined total from all other natural disasters (CDC 2003; CDC 2008). Long-term climate change may result in more heat-related illness and death as the average temperature of the globe increases, along with increased frequency, intensity and duration of heat waves in some locations (Meehl and Tebaldi 2004). Heat waves are “extended periods of unusually high-atmospheric related heat-stress, which causes temporary modification in lifestyle and which may have adverse health consequences for a population”(Robinson 2001).

Epidemiological studies of heat-related illness and death commonly use a time-series or case-crossover design to determine the association between ambient temperature exposure and illness or deaths, recorded in vital statistics data and hospital records. Temperature exposure is often estimated using an airport monitoring station and applied to residents of an entire community. Measuring ambient temperature exposure at this city/county scale likely misclassifies temperature exposure that is more variable at the home or neighborhood scale (Basu 2009). Additionally, people spend approximately 90 percent of their time indoors (Environmental Protection Agency 2009), especially older people who have been shown to be more vulnerable to heat (Kovats and Hajat 2008). Thus, indoor temperatures are likely to better represent heat exposure of such vulnerable individuals (Smargiassi, Fournier et al. 2008). However, few studies have addressed how indoor temperatures, housing, environmental characteristics, and ambient temperature measures are related in residences occupied by the elderly.

2.5 Objectives

Filling gaps in knowledge regarding the role that ambient temperatures, housing, and other environmental characteristics may play in personal temperature exposure among the elderly is important for improving heat epidemiology and guiding prevention programs. Little information exists on: (a) indoor temperature variance between homes; and (b) differences in temperature exposure estimates between city/county level and more localized temperature monitors. The present study addresses some of these gaps by exploring the relationship between ambient and indoor temperatures in homes occupied by elderly individuals in metropolitan Detroit, Michigan, using data on indoor and outdoor temperatures, housing characteristics and environmental surroundings.

2.6 Methods

The purpose of this analysis was 1) to document, over summer 2009, hourly indoor temperatures in thirty different residences in the city of Detroit, and 2) to evaluate sensitivity of these indoor temperatures to changes in external and physical stimuli.

2.6.1 Study population

Thirty volunteer participants over age 65 in Detroit were enrolled based on written consent and their willingness to allow temperature monitoring in their homes. Recruitment efforts targeted senior agencies, family and friends. Participants represented a wide range of neighborhoods and housing types. Individuals living in single family residences or high rise apartment buildings, with and without air conditioning, were sought to determine how access to air conditioning affected residential temperatures. Research staff entered their homes every two weeks to collect temperature data and compensated participants ten dollars per visit. The University of Michigan Institutional Review Board approved this study.

2.6.2 Housing characteristics

Home-specific characteristics that can influence indoor temperature were obtained from the city of Detroit property tax assessment database. These included exterior construction (brick/asphalt, vinyl paneling or wood siding); date of construction (built before 1940, after 1940), housing type (single family, high rise, two-family flat). Number of floors, air conditioning status and prevailing surroundings were also obtained through participant interviews and principal investigator observation. Prevailing surroundings were defined as the dominant surroundings (i.e. concrete, urban, residential or yard/park) directly north, east, west and south of the home.

2.6.3 Indoor temperatures

Each residence's indoor temperatures were monitored and recorded continuously at half hour intervals from June 1 to September 1, 2009 using a HOBO Temperature Logger H08-001-02 from the Onset Corporation: a one-channel temperature recorder, with selectable sampling intervals. All loggers were pre- and post- calibrated for 27 hours using a National Institute of Standards and Technology (NIST) probe, EXTECH Instruments 407445 Heavy Duty Hygro-Thermometer. The HOBO loggers were placed in an enclosed room with the NIST probe among them to assess their accuracy and precision.

To minimize individual indoor factors that could influence temperature readings, all loggers were affixed to a wall or piece of furniture using double-sided tape and installed on walls without windows or vents, approximately 1.5 meters from the floor, away from any heat sources (e.g., kitchen, floor heater/air conditioner) or a door to the outside. Two loggers were installed in each residence, primarily in rooms frequently used by the resident. An average indoor temperature was calculated by taking the average temperature of both rooms being monitored.

2.6.4 Outdoor weather data

Hourly ambient temperature and dewpoint temperature data was downloaded from Detroit metropolitan airport weather archives (KDTW).

2.6.5 Solar radiation data

Solar radiation can affect indoor temperatures through heat absorption. Daily solar radiation measures in mega joules per square meter (MJ/m^2) were obtained from the Midwestern Regional Climate Center. Solar radiation, $Solar_{(t)}$, was operationalized in two ways: 1) hourly averages, 2) 24 hour (daily) average. The 24 hour average was used to minimize the influence of measurement error in the modeled data on our results and to account for possible lagged effects of solar radiation on home indoor temperatures.

2.6.6 Statistical analysis

Descriptive statistics of hourly indoor temperatures and external stimuli (temperature, solar radiation, dewpoint temperature) throughout the entire summer were calculated.

2.6.7 Energy balance model

To develop a model evaluating indoor temperature sensitivity to external stimuli across residences, we initially used methodologies from energy and building science to create a conceptual model for predicting the building's thermal performance. Energy balances are a systematic way of accounting for energy flows in and outside of a controlled space. The flow of energy relates to our research goals because this flow can alter indoor temperature. Energy balances are typically used to calculate cooling and heating loads for buildings based on climate, design and building conditions. The initial energy balance equation (Equation 1) is shown below.

$$C\frac{T_{in(t)} - T_{in(t-\Delta t)}}{\Delta t} = S_{absorption\,(t)} * Solar_{(t)} + Dewpoint_{(t)} + R_{0,in} - (h_0 + t_{open} * h_v) * (T_{in(t)} - T_{out(t)})$$

(Equation 1)

The left side of the equation represents the change in amount of energy stored within a home, based on:

- **C**: equivalent thermal heat capacity, i.e. the capacity of a building to store heat that depends on the type of construction (MJ/˚C)
- **$T_{in(t)}$ - $T_{in(t-\Delta t)}$** : the change in indoor temperature, i.e., previous hour minus the current hour's indoor temperature (˚C)
- **Δt:** Time interval of one hour (h)

The right side of the equation sums the solar energy absorbed, the dewpoint temperature, the internal energy sources minus the energy transferred from inside air to outside air, where:

- **$S_{absorption(t)}$**: Apparent surface area of the house collecting solar energy (m^2)
- **$Solar_{(avg)}$**: daily average global horizontal solar radiation reaching the earth's surface (MJ/m^2)
- **R_{oin}:** Internal heat sources like using the stove, lighting, etc. (W)
- **$Dewpoint_{(t)}$:** current dewpoint temperature
- **h_0 + f_{open}*h_v :** overall heat loss coefficient from window closing and opening (h_0), and heat loss to ventilation, based on the fraction of time the vent is open (f_{open}) (W/˚C)

- $\mathbf{T_{out(t)}}$- $\mathbf{T_{in(t)}}$ **:** difference between current outdoor temperature and current inside temperature (˚C)

Hence, this conceptual equation represents the equilibrium between the change in energy stored in the home and the ability of external stimuli (solar radiation, dewpoint temperature), physical stimuli (internal heat gain) and behavioral stimuli (heat gain/losses by ventilation through the opening of windows/doors) to influence this energy balance. However, some parameters in the balance -- such as C, S, h_o and h_v – have values unique to each residence and the data for these variables were not collected for this study. Therefore we reduced this conceptual equation to represent terms for which data was collected, and to enable us to derive a regression model to fit the data. We used $Solar_{(avg)}$ in our model instead of $Solar_{(t)}$ because the hourly solar radiation data source had missing values.

2.6.8 Regression: house-specific model

To transform the energy balance equation (1) into a model to be used for regression, we solved the general equation for indoor temperature at a particular time t ($T_{in\ (t)}$). We turned this general equation into the proposed house-specific regression model shown below. This regression model has four measured predictors: daily average solar radiation ($Solar_{(avg)}$), dewpoint temperature ($Dewpoint_{(t)}$)previous hour's temperature ($T_{in(t\text{-}\Delta t)}$), and outdoor temperature (T_{out}), and the outcome is indoor temperature at time t, $T_{in(t)}$.

$$T_{ini(t)} = \beta_0 + \beta_1 * Solar_{(avg)} + \beta_2 * T_{in(t-\Delta t)} + \beta_3 * T_{out} + \beta_4 * Dewpoint_{(t)} + e_i$$

(House specific model)

Each coefficient represents the influence of different factors on indoor temperature: β_0 , internal heat sources' contribution to hourly indoor temperature; $\beta_{1,}$ the effect of daily average solar radiation; β_2, the effect of previous hour's indoor temperature; β_3, the effect of hourly outdoor temperature, and $\beta_{4,}$ the effect of hourly measures of dewpoint temperature. The term e_t represents random error, i.e. variability in a specific house's indoor temperature not explained by the measured predictors at only given time *t*.

The parameters in the house-specific model can be written in terms of the parameters in the energy balance equation (Equation 1):

$$\beta_0 = \frac{R_{0,in}}{\frac{C}{\Delta t} + (h_0 + f_{open} \cdot h_v)}, \beta_1 = \frac{S_{absorption\,(t)}}{\frac{C}{\Delta t} + (h_0 + f_{open} \cdot h_v)}, \beta_2 = \frac{\frac{C}{\Delta t}}{\frac{C}{\Delta t} + (h_0 + f_{open} \cdot h_v)},$$

$$\beta_3 = \frac{(h_0 + f_{open} \cdot h_v)}{\frac{C}{\Delta t} + (h_0 + f_{open} \cdot h_v)}, \cdot \beta_4 = \frac{Dewpo\,\mathrm{int}(t)}{\frac{C}{\Delta t} + (h_0 + f_{open} \cdot h_v)}$$

The sensitivity of indoor temperatures to stimuli, $\beta_{0,}\ \beta_{1,\ldots}\beta_4$, can be estimated by fitting a regression model where the dependent variable is hourly indoor temperature data in one or more interior rooms. The sensitivity to outdoor temperature is the regression coefficient and shows the magnitude of change of the indoor temperatures given a 1 degree Fahrenheit increase in outdoor temperature, controlling for the other predictors. The $T_{in(t-\Delta t)}$ term allows explicit modeling of the autocorrelation among temperatures from each subsequent hour. Lastly, the model assumes the relationships between the predictor variables and outcome are linear; this was checked by plotting the predictors against the hourly indoor temperature. Since each location is likely to have its own heat absorption heat loss coefficients, etc., we expect the model parameters, $\beta_{0,}\ \beta_{1,\ldots}\beta_4$ to differ by location. The house-specific model therefore needs to be applied successively to each location. In summary, house-specific model is therefore an autoregressive model specific to each location.

2.6.9 Mixed model

The previously described house-specific autoregressive model can be estimated using ordinary multiple linear regression separately for each location. However, we chose to employ a mixed model to obtain both the average effect across the sample of thirty Detroit houses, and the house-specific parameter estimates. The single mixed effect regression analysis model (Mixed model shown below) is more streamlined than running thirty separate regressions for each location:

$$T_{in(t)} = \beta_{0i} + \beta_{1i} * Solar_{(avg)} + \beta_{2i} * T_{in(t-\Delta t)} + \beta_{3i} * T_{out} + \beta_{4i} * Dewpoint_{(t)} + e_{it}$$
(Mixed Model)

The mixed model is similar to the house-specific regression model with the exception of the subscripts *i*, which indicate that the coefficients vary across locations. That is, $ß_{oi}$, $ß_{1i}$, $ß_{2i}$, $ß_{3i}$ and $ß_{4i}$ are location specific and can be written as, for example,

$\beta_{oi} = \beta_o + b_{oi}$, where β_0 is the average internal heat source contribution across all homes and b_{oi} is the difference between house *i*'s internal heat and the average internal heat sources contribution. Similarly, the overall parameters β_1, β_2, β_3, and β_4 called "fixed effects", represent the average associations between solar radiation; previous hour's indoor temperature; outdoor temperature and indoor temperature, and dewpoint temperature. The so-called "random effects" term $b_{\#i}$ for the parameter estimates for solar radiation, outdoor temperature, previous hour's temperature and dewpoint temperature for each house, allow the influence of these predictors on indoor temperature to vary for each location. The parameters $b_{\#i}$ represent the departure from the fixed effect parameter estimates for each location. In this case, a positive or negative deviation from the fixed effect (i.e. average) means the location will have a greater, or lesser, change in indoor temperature, respectively, associated with, for example, solar radiation, compared to the overall average response of the thirty homes. Table 1 identifies the parameters included in the autoregressive mixed model.

2.6.10 Implemented mixed model versions

The mixed model allows us to address how well indoor heat exposure can be estimated using outdoor environmental data by evaluating the predictability of indoor temperatures. The first step in this process was to create several versions of the base model. Model 1 contained all four parameters (solar radiation, outdoor temperature, previous hourly indoor temperature, dewpoint temperature); Model 2 omitted solar radiation; Model 3 omitted previous hourly indoor temperature; Model 4 included dewpoint temperature and outdoor temperature; and Model 5 omitted only dewpoint temperature. Models 3 and 4 are the models of most relevance for use by public health practitioners to estimate heat exposure for epidemiology studies, since direct indoor measurements are rarely available.

To evaluate how well these models worked in predicting actual indoor temperatures, we did the following: After fitting models 1-5 to the entire summer's data, we used the intercepts and coefficients of these models to create a series of predicted hourly indoor temperatures based on the measured values of the predictors (solar radiation; outdoor temperature; previous hourly indoor temperature, dewpoint temperature) corresponding to the set of predictors chosen for each of the mixed models. To calculate an R^2 we squared the Pearson correlation between the actual measured indoor temperatures and the predicted indoor temperatures, deriving one R^2 for each of the models. The R^2 for each mixed model can be interpreted as the percent of variance in indoor temperatures explained by the predictors corresponding to each model.

2.6.11 Use of the mixed model for sensitivity analyses

Sensitivity analyses were also conducted stratifying homes over the following categories: exterior construction (brick, asphalt, vinyl paneling, woodsiding); occupancy (high rise, non-high rise); date built (1912-1939, 1940-1970, after 1970); prevailing surroundings (concrete, residential, yard or park, urban), and air conditioning status (central air, no central air). Because only one home was represented in each of the exterior construction categories "vinyl paneling" and "woodsiding", and only two in 'asphalt', linear regressions were fit for data from these four homes, rather than the mixed models which were used for all the remaining stratified sensitivity analyses.

2.6.12 Statistical analyses and representation

The SAS procedure PROC MIXED was used to fit the models. From the mixed model results, we obtained the average and location specific effect estimates for each parameter. These effect estimates can be interpreted as the change in indoor temperature per increase in one of the parameters. Only the fixed effect estimates are discussed in this analysis.

2.6.13 Checking model assumptions

Residual diagnostics revealed no violations of the normality, linearity or constant variance assumptions for the regression models. The Durbin-Watson d statistic revealed the presence of autocorrelation between the residuals of indoor temperature with the residuals at the previous hour for most locations. Such autocorrelation would typically lead to underestimation of standard errors of regression coefficients. However, we used robust standard errors which protect from deviations from independence within locations.

2.7 Results

We explored the relationship between ambient and indoor temperatures in thirty homes occupied by elderly individuals in metropolitan Detroit, Michigan, using data on housing characteristics and environmental surroundings, during summer, 2009. The homes spanned an area totaling 72 square miles (Figure 1). Table 2 shows the characteristics and indoor temperatures of each home. 86% of the homes were constructed of brick. Over half had central air conditioning (53%). The prevailing surroundings of 40% of the homes were residential, while equal percentages of homes had prevailing surroundings defined as either “concrete” or “urban”. Each home was sampled from the indicated start date to August 31. The average room temperature across all homes ranged from 16.76 ˚ C to 34.83˚ C. For homes with central air conditioning, the temperatures ranged from 19.23 to 34.85˚ C; homes without air conditioning ranged from 16.76 to 34.42 ˚ C. The highest room temperature amongst all the study homes was 35.27˚ C.

2.7.1 Outdoor temperature, solar radiation and indoor temperatures

Average daily values of solar radiation ranged from 8.6 – 29.7 MJ/m^2, with a mean of 20.0 MJ/m^2 . Outdoor temperatures at Detroit Metropolitan Airport ranged from 7.2 to 34.38°C, with a mean temperature of 21.05◦C. The highest average indoor temperatures were experienced by Locations 8 and 13, 34.83◦C and 34.44◦C, respectively. For all homes, approximately 50,000 hourly indoor temperatures were measured over the entire study period.

We examined the differences in individual room indoor temperatures across all monitored rooms by occupancy type, prevailing surroundings, date built and exterior construction. Dining rooms had the highest temperatures of all rooms, reaching a maximum of 95.5 ◦F in the dining room of location 8. The range of temperatures for all room types ranged from 60.1 to 95.5 ◦F (IQR: 5.6).

For exterior construction, the two asphalt homes had the highest indoor temperatures ranging from 16.77 to 34.83 ◦C. The locations (n=14) built between 1940 and 1969 experienced a range of temperatures from 18.83 to 34.83◦C, approximately 2.8 degrees higher than other homes.

For occupancy type, single family residences had the highest maximum temperatures, ranging from 16.76 to 34.85 ◦C. Locations with residential prevailing surroundings had the highest maximum temperatures.

2.7.2 Mixed model results

2.7.2a Distribution of effect estimates for the applied health model

Figure 2 displays the range of effect estimates calculated by the applied heat exposure model. Histograms were generated for 3 parameters: outdoor temperature

(Ntairport), solar radiation (NSolar) and dewpoint temperature (Ndewp_C). For each of the three histograms, the effect estimate was larger for without air conditioning, compared to homes with air conditioning.

2.7.2b Regression parameter effect estimates by location categories

Table 3 shows results of the applied heat exposure model stratified by 1) exterior construction, 2) occupancy, 3) date built, 4) prevailing surroundings, and 5) air conditioning status. Locations with higher sensitivity to outdoor temperature were made of asphalt and vinyl paneling, non high rise, built between 1912-1939, mostly located in residential surroundings, and had no central air conditioning. Solar radiation was a significant predictor of indoor temperature in all location categories. Sensitivity to solar radiation was especially high with prevailing concrete surrounding and for non brick houses. Locations that had the highest sensitivity to dewpoint temperature were asphalt, non high rise locations, those built between 1912-1939, those with residential prevailing surroundings and those with no central air conditioning.

2.7.3 Prediction of indoor temperatures

The intercepts and coefficients of the five variations of the mixed model (fit to data for the entire summer) were used to generate the five versions of the mixed model to create the predicted series of indoor temperatures. Table 4 summarizes how well the various versions of the mixed model can predict indoor temperature for heat exposure studies. Squared correlation coefficients were calculated between actual measurements and predictors. Both Models 1, 2 and 5 explained 98% of the variance in indoor temperatures. Models 3 and 4, reduced forms of the mixed model explained 38% and 34% of the variance in indoor temperature, respectively. Graphs comparing predicted indoor temperatures using each of the modeling equations were generated for the following: specific home locations (location #26, location #13, location #8), homes with air conditioning, homes made of brick and non high rise homes (shown in the appendix).

2.8 Discussion

This analysis explored the relationship between ambient and indoor temperatures in homes occupied by elderly individuals in metropolitan Detroit, Michigan, using data on housing characteristics and environmental surroundings. A variety of dwellings were monitored – single family homes, high rise apartments and two family flats; and those with or without air conditioning. Outdoor temperature, solar radiation measures, dewpoint temperature and previous indoor temperatures were used to generate predictive models for indoor temperatures. The sensitivity of indoor temperature to outdoor temperature varied based on residence type, outdoor temperature, and city location.

The normal daily maximum temperatures for the city of Detroit (from 1971 – 2000) for the months of June, July and August were 26°C, 28°C, and 27°C respectively. However, the maximum monthly temperatures for our study period for the months of June, July and August were 32°C, 29°C and 34°C, respectively. The mean number of days that reached a maximum temperature over 90°F from the years 1958 to 2009 for the city of Detroit totaled 11 days; during our study period, we had a total of 9 days with temperatures over 32°F. In general, because the summer of 2009 was a relatively warm summer compared to the most recent data on climatological norms, our study results suggest that the temperatures that we monitored in our indoor heat exposure study could increase over time, if the number and intensity of heat waves continue to increase. The use of adaptive behaviors by elderly populations could further be underused, due to oppressive indoor temperatures. Individual room indoor temperatures for some of the locations reached maximums of almost 35 ◦C.

Surprisingly, maximum temperatures over 29 ◦C were reached in 24 locations, and at least 5 locations had maximum temperatures above 32◦C. The majority of these residences were single family homes with no air conditioning. This was an unexpected finding as based on previous studies of large heat waves, high rise apartments typically place more people more at risk. For sedentary activities, a typical comfort temperature with limited air movement has a maximum of no more than 28◦C (82.4 ◦F). (Evans et al., 2003) This suggests that the indoor temperatures we measured were likely to induce discomfort if not more serious effects in occupants. Both asphalt homes reached the highest maximum indoor temperature of all the dwellings. Locations 30 and 10 recorded the lowest average temperatures and were located outside the downtown area of the city.

Based on the Model 3 (including all parameters except previous indoor temperature) locations without central air conditioning had higher sensitivity to outdoor temperature, solar radiation and dewpoint temperature.

The model also showed that homes more sensitive to outdoor temperature and solar radiation were made of asphalt, non high-rise, built between 1912-1939, and had prevailing surroundings of a yard or park. Our limited observations suggest that the higher heat capacity of the brick building contribute to keeping the home protected from high ambient temperatures. The locations built during the earlier years could have less insulation or none at all, thus possibly explaining the higher sensitivity observed for older buildings. Several residents were aware that their homes had not been insulated. The unexpected result that prevailing surroundings of yard or park and residential made locations more sensitive could possibly be due to the compactness of the neighborhoods. However for dewpoint temperature the highest effect estimate was seen in homes built 1912-1939, as well as homes in residential surroundings since dewpoint is a measure of humidity, it is possible that the homes built before 1940 could be more vulnerable to humidity due to aging, lack of sealing, insulation and other structural concerns.

For seniors who spend a lot of time indoors, indoor temperature is a more accurate measure of exposure than relying on outdoor temperature in epidemiological studies. Similar to Smargiassi 2008, we compared the predictive capacity of several variations of our complete model. Prediction models 1, 2 and 5, explained 98% of the variance. But of course, previous hour's indoor temperature is rarely available in the field. The predictive capacity of our models that did not include previous indoor temperature was weaker than the other models, which we expected , since previous indoor temperature would be highly correlated with the current temperature.

We were able to reliably predict indoor temperatures based on our full model suggesting that future epidemiological studies could use models like the one we developed to improve exposure assessment accuracy. While the correlation coefficient in the model using only outdoor temperature was not large, the robustness of the model could be improved by adding more predictive parameters to the model, as discussed in the Conclusions section.

2.8.1 Limitations

Without direct measures of solar radiation reaching each room, and data on home orientation, we might not have captured the entire influence of solar radiation on indoor temperatures for our volunteer homes. Further evaluation of homes with no shading, as well as measurements of solar radiation at each home would be necessary for an improved evaluation of how much solar radiation contributes to indoor temperature.

A study underway to investigate the Detroit heat island thermal structure found cooler temperatures near the east side of Detroit, and the center of city was cooler than the northwest side. (Evan Oswald, personal communication, February 2010) Locations 9, 22, 21, and 15, all located in northwest Detroit, were warmer than the other locations, possibly due to a unique microclimate.

Other limitations are inherent to our sample of homes. However, other recent studies had similar, or smaller, sample sizes. While data on window size and house position was recorded, this was not included in the model due to the complications with adjusting for window treatment type for all 30 homes. A larger sample of non-brick residences would have allowed a better model comparison to brick homes. Additional house-specific construction information related to insulation type and method of construction was unavailable. For further studies, it would be of interest to get a wide representation of homes throughout Detroit, which could allow generalization to other homes in the area. A clustered sample of 2-3 homes per area would also be informative in comparing not only house-specific categories, but environmental (outside) factors.

2.8.2 Future directions

The data collected in this study could be used with other data sources to better examine intervention and prevention strategies to address vulnerability to heat for different populations. Geographic data resources like land cover/land use, surface imperviousness and satellite images could be useful additions to the prediction equation. Finding specific values for some of the equation parameters that are unique to different residences could be useful for urban planning and design for urban areas. For example, if this model is able to support that asphalt homes, built in the 1940s, with prevailing surroundings of concrete are more sensitive to temperature changes, then heat-vulnerable people could be advised to choose another home type or be made eligible for monies to weatherize the home (i.e. insulation, upgrades) before occupation.

This is the first study of its kind to be conducted in Detroit, Michigan, a location where heat and cold both have significant health effects in the population. (O'Neill et al 2003) Our modeling approach could be extended to study exposure to cold as well as heat.

2.9 Conclusions

The average home in Detroit experiences varying levels of indoor heat exposure, depending on weather conditions and the home's physical characteristics. People living in single family homes, made of asphalt, in a residential surrounding, built between 1912-1939, with or without air conditioning could prove to be more vulnerable and at risk during hot weather, as they may experience higher indoor temperatures. Education and outreach efforts could be focused on the elderly in these types of homes. This study provides valuable information on how different housing stock within the city of Detroit responds to heat. These observations can be used to substantiate the need for policies and practices around home weatherization or greening activities for the elderly and other vulnerable populations.

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TABLES

Table 2-1. Variables of transformed energy balance equation into autoregressive mixed model.

Variable	Definition
$T_{in(t)}$	Observed value of indoor temperature at current time (t) (unit: degrees Fahrenheit, ˚C)
ßo	Intercept that represents internal heat sources contribution to indoor temperature at time (t)
$ß_1$	Represents the fixed effect estimate of how solar radiation (building absorption) contributes to indoor temperature at time (t)
$Solar_{(t)}$	Modeled hourly amount of global horizontal solar radiation reaching the earth's surface (unit: Mega Joule/meter2, MJ/m2)
$Solar_{(avg)}$	Modeled daily average of the amount of global horizontal solar radiation reaching the earth's surface (unit: Mega Joule/meter2, MJ/m2)
$ß_2$	Fixed effect estimate (also an autocorrelation term) which represents the influence of the previous temperature on the current temperature
$T_{(t-\Delta t)}$	Observed hourly value for indoor temperature at lagged interval to current temperature at time (t) (unit: degrees Fahrenheit, ˚C)
$ß_3$	Fixed effect estimate that represents the influence of outdoor temperatures (and unmeasured factors such as windows being opened, heat absorption of the home and external and internal convection) on indoor temperature
$ß_4$	Fixed effect estimate that represents the influence of dewpoint temperature on indoor temperature
T_{out}	Observed hourly outdoor temperature at current time (unit: degrees Fahrenheit, ˚C)
e_{it}	Difference in estimate between the observed temperature value and the actual location temperature

Table 2-2: Housing characteristics and average and maximum indoor temperatures (°C) for locations monitored during the indoor heat study in Detroit, Michigan in Summer 2009. June 25, 2009 and August 8, 2009 were two of the hottest days during the summer.

Location	Start Date[a]	Type[b]	Floor Area Sq. Ft.[c]	Date Built	# of floors	Exterior Construction	Central AC	Room1[d]	Room2[d]	Prevailing Surroundings[e]	6/25/2009 (Max, Mean)	8/9/2009 (Max, Mean)
1	1-Jun	Single Family	950	1951	2	Brick	yes	lr*	br	Residential	27.5, 26.2	25.5, 24.6
2	1-Jun	Single Family	1488	1914	2	Brick	no	dr	br	Residential	31.3, 30.5	25.5, 24.6
3	1-Jun	Single Family	2600	1929	3	Brick	yes	dn	br	Residential	28.3, 27.6	24.7,23.9
4	1-Jun	High rise	800	1987	14	Brick	yes	br	lr*	Urban	30.3, 29.5	27.7, 26.9
5	1-Jun	High rise	800	1987	14	Brick	yes	lr*	br	Urban	28.7, 28.0	27.9, 26.8
6	1-Jun	High rise	800	1987	14	Brick	yes	lr*	br*	Urban	26.9, 24.8	26.1, 24.4
7	1-Jun	Single Family	1348	1940	1	Brick	no	br	lr	Residential	31.5, 30.3	26.5, 25.7
8	1-Jun	Single Family	692	1944	2	Asphalt	yes	dn	dr	Residential	34.8, 33.2	29.9, 29.1
9	2-Jun	Two Family Flat	2400	1925	2	Brick	no	dr	br	Residential	28.9, 28.5	26.1, 25.3
10	2-Jun	Single Family	798	1913	2	Asphalt	no	lr	br	Residential	30.5, 29.1	24.7, 23.8
11	4-Jun	Single Family	1255	1931	2	Brick	no	dr	lr	Yard/Park	32.7, 30.7	27.1, 25.8
12	4-Jun	Single Family	1819	1927	3	Brick	yes	dn	br	Residential	31.1, 29.9	24.5, 23.7
13	4-Jun	Single Family	1457	1923	3	Brick	no	dn	.	Residential	33.5, 32.3	29.1, 26.7
14	5-Jun	Single Family	2692	1931	3	Brick	yes	dn*	br	Residential	30.7, 29.8	24.9, 24.2
15	5-Jun	Two Family Flat	2226	1922	2	Brick	no	dr	br	Concrete	30.7, 30.0	25.7, 25.2
16	8-Jun	Two Family Flat	2650	1925	2	Brick	no	dr	lr	Concrete	29.1, 28.3	24.5, 23.3
17	11-Jun	High rise	800	1982	13	Brick	yes	lr*	br*	Concrete	27.9, 25.5	25.5, 23.6
18	11-Jun	High rise	800	1980	13	Brick	yes	lr*	br*	Concrete	31.5, 29.1	29.1, 28.5
19	11-Jun	High rise	737	1980	18	Brick	yes	br	lr*	Yard/Park	29.7, 27.1	27.3, 27.13
20	16-Jun	Single Family	829	1949	2	Brick	no	br	dn	Yard/Park	29.3, 28.7	25.3, 24.4
21	16-Jun	Single Family	2371	1919	2	Brick	no	lr	br	Residential	30.9, 29.1	27.3, 26.1
22	16-Jun	Single Family	1267	1938	2	Brick	no	br	dn	Yard/Park	30.1, 28.5	25.3, 24.4
23	22-Jun	Single Family	535	1919	2	Woodsiding	no	lr	dn	Yard/Park	30.7, 29.5	25.1, 24.3
24	24-Jun	Single Family	1046	1980	1	Brick	yes	dn	br	Yard/Park	32.7, 31.1	27.9, 26.0
25	24-Jun	High rise	737	1980	18	Brick	no	lr	br	Concrete	30.7, 29.4	25.7, 25.1
26	23-Jun	Single Family	970	1962	1	Brick	yes	den	br*	Residential	28.9, 26.1	27.5, 26.2
27	10-Jul	Single Family	6746	1912	2	Brick	yes	dr*	dn*	Yard/Park	-	26.7, 26.6
28	14-Jul	High rise	737	1980	18	Brick	yes	lr*	br	Urban	-	27.1, 26.4
29	14-Jul	High rise	800	1987	13	Brick	yes	lr*	br	Urban	-	27.1, 26.4
30	1-Aug	Single Family	908	1953	1	Vinylpaneling	no	lr	br	Yard/Park	-	24.9, 23.7

a: Start date: date temperature monitoring began at residence

b: Type of residence monitored: Single Family, High Rise Apartment Building, Two Family Flat (1 family living on 1st floor, 2nd family living on second floor)

c: Floor Area Square Footage: floor area taken from the Detroit City Tax Assessor Office

d: Rooms Monitored: lr(living room), dr (dining room), br (bedroom), dn (den).

Rooms designated with a * have air conditioning (i.e. a unit installed in the room or a portable unit)

e: Prevailing Surroundings: 50% or more of the immediate surroundings on the North, East, South and West side of the home are either Res(residential),urban, concrete, or Yard /Park.

All locations were sampled until the end date of August 31, 2009.

Table 2-3: Sensitivity effect estimates (95% confidence intervals) by home category, using a reduced mixed regression model for June 1- August 31, 2009. Sensitivity effect estimates can be explained as the change in indoor temperature associated with a one degree Celsius change in the specified parameter: Outdoor Temperature, Solar Radiation, and Dewpoint Temperature. The Intercept sensitivity effect estimate represents the change as a result of internal heat gains (i.e. heat sources within the home). n represents the the number of homes in that category.

	Sensitivity Effect Estimates				
Category	Intercept	Outdoor Temp	Solar Radiation	Dewpoint Temperature	n
Average effect on all homes	17.84 (16.41, 19.27)	0.21 (0.16,19.27)	0.06(0.04, 0.07)	0.14(0.11,0.17)	30
EXTERIOR CONSTRUCTION					
Brick	17.90 (17.81, 17.99)	0.20 (0.20, 0.21)	0.05 (0.05, 0.06)	0.14(0.14,0.15)	26
Asphalt	15.79 (15.32, 16.25)	0.21 (0.19, 0.23)	0.11 (0.09, 0.12)	0.25 (0.23, 0.27)	2
Vinylpaneling	13.58 (13.08, 14.07)	0.45 (0.43,0.48)	0.04 (0.03,0.06)	0.01(-0.01,0.04)[1]	1
Woodsiding	12.95 (12.57, 13.33)	0.35(0.33,0.36)	0.06(0.05,0.07)	0.22(0.20, 0.23)	1
OCCUPANCY					
High Rise	21.6 (19.34, 23.98)	0.09 (0.03, 0.16)	0.03 (0.01,0.06)	0.10 (0.05, 0.15)	9
Non High Rise	16.21(14.91,17.50)	0.26 (0.21,0.30)	0.06 (0.05,0.08)	0.15(0.12, 0.19)	21
DATE BUILT					
1912 - 1939	15.59 (13.97, 17.22)	0.26 (0.22,0.30)	0.06 (0.05, 0.07)	0.18 (0.14,0.22)	14
1940 - 1970	18.58 (16.16, 21.01)	0.19(0.07, 0.30)	0.068 (0.009, 0.12)	0.13(0.01,0.25)	6
After 1970	21.05 (18.62, 23.48)	0.12 (0.04, 0.20)	0.04 (0.02, 0.06)	0.10 (0.05, 0.15)	10
PREVAILING SURROUNDINGS					
Concrete	18.18 (11.91, 24.45)	0.17 (0.02, 0.32)	0.05 (0.01, 0.10)	0.15(0.01, 0.28)	5
Residential	16.88 (14.91, 18.85)	0.23 (0.17, 0.29)	0.06 (0.04,0.08)	0.16 (0.10,0.21)	12
Yard Or Park	16.52 (14.04, 19.00)	0.27 (0.17, 0.37)	0.07 (0.05, 0.08)	0.12(0.06, 0.18)	8
Urban	21.93 (19.59, 24.27)	0.09 (0.02, 0.16)	0.02 (0.007, 0.05)	0.10(0.06, 0.15)	5
AIR CONDITIONING STATUS					
Central Air	19.82 (17.86, 21.77)	0.15 (0.09,0.22)	0.05 (0.03,0.07)	0.11 (0.06, 0.15)	16
No Central Air	15.59 (14.11,17.07)	0.27 (0.22,0.32)	0.06(0.05,0.07)	0.17(0.13,0.21)	14

[1] Effect estimates that were found not to be statistically significant

Table 2-4. Calculated correlation coefficients comparing actual indoor temperatures with indoor temperatures predicted by 5 different models, including the following dependent varialbes: Outdoor temperature (°C), Previous indoor temperature (°C), Solar Radiation, and Dewpoint Temperature (°C).

	Model 1	Model 2	Model 3	Model 4	Model 5
Outdoor Temperature (°C)	0.02	0.02	0.21	0.23	0.02
Previous Indoor Temperature (°C)	0.93	0.93	--	--	0.94
Solar Radiation (Mega Joules / meters2)	0.005	--	0.06	--	0.003
Dewpoint Temperature (°C)	0.01	0.007	0.14	0.12	--
R^2_a	0.98	0.98	0.38	0.36	0.9802

[a]Squared correlation between measurements and predictions.

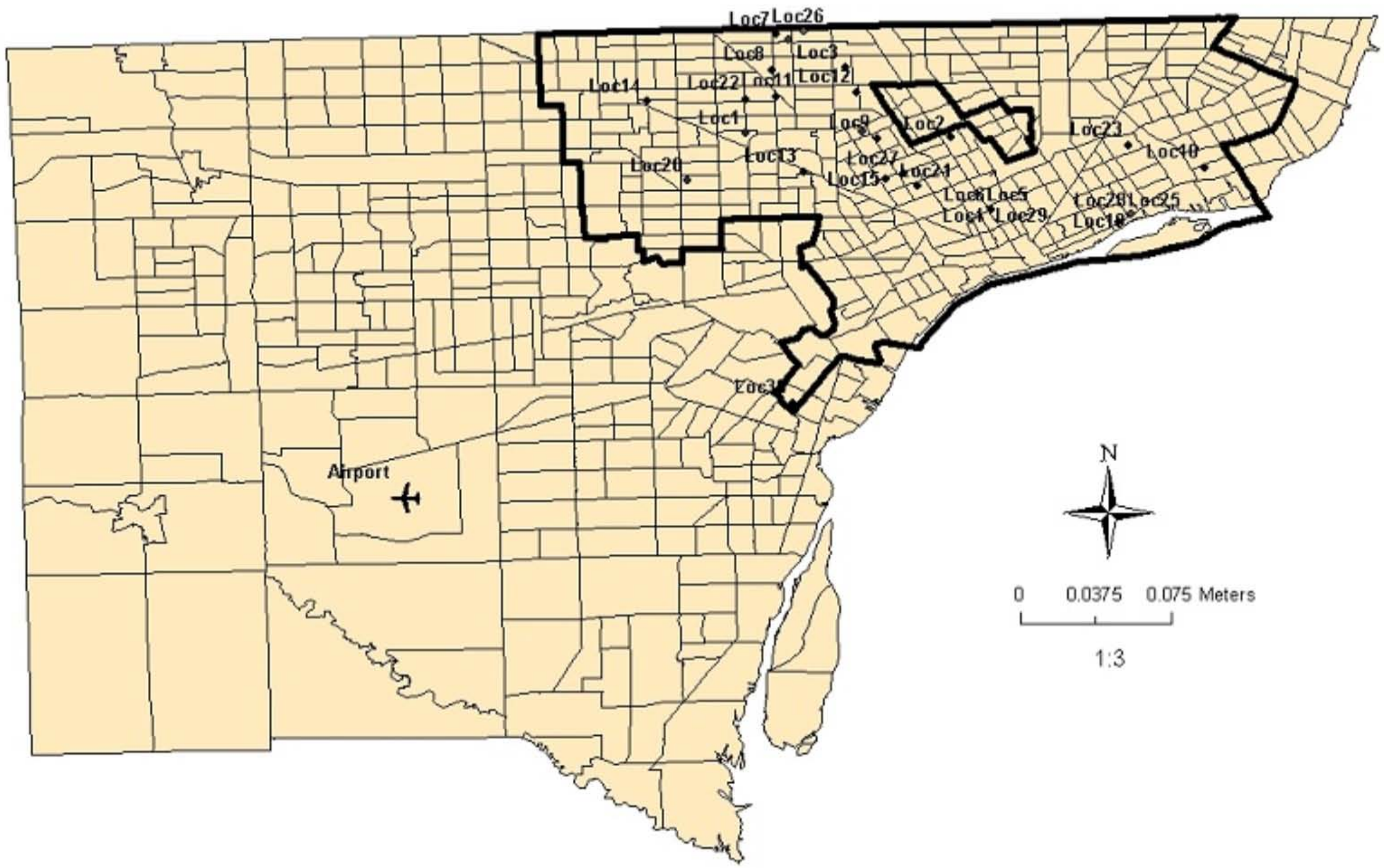

Figure 2-1 Map of study locations in Detroit, Michigan by location number. City of Detroit boundary outlined with dark line. Detroit Metropolitan Airport displayed.

Chapter 3
Assessing heat-adaptive behaviors among older, urban-dwelling adults

3.1 Abstract

Objectives

We examined behaviors the elderly used to adapt to hot indoor temperatures during summertime.

Methods

From June 1 – August 31, 2009, residents in 29 homes in Detroit, Michigan kept an hourly log of eight heat-adaptive behaviors: opening windows/doors, turning fans or the air conditioner on, changing clothes, taking a shower, going to the basement, the porch/yard, or leaving the house. Percentages of hourly behavior were calculated, overall and stratified by housing type and percent surface imperviousness. The frequency of behavior use at predetermined temperature intervals was compared to a reference range of 70-75°F.

Results

The use of all adaptive behaviors, except going to the porch or yard, was significantly associated with indoor temperature. Non-mechanical adaptations such as changing clothes, taking showers, going outside or to the basement were rarely used. Residents living in high-rises and highly impervious areas reported a higher use of adaptive behaviors. The odds of leaving the house significantly increased as outdoor temperature increased.

Conclusions

The full range of adaptation measures may be underused by senior citizens and public health interventions need to focus on outreach to these populations.

3.2 Keywords

Elderly, adaptation, public health intervention, imperviousness, indoor temperatures

3.3 Background

Heat-related mortality and morbidity are expected to rise as a result of increased frequency of extreme heat events caused by climate change. Heat strain, a consequence of heat stress, can increase heart rate, blood flow to the skin, and sweating and can ultimately cause collapse, illness, heat stroke and death in vulnerable populations (Parsons 2009). Populations vulnerable to heat include those who are socially isolated, living in homes with high thermal mass, living on the upper floors of high-rise buildings, and those with chronic diseases and the elderly (over age 65) (Hajat and Kosatsky 2009). In addition to institutional responses to heat as a health threat, personal perceptions of the health risks of heat are crucial in shaping individual actions to reduce these risks. When people perceive that adaptation to hot weather is unnecessary, they make few to no behavior adjustments to prevent heat-related risks (Wolf, Adger et al. 2010).

This study explores adaptive behaviors of elderly people to hot indoor temperatures and how residence type and environmental surroundings influence these behaviors. Specifically, this paper 1) describes how senior citizens adapt to heat during the summertime while in their homes, 2) identifies the association between behaviors, based on occupancy type (high rise, two family flat and single family) and surface imperviousness surrounding the home (% of concrete or other impervious surfaces).

3.4 Methods

Thirty volunteer participants living in the Detroit area were recruited based on their age (over 65 years of age) and willingness to allow temperature monitoring in their homes or apartments. Participants were chosen to widely represent area neighborhoods and housing types. Individuals living in single family residences or high rise apartment buildings, with and without air conditioning (central or room unit), were recruited. Recruitment efforts targeted local agencies on aging and existing community organizations or clubs, and advertising occurred through word of mouth, flyers, and formal presentations. All participants gave written consent to participate in the study and allowed research staff to come into their homes every two weeks to collect temperature data and time activity logs (discussed below) during the period of June 1 to August 31, 2009. Participants received compensation of ten dollars per visit. The University of Michigan Institutional Review Board approved this study.

Behavioral data was collected through a daily activity log. Research staff provided participants with a daily activity log book with one page per day for each month, and instructed them to record activities associated with adapting to feeling hot but not general daily activities (e.g.,showering to cool off versus daily showering). Each page had a grid with time listed on the left margin: "Before 6 a.m."; separate hourly entry lines for the hours 7 a.m. to 10 p.m.; "Evening" (11 pm) and "Bedtime" (midnight until 6:00 am the next morning). Eight adaptive behaviors were listed across the top: opening or closing a window, turning on air conditioning, leaving the house, taking a shower, going to the basement, changing clothes, turning on a fan, or going to the porch (or somewhere directly outside the house). Participants could either "check the box or draw a line through the boxes" in the grid corresponding to the time they engaged in any of the eight activities when they felt "hot". An additional column allowed for notes or special comments. Only the designated participant completed the activity log for each home. Log books were collected from each residence by the end of each study month and replaced with a new activity log for the next month.

Each residence's indoor temperatures were monitored and recorded using a HOBO Temperature Logger H08-001-02 from the Onset Corporation (http://www.onsetcomp.com/). Calibration specifications for the loggers are detailed in the appendix. To minimize individual indoor factors that could influence temperature logger readings, all loggers were installed on walls without windows or vents, approximately 1.5 meters from the floor, away from any heat sources (e.g., a kitchen, floor heater/air conditioner) or a door leading to the outside. Outdoor temperature data was downloaded from Detroit Metropolitan Airport weather archives. We used temperature data in1-hour intervals compatible with hourly activity log data.

Imperviousness represents the percentage of land surface covered by surfaces impenetrable by water, such as asphalt or concrete. High imperviousness can exacerbate the urban heat island phenomenon, which refers to higher surface temperatures occurring in urban areas versus surrounding rural areas due to urbanization (Voogt & Oke, 2003). Urban imperviousness data was downloaded from the Multi-Resolution Land Characteristics Consortium (MRLC) National Landcover Database (NLCD) (http://www.mrlc.gov) 2001 products, generated through satellite imagery collected in the year 2001 with 30 meters spatial resolution. ArcGIS software was used to map the physical address of each home onto the imperviousness image and a 30 meter pixel average of the image, representing percent imperviousness at the study location, was assigned to each home. Each home was categorized as high imperviousness (> 63%) or low imperviousness, (< 63%) based on the mean imperviousness of 63%. We reviewed adaptive behavior data by location and identified unusually long time frames during which study participants did not log behaviors. We could not determine if the lack of recording activity was due to 1) not using any adaptive behaviors, or 2) not recording adaptive behaviors when used. Given this uncertainty, we recoded the time period as "missing behavior data" if it consisted of seven or more consecutive days where no behaviors were recorded. If the time period was less than 7 days and no behavior had been selected, the entries were coded as zero. Otherwise, reported behaviors were coded as 1. This method allowed us to exclude long periods of time where participants were simply not recording their behaviors, but preserve data points that likely truly represented a particular participant's lack of heat-adaptive activities.

3.4.1 Statistical Analysis

We calculated and graphed the percentage of time each adaptive behavior was used within each of six indoor temperature ranges (< 70◦F, 70-75◦F, 75-80◦F, 80-85◦F, 85-90◦F, >90 ◦F), overall and stratifying by residence type and surface imperviousness. The proportions for these graphs were calculated using the total number of 1's divided by the total number of 1’s and 0’s for that behavior.

After computing descriptive statistics, we estimated logistic regression models to examine the probability of engaging in each behavior in a given temperature range compared to the reference ‘comfortable’ temperature range of 70-75 ◦F. The response variable for each model was behavior use (coded as 1 or 0) and the explanatory variables were indicator variables for the different temperature ranges (< 70◦F, 75-80◦F, 80-85◦F, 85-90◦F, <90 ◦F), with 70-75 ◦F as the reference category (Schabenberger 2005). Because we gathered repeated measures of reported behaviors from the same individuals over time, logistic regression models were estimated using generalized estimating equations (SAS PROC GENMOD), which accounts for correlated responses within the same study location.

3.5 Results

Of the 30 initially-recruited study participants, 29 recorded using at least two adaptive behaviors throughout the study period. One participant recorded no heat-adaptive activities during the summer and was therefore dropped from subsequent analyses. A total of 16 homes had central air conditioning and 20 had basements. Twenty five homes had an exterior made of brick, 2 of asphalt, 1 of wood siding and 1 of vinyl paneling. Eight high rise apartments were monitored, while 21 of the homes monitored were single family homes or two family flats. The range of urban imperviousness values surrounding all locations was 29% to a maximum of 89%.

Table 1 shows the heat-adaptive behaviors reported by study participants. The most frequently used behaviors over the entire study period were ‘opening windows or doors’, and ‘turning fans on’. Above 90 °F, ‘going to the basement’ or ‘going to the porch or yard’ were the least reported behaviors, while 'turning fans on' was the most common. The frequency of most reported behaviors was highest during the 75 – 80 °F temperature interval, but lowest when indoor temperatures were above 90 °F.

Odds ratios and 95% confidence intervals of engaging in behaviors at certain indoor and outdoor temperature ranges relative to the reference temperature range of 70-75° F are shown in Table 2.

The odds ratio can be interpreted as the probability of using a certain adaptive behavior versus not engaging in that behavior relative to the use of the behavior in the reference range. For certain behaviors, the odds ratios were not calculated at the lowest or the highest temperature range due to limited sample size (sparse or nonexistent reports of those behaviors). Based on Table 2, all behaviors, except going to the porch or yard, showed a statistically significant association with indoor temperature for at least one of the temperature ranges. Two behaviors, (turning on fans and turning on air conditioner) had increased odds for all temperature ranges above 75°F. In contrast, the odds of taking a shower or changing clothes were lower as indoor temperature increased. Temperatures above 90°F were not significantly associated with increases in adaptive behavior use, potentially due to lack of statistical power to detect associations given a relatively small number of time periods exceeding 90°F.

Similar to the association with indoor temperature, the odds of turning the air conditioner on increased as outdoor temperature increased; in contrast, the odds of turning the fans on did not. The odds of leaving the house increased significantly with increasing outdoor temperature.

3.5.1 Behavior frequency by housing characteristics

Figure 1 shows the percentage of time behaviors are reported being used by residential type – high-rise, single family or a two-family flat. We defined a high-rise as a dwelling with more than 4 floors with multiple residents in their own separate apartments; a single family residence is defined as a stand-alone home, and a two-family flat is a residence with two distinct living quarters with separate entrances. High-rise residents had an overall higher use of reported behaviors, followed by single family residences, than those living in two-family flats. None of the two-family flats had central air conditioning and none of the high-rises had basements. Air conditioner use was higher in high-rise residences; 'changing clothes' and 'taking a shower' were reportedly used more in single family residences. 'Opening windows and doors' and 'turning of fans' were reported by all residence types more than any other behavior. Those in a two family flat reported 'going to the basement' and 'going to the porch or the yard', less than any other behaviors.

Figure 2 shows reported percentage of time behaviors reported being used by level of surface imperviousness. Surface imperviousness levels were stratified by low imperviousness (< 63%) and high imperviousness (> or equal to 63%). Most behavior use was reported by residences in high impervious areas.

3.6 Discussion

This analysis explored the predominant adaptive behaviors to hot indoor and outdoor temperatures among elderly Detroit residents, and how residence type and percent surface imperviousness around the home was associated with these behaviors. The highest reported behavior in the overall study was ‘opening windows or doors’; the least reported behavior was ‘going to the basement’. The highest frequencies of adaptive behavior use were reported at the 70-75 °F temperature range. Surprisingly, the least number of behaviors were reported at temperatures above 90 °F, which could have also been limited by the small number of days, based on outdoor temperature, that were over 90 °F. The frequency of turning the fans on increased significantly with increasing indoor temperature. Residents in single family homes reported more use of ‘taking a shower’, ‘changing clothes’ than any other residence type. In a high rise, the use of ‘opening windows or doors’, ‘turning on fans’, ‘turning on the air conditioner’, and ‘leaving the house’ had reportedly higher use than the other residence types.

We also generated the odds ratios for behavior use based on outdoor temperature intervals. The use of taking a shower as an adaptive behavior - based on outdoor temperatures - showed the same fluctuations of use across increasing temperature intervals as the behavior use based on indoor temperatures. Changing clothes was statistically significant at the 76-80°F range, but the odds of changing clothes was higher at the lower outdoor temperature intervals. This could be true because as it gets hotter, some of the population might want to do nothing and just stay still to stay cool; that is, adapting by not acting. Some behaviors seemed to be more motivated by outdoor temperatures versus indoor temperatures. For example, the behavior of leaving the house, based on outdoor temperature, steadily increased over the pre-determined temperature intervals. This suggests that the perception of the weather being hotter – based on the media, radio, etc. - could encourage a person to leave the house, moreso than the actual temperature indoors. The odds of opening windows or doors, using a fan, or going to the basement were not statistically significant at any outdoor temperature intervals, which could indicate that those behaviors are more driven by indoor temperatures than outdoor temperature. Possibly the temperature a person is directly experiencing might cause them to engage in the simple behaviors that could bring some relief; such as using basements, which in most homes, are cooler than upper floors.

The frequency of most reported behaviors was lowest when indoor temperatures were above 90 F. This suggests that the full range of adaptation measures may be underused by senior citizens especially during a heat wave.

3.6.1. Context—other literature

Heat-related illness is avoidable and a critical intervention opportunity is to encourage appropriate prevention strategies by susceptible individuals and their care-givers (Hajat, O'Conner et al. 2010). Common ways that elderly persons in Baltimore, Maryland adapted to ambient heat included wearing less clothing, taking in more fluids, using air conditioning or going outdoors (Basu and Samet 2002). In our study, more people reported 'opening windows or doors', 'using fans', ‘leaving the house’ and ‘taking a shower’ as ways of adapting to heat. However, in our study, we did not ask explicitly about taking in more fluids.

A study of older people in London and England, aged 75 to 92, examined not only the actions people take with extreme heat, but their perceived vulnerability to heat, as well as factors that might support or impede certain behaviors. While some of the older people changed their behavior during heat waves, some did not even consider themselves to be either old or at risk during heat events (Abrahamson, Wolf et al. 2008). While we did not examine perceived vulnerability in our study, we did find fewer reported behaviors at temperatures above 90 °F. This could reflect people adapting by not engaging in any action (i.e. adapting by not adapting) at such high temperatures because of the physiological factors (fatigue, shortness of breath, etc.) that heat might exacerbate. However, we cannot make this conclusion with 100% certainty based on the small reporting frequency. In analysis not shown, we examined the total number of behaviors used on a daily basis, compared to the maximum temperature for that day. In only 4 out of the 29 homes did the highest number of reported behaviors co-occur with the highest temperature reported on that day.

A survey of adults aged 65 and older in four North American cities and Toronto (Ontario, Canada) evaluated perceived vulnerability, behavior and use of cooling systems within a home during a heat event (Sheridan 2007). More than half the respondents believed that heat is “not dangerous or only slightly dangerous to them”; few respondents reported modifying their behavior because of a heat event, but most cited that staying indoors was their most common means of dealing with a heat event. When fans were used by respondents to cool their homes, they were used incorrectly (i.e. with the windows closed) a majority of the time. This practice can enhance dehydration by re-circulating hot air. In our study, fan use was highest at temperatures above 75-80°F. Based on research staff observation, fans were not always being used correctly. Additionally, the reported use of fans in areas with high surface imperviousness was greater than in homes surrounded by low imperviousness. Because areas with high surface imperviousness have been shown to hold more heat at a ground level, incorrect use of fans for adaptation (e.g., not opening windows with fans) could have provided little to no relief from warm indoor temperatures

While perceptions can be an integral part of determining how people will choose to adapt to heat, adaptation strategies are also linked to variation in indoor and outdoor temperatures. A survey of building occupants in the United Kingdom, Pakistan and throughout Europe showed how the use of simple controls – opening of windows, the closing of window blinds, and use of lighting, heaters and fans by building occupants – varied by changes in indoor and outdoor temperature (Nicol and Humphreys 2004). Probability algorithms relating occupant behavior to outdoor and indoor temperature were derived from field studies of how controls are used in buildings. In naturally ventilated buildings (i.e. no heating or air conditioning), the proportion of recorded 'opening of windows' significantly increased at an indoor temperature of about 72 ◦ F (22 ◦ C). A small proportion of occupants reported using blinds or curtains as temperatures increased. In buildings with heating and air conditioning, air conditioning use was initiated, on average, at about 77 ◦ F (25 ◦ C). While outdoor temperature was more consistently associated with the use of heating and cooling devices, indoor temperature seemed to be a more consistent predictor of the use of windows and fans in all countries studied (Nicol and Humphreys 2004).

In contrast, we found that the odds of opening windows increased after 70 °F and then decreased after indoor temperatures reached 85 °F. Additionally, the "non-mechanical" type of cooling adaptations (i.e. changing clothes, taking a shower, going to the basement, going to the porch or yard, leaving the house), had some of the lowest reports of behavior use at the temperatures above 85°F. This is what we would expect, as sometimes people can adapt to temperatures by not acting. Observations and conversations by the research staff with some of the study participants indicated that people were sometimes too hot to move, or engage in any behavior that would cool them off. However, the odds of using air conditioning as a cooling device in our study did increase at temperatures greater than 80 °F, relative to the reference level of 70-75 °F. This observation makes sense, as people who have air conditioning would most likely use it at temperatures greater than 75°F.

3.6.2 Potential barriers for seniors to adapt to hot temperatures

Although our study did not directly address barriers for the elderly to adapt to hot temperatures, other studies have. Several studies have identified economic factors - ranging from lack of funds to maintain air conditioners or pay for electricity for air conditioners - to lack of funds to weatherize (i.e. add better insulation, purchase energy efficient appliances, seal leaky windows, etc.) and modernize the house to be more energy efficient, as important barriers to adaptation.(Walters 2008; Simmons 2010; Snyder and Baker 2010) In our study, the dates residences were built ranged from 1912 to 1987, which can influence the amount and type of insulation in the thermal envelope of the home. Of our 29 elderly volunteers, only two indicated that they had had insulation added or some type of weatherization done on their home to help with reducing energy consumption.

Means of communication can also be a barrier to adaptation. A study by Semenza et. al explored whether a public outreach system for the cities of Houston and Portland was a reliable trigger to change behavior based on environmental conditions.(Semenza, Wilson et al. 2008) The results suggest that heat health warning alerts have limited impact on the population at large, and reveal a need for weather-related planning communication and outreach to the general public, with a particular focus on marginalized groups, since they have lower air conditioning saturation.

3.6.3 Limitations

Our findings must be interpreted in the context of several limitations. Our study was dependent on data recorded by our volunteer residents. The recording of adaptive behaviors could have decreased as the study progressed since we asked volunteers to participate for a total of 3 months, a longer period than any other study has used to assess the activity of senior citizens.

3.7 Conclusions

Elderly persons in Detroit, Michigan tend to engage in fewer heat-adaptive behaviors when indoor temperatures are greater than 85 degrees. Those who live in high-rise residences reported the use of more adaptive behaviors than for other residence types. Volunteers who lived in areas of high surface imperviousness reported more adaptive behaviors than those who lived in areas of low surface imperviousness.

Further research on how the use of other indoor home cooling strategies – such as window shading, closing off one section of a home, etc., as well as the influence of outdoor temperatures, financial barriers and impacts of weatherization would complement the insights we gained. In general, our research is consistent with other studies that suggest heat-adaptation strategies are under-used by the elderly, and serious health consequences may result. Understanding the predictors of such behaviors in vulnerable populations can help direct interventions, and inform the choice of mitigation strategies (e.g. tree planting, home weatherization) as communities prepare for climate change.

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Table 3-1: Heat-adaptive behaviors reported in an hourly activity log by seniors in 29 residences in Detroit, MI. Number/percent of total monitored hours when behavior was reported are provided for the entire summer 2009 (36,541 total monitored hours), and during times when indoor temperatures (measured hourly in each home with indoor temperature monitors) fell into specific ranges. All temperatures are measured in degrees Fahrenheit.

		BEHAVIOR							
		Opening windows or doors	Turning fans on	Turning air conditioner on	Changing clothes	Taking a shower	Going to the basement	Going to the porch or yard	Leaving the house
Number of homes where behavior was possible (N)		29	29	16	29	29	20	29	29
% of total study period[1]		14.8%	10.2%	4.8%	4.0%	4.0%	1.2%	2.2%	5.1%
Total hours monitored of behavior reported at locations where possible		5413	3734	960	1471	1476	270	792	1867
Total hours monitored in homes where behavior possible		36541	36541	19813	36541	36541	23196	36541	36541
< 70 ° F	% of time reported[2]	7.8%	4.8%	0.0%	1.8%	2.7%	1.7%	3.8%	6.6%
	Hours behavior reported	111	68	0	25	38	23	54	94
	Total hours monitored	1419	1419	386	1419	1419	1365	1419	1419
>= 70^0 F, < 75^0 F	% of time reported[2]	17.4%	9.2%	2.0%	4.2%	4.4%	1.4%	2.6%	4.9%
	Hours behavior reported	1160	614	60	281	292	75	173	330
	Total hours monitored	6677	6677	2943	6677	6677	5258	6677	6677
>= 75^0 F, < 80^0 F	% of time reported[2]	16.8%	11.3%	4.3%	4.8%	4.9%	1.2%	2.3%	5.2%
	Hours behavior reported	2622	1762	377	748	759	117	354	812
	Total hours monitored	15598	15598	8768	15598	15598	9996	15598	15598
>= 80^0 F, < 85^0 F	% of time reported[2]	12.4%	10.3%	7.0%	3.2%	2.9%	0.8%	1.8%	5.2%
	Hours behavior reported	1388	1148	478	353	325	44	198	584
	Total hours monitored	11180	11180	6856	11180	11180	5432	11180	11180
>= 85^0 F, < 90^0 F	% of time reported[2]	7.9%	8.3%	5.5%	3.6%	3.6%	1.0%	0.8%	2.8%
	Hours behavior reported	124	130	44	56	56	11	13	44
	Total hours monitored	1560	1560	807	1560	1560	1050	1560	1560
>= 90^0 F	% of time reported[2]	7.5%	11.2%	1.9%	7.5%	5.6%	0.0%	0.0%	2.8%
	Hours behavior reported	8	12	1	8	6	0	0	3
	Total hours monitored	107	107	53	107	107	95	107	107

[1] % of total study period: Total hours of behavior reported / Total hours where behavior possible

[2] % of time reported = Hours behavior reported / Total hours monitored

Table 3-2: Odds ratios and 95% confidence intervals (CI's) for seniors reporting adaptive behavior use at different temperature intervals (indoor temperature and outdoor temperature intervals), compared to a reference temperature of 70 -75 F. Data obtained from 29 residences in Detroit, Michigan, June- August, 2009. Indoor temperatures were the temperatures recorded by the indoor temperature loggers in each home. Outdoor temperatures were taken from Detroit Metropolitan Airport archives.

Indoor	Behavior	< 70 ◦F	76 - 80 ◦F	81 - 85 ◦F	86 - 90 ◦F	> 90 ◦F
	Opening windows or doors	0.59 (0.39, 0.88)	1.10 (0.75, 1.61)	1.27 (0.69, 2.32)	0.93 (0.45, 1.94)	0.98 (0.57, 1.67)
	Turning fans on	-	1.88 (1.04, 3.39)	3.34 (1.47, 7.59)	3.46 (1.48, 8.08)	-
	Turning air conditioner on	-	2.34 (1.34, 4.09)	3.43 (1.73, 6.83)	2.99 (1.66, 5.41)	-
	Changing clothes	0.82 (0.68, 0.98)	0.92 (0.82, 1.03)	0.73 (0.56, 0.91)	0.68 (0.52, 0.90)	0.55 (0.08, 3.60)
	Taking a shower	1.14 (0.95, 1.37)	0.79 (0.62, 1.01)	0.55 (0.40, 0.76)	0.56 (0.30, 1.03)	0.34 (0.09, 1.28)
	Going to the basement	1.36 (0.94, 1.98)	0.66 (0.29, 0.85)	0.49 (0.29, 0.85)	0.49 (0.12, 2.09)	-
	Going to the porch or yard	1.40 (0.69, 2.84)	0.99 (0.71, 1.39)	0.96 (0.62, 1.48)	0.65 (0.39, 1.10)	-
	Leaving the house	1.59 (0.94, 2.68)	1.07 (0.73, 1.58)	0.99 (0.61, 1.61)	0.58 (0.37, 0.91)	0.78 (0.28, 2.16)

Outdoor	Behavior	< 70 ◦F	76 - 80 ◦F	81 - 85 ◦F	86 - 90 ◦F	> 90 ◦F
	Opening windows or doors	0.90 (0.68, 1.19)	0.39 (0.65, 1.25)	0.99 (0.54, 1.80)	0.79 (0.39, 1.56)	0.95 (0.41, 2.18)
	Turning fans on	-	0.98 (0.69, 1.40)	1.22 (0.57, 2.61)	0.97 (0.36, 2.61)	-
	Turning air conditioner on	-	2.31 (1.37, 3.94)	3.03 (1.54, 5.92)	5.77 (2.74, 12.15)	-
	Changing clothes	1.39 (0.93, 2.09)	0.78 (0.63, 0.96)	0.65 (0.41, 1.01)	0.68 (0.38, 1.20)	0.63 (0.32, 1.23)
	Taking a shower	1.64 (1.37, 2.11)	0.60 (0.49, 0.76)	0.32 (0.20, 0.52)	0.57 (0.27, 1.18)	0.37 (0.18, 0.79)
	Going to the basement	1.17 (0.86, 1.60)	0.93 (0.65, 1.32)	0.83 (0.57, 1.20)	1.00 (0.52, 2.22)	-
	Going to the porch or yard	0.74 (0.63, 0.88)	1.23 (0.86, 1.76)	1.43 (0.83, 2.48)	1.12 (0.61, 2.07)	-
	Leaving the house	0.57 (0.41, 0.81)	1.39 (1.06, 1.80)	1.87 (1.35, 2.58)	2.23 (1.35, 3.70)	3.12 (1.61, 6.05)

Statistical significance denoted by gray shading.

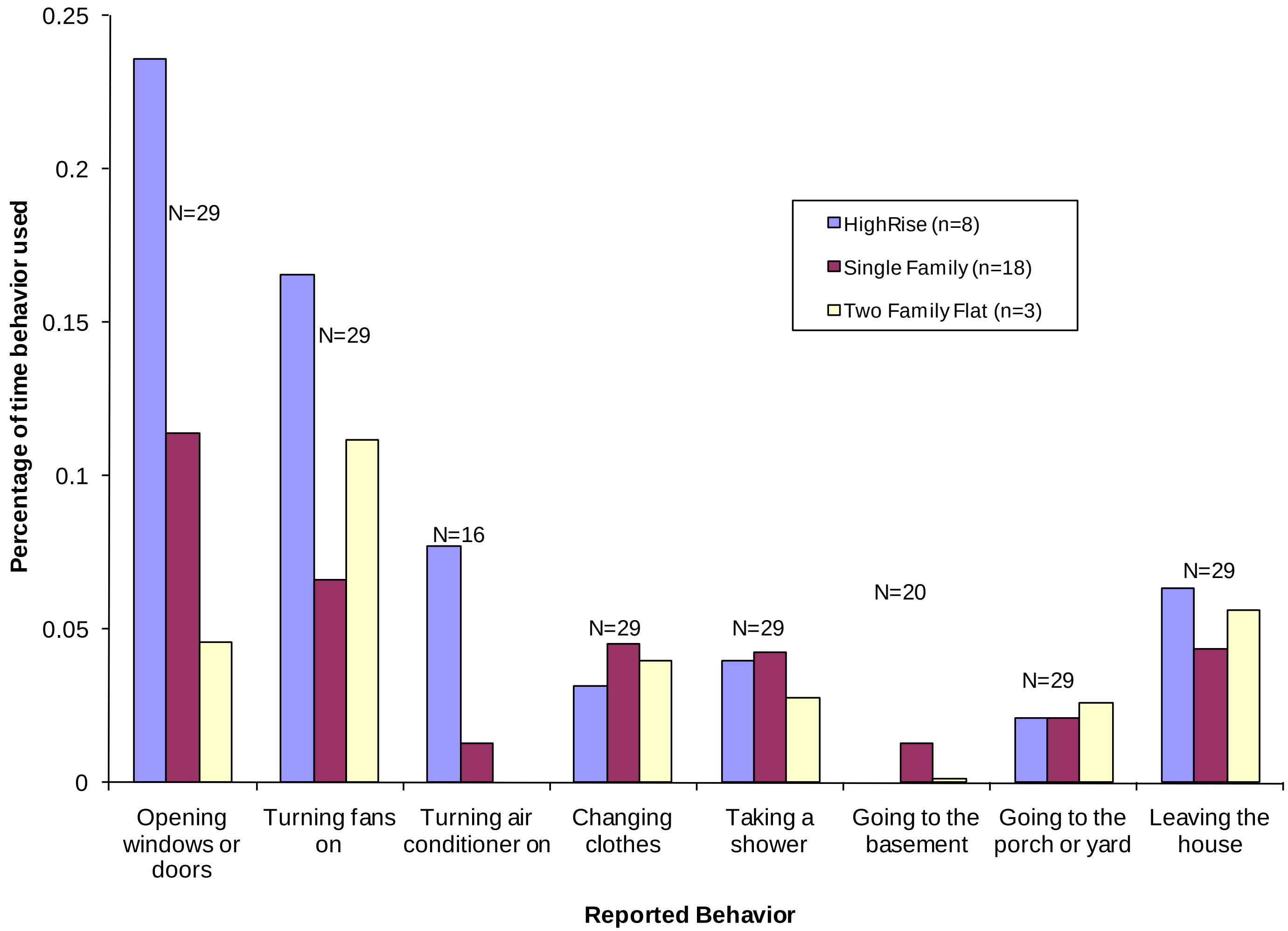

Figure 3-1. Percentage of time heat-adaptive behaviors reported being used by elderly residents in 29 Detroit, MI homes, summer 2009, by residential type. N = number of homes.

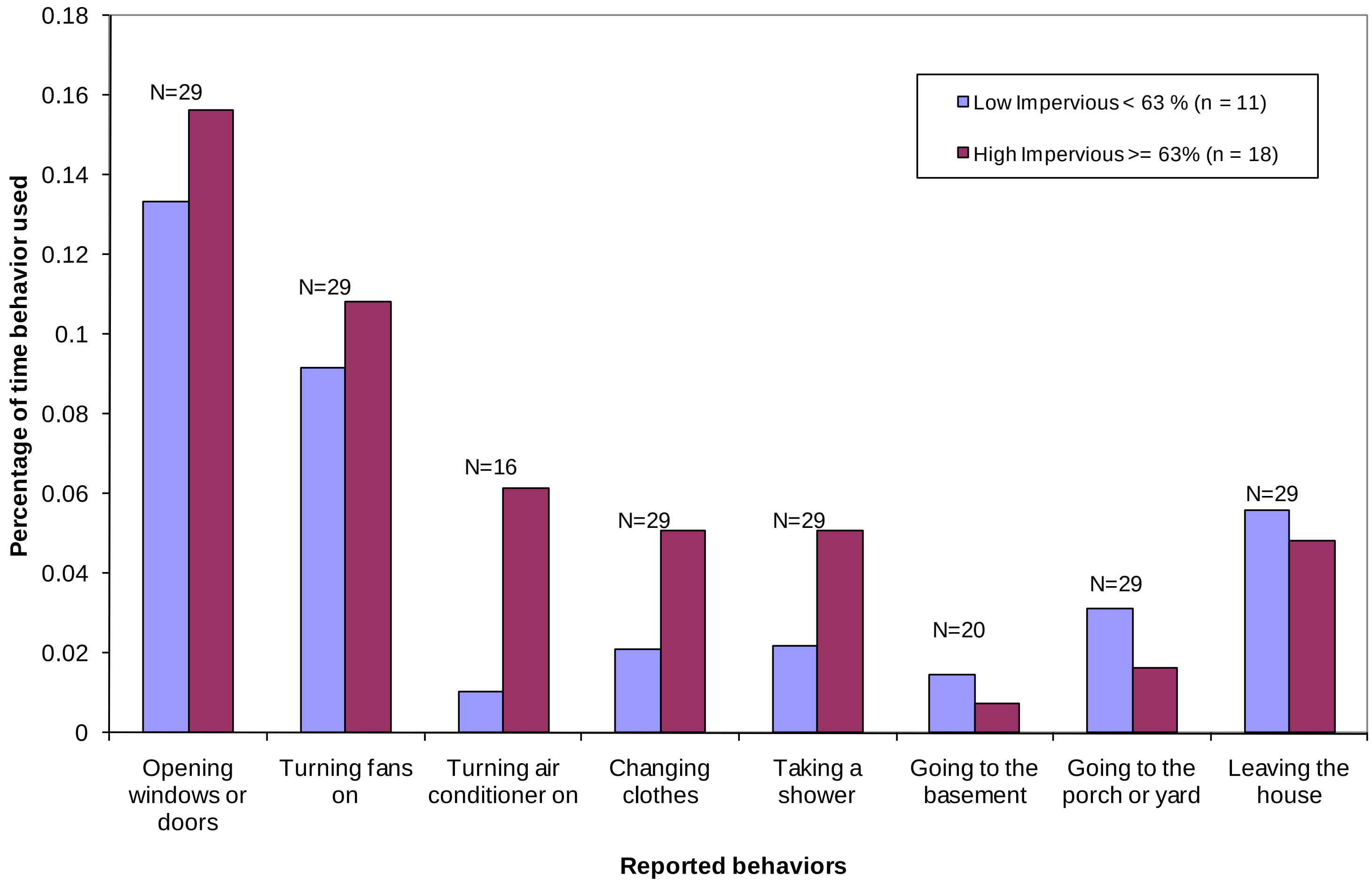

Figure 3-2. Percentage of time behaviors reported being used by elderly residents of 29 Detroit, MI homes, summer 2009, by level of surface imperviousness (< 63%) or (> or = to 63%) from the National Land Cover Dataset (NLCD 2001). N is number of homes.

Chapter 4
Validating satellite-derived land surface temperature with in-situ measurements: a public health perspective

4.1 Abstract

Background

Land surface temperature (LST) and surface imperviousness (SI), both derived from satellite imagery, have been used to characterize the urban heat island effect, a phenomenon in which urban areas are warmer than non-urban areas. As summer temperatures heat events increase due to climate change, heat-related health effects may increase. Using LST to quantify air surface temperature at a local scale has been proposed to support public health interventions.

Objectives

We compared LSTs from the Landsat-TM 5 satellite and SI landcover images with actual temperature readings from a ground-based network of outdoor monitors.

Methods

We evaluated the relationship between LST calculated from a 2009 summertime satellite image of Wayne County, Michigan with ground-based temperature measurements (10 minute intervals) monitored during the same time period at 19 residences throughout Wayne County, Michigan. The associations between average LSTs (degrees Fahrenheit)

and SI (percent impervious cover)-evaluated at different radii (in meters) around the point of measurement (0, 100, 300, 400, 500 and 800 meters (m)) - and the ground-based temperature data (evaluated at four different time intervals ranging from the exact time of the satellite image capture to the entire study period) were assessed with Spearman correlation coefficients and corresponding p-values.

Results

One usable Landsat TM-5 image captured on August 19, 2009 at 11:05 am was available during the period ground temperatures were monitored (June 13 to September 30, 2009). No statistically significant correlations between either satellite derived LSTs or SI and ground temperatures at any radii around the 19 residences at any temperature interval, were found. Statistically significant r-values ranging from 0.59 to 0.91 were observed between LST and SI.

Conclusions

Neither SI nor LST resulted in useful information about heat exposure at the ground level in Wayne County, MI. For this area, these data sources thus may not be useful for public health research and applications. Given challenges and limitations in obtaining and using satellite data, other approaches may be necessary to target public health interventions to the most vulnerable and most exposed.

4.2 Abbreviations

Heat Health Warning System (HHWS):	a system that uses meteorological data and other inputs to predict adverse weather conditions and trigger adaptation responses to heat
Landsat-5 Thermal Mapper (L5-TM):	satellite developed and launched by the U.S. National Aeronautics and Space Association (NASA) that provides measurements of the earth's features through remote sensing
Land Surface Temperature (LST):	on-the-ground temperature estimate derived from the Landsat-5 satellite measurements that have been calibrated and converted to a temperature values using calibration constants specific for the Landsat-5 Thermal Mapper.
ground-based temperature monitoring network:	ground-based outdoor air temperature monitoring network established to collect temperature measurements at various locations around the study area
Surface imperviousness (SI):	characteristic of land surface that represents the percentage of the surface impenetrable by water
Geographic Information Systems (GIS):	an information system that displays, analyzes, stores and presents data spatially
US Geological Survey (USGS):	The USGS is a science organization that provides impartial information on the health of our ecosystems and environment, the natural hazards that threaten us, the natural resources we

	rely on, the impacts of climate and land-use change, and the core science systems that help us provide timely, relevant, and useable information.
Emissivity:	Emissivity: The ratio of the radiation emitted by a surface to the radiation emitted by a blackbody at the same. (i.e. water has emissivity ~ 1)
Normalized difference vegetative index (NDVI):	Index used to estimate the amount of vegetative cover

4.3 Introduction

Use of thermal remote sensing and advanced spatial modeling are emerging trends in the field of environmental epidemiology and public health. Geospatial technologies provide a valuable resource to assist public health practitioners and emergency response planners in identifying areas that are most at risk, as well as using these scientific outputs to inform policies and practices. Thermal remote sensing products such as thermal images captured by the Landsat-5 Thermal Mapper (L5-TM) instrument have been used to study temperatures within a city, also known as micro-urban heat islands (Johnson 2009). While other methods have and can be used to explore urban heat islands or hotspots within a city, satellite data from Landsat provides repeatability and the ability to capture very large areas of data at one time period (Aniello, Morgan et al. 1995). The data captured by the satellite can be transformed into several helpful measures, including land surface temperatures (LST) and surface imperviousness (SI). LSTs are a primary factor in determining surface radiation and human comfort in cities.(Weng 2009) The amount of surface imperviousness is defined as the amount of the surface of an area that is not penetrable by water, such as concrete or asphalt. This characteristic has been commonly used in studies to assess the degree of urbanization of an environment as well as explore the spatial extent of surface urban heat islands.(Roy and Yuan 2009)

Adaptation to the consequences of climate change and predicting areas of high vulnerability to climate change in cities are necessary as future scenarios of heat-related morbidity and mortality become a major public health concern. A study in Philadelphia used geographic information systems (GIS) and thermal imaging to investigate the relationship between the spatial distributions of vulnerable populations, urban heat island intensities and heat-related deaths (Johnson and Wilson 2009). This study recommended more multi-year studies use spatial modeling and remote sensing methods to better help determine areas of risk throughout cities.

The relationship between LST and vegetation-filled agricultural areas has been documented in the literature. A study by Aniello and colleagues compared the spatial distribution of micro-urban heat islands and tree cover in Dallas, Texas using L5-TM and GIS (Aniello, Morgan et al. 1995). They examined the usefulness of L5-TM for classifying tree-cover information and using thermal band 6 to produce a thermal map of Dallas. Their methods involved processing and classifying Landsat thermal images and tree cover data in GIS. While L5-TM data was useful for mapping micro-urban heat islands in Dallas, the authors recommended use of exact on-the-ground temperatures for image calibration in future studies. Applications of remote sensing data to help model urban surface temperatures have been limited; specifically, validating LST data with actual on the ground temperature measurements.

Integrating information from the ground-based temperature monitoring networks and satellite-derived images using a GIS platform can provide useful data for exposure assessments in urban areas, specifically for heat epidemiology. Validation of satellite data sources by ground-truthing can help characterize and identify neighborhood-level urban heat islands, which could be useful for public health professionals, urban planners and environmentalists who can work together to prevent heat-related mortality and other adverse health effects from high summer temperatures. This kind of data could also direct intervention strategies to reduce the urban heat island effect. The purpose of this study is to determine if the spatial variation of temperatures within a network of ground-based outdoor temperature monitors is correlated with satellite derived LST and SI. We hypothesize that the temperatures collected by a ground-based temperature monitoring network would be highly correlated with areas displaying higher values of LST, as well as higher values of SI.

4.4 Methods

4.4.1. Ground based temperature monitoring network and surface imperviousness

Initial site selection for the ground based temperature monitors was based on getting a diverse representation across the study area of the amount of surface imperviousness. We strategically picked locations that were urban and rural, to assess the temperature differences amongst areas within the same county that might have different land-use patterns that would validate the existence of the urban heat island structure in our study area of Wayne County, Michigan. Percent surface imperviousness (SI) from the United States Geologic Survey (USGS) National Land Cover Dataset product (2001) (http://www.mrlc.gov/nlcd_multizone_map.php) was overlaid with Wayne County census tracts. HOBO Pro v2 U23-002 (External Temp/RH) outdoor temperature monitoring devices from the Onset corporation were calibrated and used to record temperature and relative humidity at 10 minute intervals from June 13 to September 30, 2009.

Monitors were positioned in residential grass-covered backyards of volunteers following a strict placement protocol that required monitors to be sited at least 10 feet away from buildings, homes and trees; 1.5 meters from the actual surface; not in the direct pathway of an automatic lawn sprinkling systems; not in a shady area or near falling rocks, dead trees or other objects that could fall on them; away from power lines and swampy damp ground; and facing southwest. All volunteers signed an agreement letter to participate.

4.4.2 Processing the LANDSAT TM-5 satellite image to derive land surface temperature

Images of the Earth have been taken nearly continuously from March 1, 1984 to the present with a 16-day repeat cycle from the Landsat Thematic Mapper sensor (TM-5), which consistently images the Detroit metro area at about 11:05 am at each pass. TM-5 captures images are collected at a 705 kilometer altitude, 185 kilometer swath and 120 meter spatial resolution for thermal band data, and 30 meter resolution for the other spectral bands. The satellite images captured by the Landsat TM-5 are free and downloadable from the USGS at (http://edcsns17.cr.usgs.gov/EarthExplorer/). Satellite images were downloaded for use only if they met the following criteria: the images were captured during the study period; the images covered the entire study area (geographically); images with less than 4% cloud cover and the clear weather conditions. The more cloud cover and unclear weather conditions can inhibit the signal strength reflected back to the satellite and give an underestimated reading of the ground surface temperature.

Each image had eight spectral bands of information. Thermal infra-red band 6 (10.4 – 12.5 μm) data provides the data that can be converted from raw digital numbers to LST. To convert from a digital number to a temperature, calibration formulas, atmospheric correction tools and transformations were necessary. The diagram below describes the procedure employed.

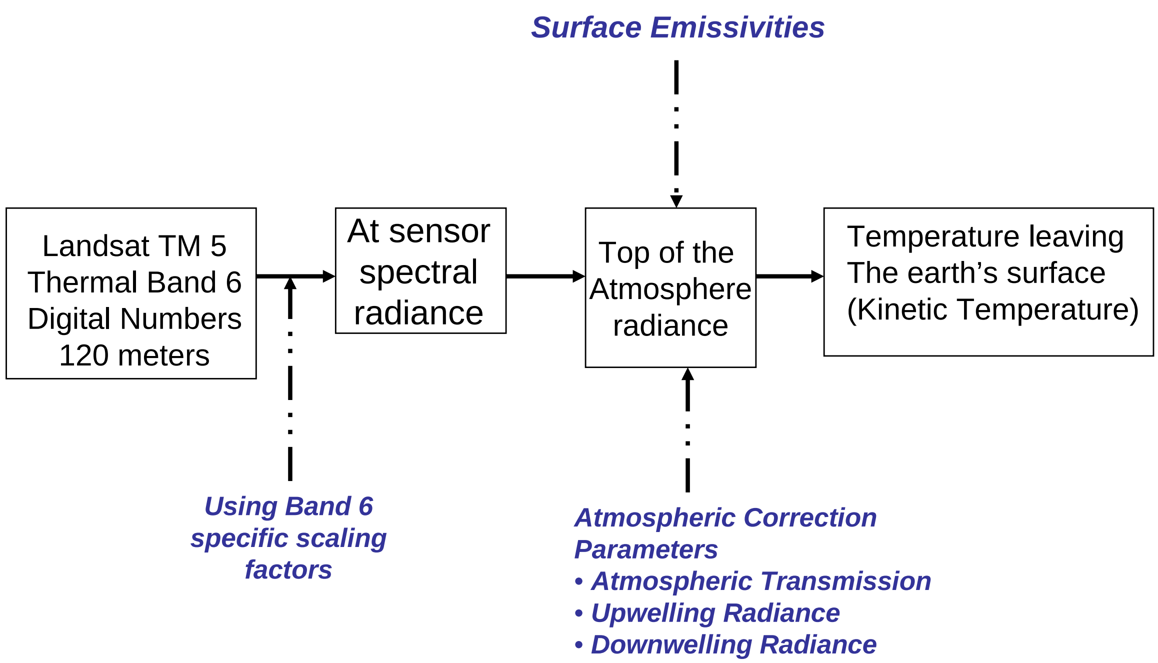

Figure 4-1: Processing method for converting raw satellite images to land surface temperature

Once an image was selected by our criteria, ERDAS Imagine 9.2 software (Leica Geosystems, Inc., Atlanta, Georgia) was used to convert the image (from a TIFF file to an IMG file) to a usable format for GIS. GIS was used to perform the calculations outlined below. The first step was to convert the digital numbers taken from the raw image, into at-sensor spectral radiance (i.e. the temperature read at the sensor). The source equations and calibration constants developed specifically for Landsat TM-5 images were used from the process outlined by G. Chander et. al (Chander, Markham et al. 2009). Once an at-sensor spectral radiance temperature was calculated, this value was used to calculate an actual ground surface temperature.

Because the satellite signal received by the sensor is in space, the effects of the atmosphere (i.e. air pollution, weather) and surface emissivity (i.e. how well different surface reflect the solar energy) can have considerable influence on the accuracy of the satellite derived surface temperature. To account for these influences, we performed two tasks: 1) used a tool to estimate atmospheric influences, and, 2) developed a data layer of emissivity for the study area. Using an atmospheric correction tool developed by Barsi et. al (Barsi, Barker et al. 2003), scene specific parameters (atmospheric transmission, sky radiance, atmospheric path radiance) were estimated for each satellite image, using the web-based atmospheric correction parameter calculator located at http://wwwt.emc.ncep.noaa.gov/gmb/gdas.

The tool required the following inputs for each satellite scene: year, month, day, Greenwich Mean Time (GMT) hour and minute, latitude and longitude coordinates. The outputs of this tool were three parameters that could be used in the next calculation step: atmospheric transmission, atmospheric path radiance and sky radiance. Additionally, values of emissivity for the study area were also estimated by examining the land use/land cover designations, downloaded for Wayne County, Michigan from the 2001 Multi-Resolution Land Characteristics Consortium. Emissivity, the emitting ability of a real material compared to that of a blackbody, ε ranges from 0 to 1. Using several references, we created a layer of emissivity for the study area based on reference emissivity values for various land cover classes used in other studies (Lillesand and Kiefer 2008). These values of emissivity, coupled with the atmospheric correction parameters, were used in the equation presented below to calculate the radiance of a blackbody target of kinetic temperature (L_T), which ultimately served as a surface temperature:

$$L_T = \frac{L_{TOA} - L_u - (1 - \varepsilon)*L_D}{T*\varepsilon}$$

L_T = Radiance of a blackbody target of kinetic temperature

L_u = atmospheric path radiance, W/m2*sr*µm

L_d = sky radiance, W/m2*sr*µm

T = atmospheric transmission, unitless (ibit)

L_{TOA} = at sensor spectral radiance, W/m2*sr*um

The last two steps involved transforming L_T into a temperature in Kelvin (using Planck's equation), and then converting Kelvin to Fahrenheit.

Once the scene was transformed to a surface temperature in units of degrees Fahrenheit, temperatures outside our range of interest (i.e. below 32 degrees Fahrenheit) or areas of no data (i.e. water) were masked out of the layer (i.e. given a value of NoData). Typically, these undesirable ranges were a result of some cloud cover over a certain point, values over a body of water, or possibly a source of error in the reflectance value that would cause noise in the analysis

4.4.3 Geographical and statistical analysis

Using the processed LST satellite image in GIS, the mean LST and percent SI was calculated for six concentric circles with different radii around each outdoor monitoring unit: at the point (0 meters), 100, 300, 400, 500, and 800 meters. It is important to assess the value at different radii around each monitoring unit, or "buffer zone," because it can be representative of physical processes that can occur at different spatial scales within the urban canopy layer (UCL), the layer of the urban atmosphere extending upward from the surface to building height. (Roy and Yuan 2009) Cells that were contained completely within and intersected the corresponding zone were included in the calculation. The zonal stats operation in ArcGIS v. 9.3.1 (ESRI, 2009) was used to generate the average LST and percent SI for each of the radii. The average satellite derived LSTs at different radii around the outdoor monitors (0, 100, 300, 400, 500 and 800 meters) were examined to explore the potential change in the temperature profile, starting at the micro-level (at the home = 0 meter) to more macro-level (block, neighborhood) exposures. Spearman rank correlation coefficients were also calculated between the mean LST and the temperatures from the outdoor monitoring network at four different time points: monthly average temperatures (August 2009); instantaneous temperature monitored at 11:05 am EST; three-hour average temperatures recorded from 9:00 – 11:00 a.m.; and, the entire study period average of temperatures from June 13 – September 30, 2009. These same time points were used to calculate correlations with SI. These different time intervals were chosen to see whether the relationships between certain temperatures were stronger with LST and SI than others; and whether LST and/or

SI taken at one point of time could give a good picture of longer-term spatial variation in temperatures, if not the short-term variability.

SAS v 9.2 was used for all statistical analysis and ArcGIS 9 (Version 9.3.1, copyright ESRI 2009) was used for all geostatistical analysis.

4.5 Results

4.5.1 General statistics

Temperature data from 19 out of 24 ground-based temperature monitors positioned throughout the county were used in the analysis. Five of the temperature monitors were excluded due to siting conditions that could have jeopardized the readings, such as being too close to a building. A search in the Landsat TM 4-5 archive datasets for the Detroit, Michigan area (Lat 42.331427, Long. -83.0457538), yielded a total of 21 satellite images. Out of these 21 images, 17 had a cloud cover percentage greater than 4%, and 16 did not cover the study area geographically. Consequently, one image, taken by the satellite on August 19, 2009, met our criteria. This image, identified by the Landsat scene identifier number LT50200302009231EDC00, was acquired during the daytime at 16:05 GMT (11:05 AM EST). The quality of band 6 was scored as a 9, the highest score for images. Figure 2 shows the final processed band 6 image of the study area of Wayne County, Michigan.

The ground-based temperature monitoring network readings at three time intervals are shown below: an instantaneous temperature at 11:05 a.m. on 8/19/2009; a three hour average from 9:00 – 11:00 a.m. and a monthly average (Table 1). The maximum and minimum temperatures and standard deviation for each column were calculated.

The highest levels of mean surface imperviousness was seen at the 500 meter radii mark amongst all of the locations (Table 1). Overall, the New Center location had the highest percentages of surface impervious (high-low range: 77.3 to 87.9 %), and the New Boston location had the lowest overall surface impervious levels (high-low range: 9.03 to 19.72 %). The minimum temperatures for the satellite derived LSTs were overall lower than the temperatures read by the ground-based temperature monitoring network. The highest LSTs were seen at the 200 meter and 300 meter radii around each monitoring station. The New Center area location had the highest LST readings compared to other locations (high-low range: 76.0 to 78.1 °F), while the New Boston area had the lowest overall LST readings (high-low range: 64.9 to 65.2 °F). The smallest standard deviations amongst the LST temperatures derived across the radii were at the 500 and 800 meter radii. With regard to the ground-based temperature monitoring network, the instantaneous temperature and the three-hour average temperature on August 19, 2009 were very similar, and consistently higher than the August monthly average, as expected, since the monthly average includes night-time temperatures. The maximum temperatures measured by the ground-based temperature monitoring network were at least 4 degrees higher than the highest satellite derived LST. Also the maximum instantaneous temperature and three-hour average temperature for the ground-based temperature monitoring network were higher than the satellite derived LSTs on the same day; but the August monthly temperature was lower than the LST.

4.5.2 Correlations among data sources

No statistically significant correlations between satellite derived LSTs and the ground-based temperature measurements were seen (Table 2). No statistically significant correlations between percent surface impervious and the ground-based temperature measurements were seen (data not shown).

Statistically significant correlations, ranging from 0.59 to 0.91, were found between the satellite derived LSTs and percent SI at the following radii: 100, 300, 400, 600 and 800 meter (Table 3).

4.6 Discussion and conclusions

Land-cover data has commonly been used to estimate the urban heat island effect in cities for urban planning purposes and can be obtained and processed in a relatively simple manner. While these measurements can be an indicator of warming potential, they do not necessarily provide an indication of the actual air temperatures that would be experienced by people, but they could provide estimation, just with larger uncertainties. The purpose of this study was to assess the relationship between satellite-derived land surface temperature (LST) measurements and surface imperviousness (SI) measurements with air temperature measurements from a ground-based temperature monitoring network for Wayne County, Michigan. Our results showed a statistically significant relationship between LSTs and SI; no statistically significant relationship between LST and the ground based temperature monitoring network; and no statistically significant relationship between the ground-based temperature monitoring network and SI. These findings suggest that the satellite-derived LST images, corrected for atmospheric effects and emissivity, as well as the surface imperviousness images would not be suitable to use as an indicator of air temperature for heat exposure studies in the Wayne County, Michigan area (from this one day of evaluation) for assessing fine scale spatial variations in heat exposure across such an urban area. However, the images might still be useful for day-to-day community-level exposure assessments.

There were some limitations of our study, as well as the limitations of satellite imagery. In our study, the ground-based temperature monitoring network had sensors that were monitoring air temperatures 1.5 meters from the actual surface, not on the ground. We selected this monitoring height to better assess the level of exposure that would be experienced by a person of average height (approximately 5 feet), as well as this is consistent with the instrument siting protocols used by The World Meteorological Organization, as well as NOAA's National Weather Service. (Organization 2008) However, if LST is supposed to be an indication of the estimated 'air temperature at the ground' , then the non statistically significant relationship that we found between SI and the ground-based temperature monitoring network might be a result of mixing, advection, and convection processes within the boundary layer that influence the air temperatures recorded by the outdoor temperature monitor. Since we are comparing two different types of measurements – surface temperature and air temperature – the correlations between these measurements might not be as strong, due to logistical (e.g. timing and resolution), as well as physical (i.e. advection, wind) that could impact the derived surface temperatures. All of the outdoor monitoring devices were sited over grass, which could give a lower temperature than the average, where the average would include temperatures directly over impervious surfaces. Additionally, there are differences in scale between the ground monitor and the satellite image resolution of 120 meters that could influence the relationships. Accuracy as well as precision of the monitor itself could also be considered as a limitation.

Satellite image products also have limitations in terms of image quality. Out of 21 scenes examined, only one scene was usable to be processed in that it lacked significant cloud cover and covered the study area geographically. The 16-day cycle on which images are available for a specific area does not afford researchers the opportunity to compare multiple images within a useful timeframe. Additionally, the Landsat TM-5 image resolution is very coarse and might provide some challenges at the local scale. Also, the overpass time of 11 a.m. is not ideal for measuring the effect of surface temperature on air temperature. The signal of the surface temperature driver may be stronger earlier or later, when the differences between surface and air temperatures are greater. Other sources of error could have resulted from instrument calibration procedures as well as the sensor precision. Additionally, no standard, best practice method exists for processing single-band thermal infrared data.

Our results suggest that using either satellite-derived LST and/or surface imperviousness as a proxy for on-the-ground temperature exposure may not be the best approach. While LST and SI were strongly correlated and these measurements have been widely used in literature, our findings show that there is a need for more and better ground-truthing in order to understand the true temperatures people are exposed to on the ground. Consequently, careful consideration needs to be used when using these satellite images as a basis for public health intervention efforts that include heat adaptation strategies for urban environments.

4.6.1 Recommendations

Our study results support the need for an increased effort, nationally, by public and private entities, to create useful remotely-sensed data sources that can be applied to public health practice. A workshop report from the National Academy of Sciences discussed the challenges and potential applications of using remotely sensed data for public health.(2007) Two particular thoughts from this workshop speak to our study limitations:

> *"Successful application of remotely sensed data to public health issues depends on the development of multi-resolution sensors at multiple spatial and temporal resolutions, especially sensors that are able to detect conditions in urban areas with complex mixtures of vegetation, buildings and roads."*
> *"Maintaining the continuity of current satellite coverage so that change of environmental conditions and their effects on health can be monitored over extended time frames" (pp. 33-34)*

The report cited that one of the major challenges to applying this remotely sensed data in the health arena is the limited in-situ ground-truthing data accompanying remote sensing technology to verify analysis, and the high learning curve to using the tools required to analyze remotely sensed data. Our study gathered "ground-truthing" data needed to validate satellite derived LST as well as surface imperviousness; but regardless of sample size, issues of spatial resolution, image availability over certain time periods and the complex urban landscape remain challenges in the effort to integrate remotely sensed data with public health research and practice.(2007)

Other validation studies have found concordance between satellite data and ground-based observations. An experimental set up to validate satellite-derived LST over a one square kilometer area of rice crops in Valencia, Spain was constructed. The satellite data was taken from the AATSR and MODIS satellite. Ground temperature measurements were taken by thermal infrared radiometers (TIR). Three split-window algorithms were used to develop the LSTs. The algorithms were found to work well, as long as the site was carefully characterized.(Coll, Caselles et al. 2005) While their study site is more ideal for this type of validation work – i.e. fully vegetated surfaces, deserts, bare surfaces - that study shows that calculating estimates of surface temperature can still be very complicated and time-intensive for someone not trained in the field of remote sensing, even if choice of site for validation could possibly yield better results than we found for Wayne County's complex urban terrain. Air temperatures were modeled using remotely sensed data – land-surface temperature, albedo, normalized difference vegetative index (NDVI), along with geographical variables including altitude, latitude, continentality and solar radiation in Catalonia, a province in the northeast of Spain. Catalonia is a heavily vegetated area. After using 136 meteorological station measurements and 156 satellite images from multiple sensors, they found that models using both remotely sensed and geographic variables were robust predictors of air temperature. (Cristobal, Ninyerola et al. 2008)

To our knowledge, no other studies have attempted to ground-truth satellite derived LSTs and SI with air temperatures measured in mixed urban area from Landsat TM-5, using a unique ground monitoring network of outdoor temperature monitors, and using the standard corrections for atmospheric effects and emissivity. There have, however, been studies in the literature that have ground-truthed Landsat TM-5 data using airborne thermal scanner flights(Voogt and Oke 1998) , or using satellite data in conjunction with ground-based (air, or surface?) temperature measurements with other remote sensing predictors to create a model for air temperature. (Cristobal, Ninyerola et al. 2008) While the data we gathered did not provide the statistically significant correlations we expected between the satellite derived measures and the ground-based air temperature monitoring network, our exploration underscores the limitations and challenges of using remote sensing data, as well as the necessity of utilizing complex methods and additional datasets to utilize the high spatial resolution afforded by satellite imagery to better understand variations in surface air temperature that are highly relevant for public health, especially during hot weather.

As we found in this study, percent surface imperviousness appears to be strongly correlated with the satellite derived LSTs. Other studies have found a positive correlation between these two measures as well. (Yuan and Bauer 2007) This suggests that surface imperviousness data, which requires much less processing compared the land surface temperature data, could be used as a proxy for land surface temperature. Consequently, public health practitioners will not have to become remote sensing experts, but still be able to use a fairly easy method to determine city hot-spots using high surface imperviousness as an indicator of potential increased temperature exposure. An added benefit is that increasing vegetative cover and other changes can reduce the heat-trapping potential of the urban landscape, so results of studies using surface imperviousness could be of direct relevance for policy changes. However, while this finding might be helpful in the urban planning sector, in environmental epidemiology, where we are interested in measuring personal exposure, the lack of correlation between these satellite data sources and the actual ground-based air temperature readings underscores the importance of identifying a data source and other tools to better gauge actual temperature exposure near the ground surface.

4.6.2 Where do we go from here

From a public health perspective, it is important to target resources and health interventions for the most vulnerable populations. The availability and usefulness of remote sensing data, integrated with social and economic demographic data, can provide a powerful tool for assessing vulnerability. A quality of life study conducted by Athens-Clarke County used one cloud-free image, aerial photographs and U.S. Census data to overlay biophysical (land surface temperature, NDVI, land use and land cover) and socioeconomic layers (population density, per capita income, median home value, education) to create a quality of life indicator. (Lo and Faber 1997) The research found a strong relationship between biophysical and socioeconomic variables, which could be useful to assess vulnerability in the public health arena. In the field of heat epidemiology, being able to utilize a user-friendly data source, like percent surface imperviousness as a proxy for surface temperature exposure can further validate the need for targeted interventions related to heat health concerns. Another study has already shown that areas of Wayne County, Michigan (which includes the city of Detroit) with high surface imperviousness had statistically significant correlations with several socio-demographic variables: being age 65 years and older living alone, go-outside disability (a census-tract variable that evaluates a persons ability to leave or go-outside the home), education level, living below the poverty line and being non-White.(White-Newsome, O'Neill et al. 2009)

In order to successfully integrate remote sensing data, specifically land surface temperature data and other potential satellite based data sources for public health practice, we suggest the following to the remote sensing community: increase the frequency and usability of remotely sensed images that are accessible to the public; provide images at a finer resolution (10 – 15 meters) and if possible at a higher temporal frequency that could be more useful for city and county level authorities; commission more research to ground-truth satellite-derived land surface temperatures for different sized urban areas; establish a set of fairly simple, standard best practices that can be used to estimate the influences of atmospheric and other factors on deriving a precise land surface temperature value from remote sensed imagery.

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Table 4-1: A summary, by location, of percent surface imperviousness and satellite-derived average land surface temperature measurements at different radii and ground-based temperature monitoring network temperatures. The mean surface imperviousness and mean LST was calculated at 0, 100, 300, 400, 500, and 800 meter circles around the monitoring point. Ground-based temperature monitoring measurements were calculated at 3 timepoints: the time the satellite image was taken (i.e. 11:05 am on 8/19/2009), the three hour average temperature and the monthly average. The maximum and minimum temperatures, and their standard deviations were calculated for both measurements.

	Percent surface imperviousness at different radii (in meters) around the outdoor monitoring point						Landsat derived surface temperatures (°F) at different radii (in meters) around the outdoor monitoring point						Ground based temperature network readings (°F)		
Location Name	0	100	300	400	500	800	0	100	300	400	500	800	Instantaneous temperature at 11:05 am on 8/19/2009 (F)	Average temperature from 9 am - 11 am	August average temperature
Allen Park	13.0	25.8	51.6	50.6	48.3	44.7	69.0	70.3	71.7	72.0	72.0	71.3	77.5	78.6	71.1
Canton	16.0	30.8	35.5	36.4	37.7	34.5	70.1	70.5	71.4	71.7	71.5	71.2	79.0	79.1	69.6
Conner	69.0	61.9	73.9	73.9	75.1	73.9	74.1	73.8	73.2	73.3	73.7	74.6	77.9	78.2	70.0
Corktown	13.0	46.8	48.9	52.2	57.9	65.3	70.0	71.0	71.6	72.3	72.9	74.1	77.7	78.7	71.5
East Detroit	61.0	72.0	50.4	51.8	53.0	54.5	72.2	71.4	70.1	70.2	70.3	70.6	76.1	77.0	71.0
East Jefferson	26.0	37.3	41.4	44.1	45.1	49.2	66.5	66.8	67.5	68.0	68.2	68.9	76.6	77.8	71.4
Garden City	47.0	51.0	50.8	51.3	51.3	52.9	71.7	71.6	71.3	71.6	71.9	72.2	75.7	77.0	69.3
Indian Village	58.0	42.2	41.8	43.1	46.1	51.2	68.0	68.1	68.1	68.6	69.3	70.3	76.9	78.6	71.0
Joy Rd	35.0	23.4	14.4	13.7	12.5	13.1	69.9	69.1	67.2	66.3	65.8	66.0	77.5	78.6	71.1
New Boston	9.0	9.0	19.4	18.9	16.1	11.9	64.9	65.2	65.2	65.5	65.4	65.2	77.7	78.9	71.7
New Center	42.0	77.3	86.8	87.2	87.8	83.2	76.8	77.7	77.9	77.3	76.9	76.0	77.6	78.2	71.5
Redford2	44.0	48.4	55.3	55.8	57.3	57.0	72.6	72.9	73.0	73.0	73.0	72.4	75.2	75.9	70.7
UM Dearborn	9.0	32.8	34.8	35.4	35.2	32.7	70.4	70.0	70.1	70.0	69.8	68.8	77.5	78.8	70.1
West Detroit 1	58.0	42.2	41.8	43.1	46.1	51.2	68.0	68.1	68.1	68.6	69.3	70.3	79.3	80.1	71.3
West Detroit 3	57.0	67.1	69.4	66.1	63.3	57.7	73.7	74.2	74.0	73.2	72.7	72.1	80.8	80.6	70.9
West Detroit 5	25.0	20.6	27.8	19.8	16.6	22.4	70.9	70.4	70.2	69.6	69.2	68.5	75.8	76.1	70.2
West Village	30.0	45.8	50.0	50.3	48.4	50.1	69.0	69.1	69.5	69.5	69.7	70.3	75.2	77.3	70.3
Westland	22.0	20.8	31.1	38.8	40.4	36.3	75.1	74.6	72.2	71.7	71.2	70.0	73.4	74.1	69.7
Wayne State University	32.0	72.5	82.1	76.4	72.2	72.0	73.8	74.4	75.3	74.8	74.4	74.3	77.9	78.4	72.2
Min	9.0	9.0	14.4	13.7	12.5	11.9	64.9	65.2	65.2	65.5	65.4	65.2	73.4	74.1	69.3
Max	69.0	77.3	86.8	87.2	87.8	83.2	76.8	77.7	77.9	77.3	76.9	76.0	80.8	80.6	72.2
Standard Deviation	19.3	19.8	19.7	19.3	19.7	19.4	3.0	3.1	3.0	2.9	2.8	2.8	1.7	1.5	0.8

Table 4-2: Spearman rank correlation coefficients and corresponding p-values quantifying the relationship between satellite-derived land surface temperature (LST) -from a Landsat TM-5 image captured on August 19, 2009 - compared with ground-based temperature measurements collected by 19 outdoor monitoring devices deployed throughout Wayne County, Michigan. The mean LST was calculated at 6 concentric radii around each monitoring points: 0, 100, 300, 400, 500, 800 meter. The ground based temperature measurements were collected and examined at 4 different time intervals: monthly average temperature for August 2009, instantaneous temperature on August 19, 2009; three-hour average temperature on August 19, 2009; and study period average temperature from June 13 - September 30, 2009.

	Concentric radii distances around monitoring point used to calculate an average LST					
	At Point (0 m)	100 meters	300 meters	400 meters	500 meters	800 meters
Monthly average temperatures monitored, month when satellite image was taken	-0.32 (0.17)	-0.24 (0.33)	-0.11 (0.64)	-0.068 (0.78)	-0.039 (0.87)	0.032 (0.89)
Instantaneous temperatures monitored, at the hour the satellite image was taken	-0.05 (0.82)	0.0026 (0.99)	0.17 (0.47)	0.22 (0.36)	0.22 (0.37)	0.25 (0.29)
Three hour average of temperatures monitored, the hour before up until the hour after the image was taken	-0.40 (0.08)	-0.35 (0.13)	-0.18 (0.44)	-0.13 (0.59)	-0.11 (0.65)	-0.085 (0.72)
Entire study period average of temperatures monitored, June 13 - September 30, 2009	-0.18 (0.44)	-0.15 (0.66)	-0.04 (0.86)	-0.02 (0.92)	-0.053 (0.83)	-0.075 (0.75)

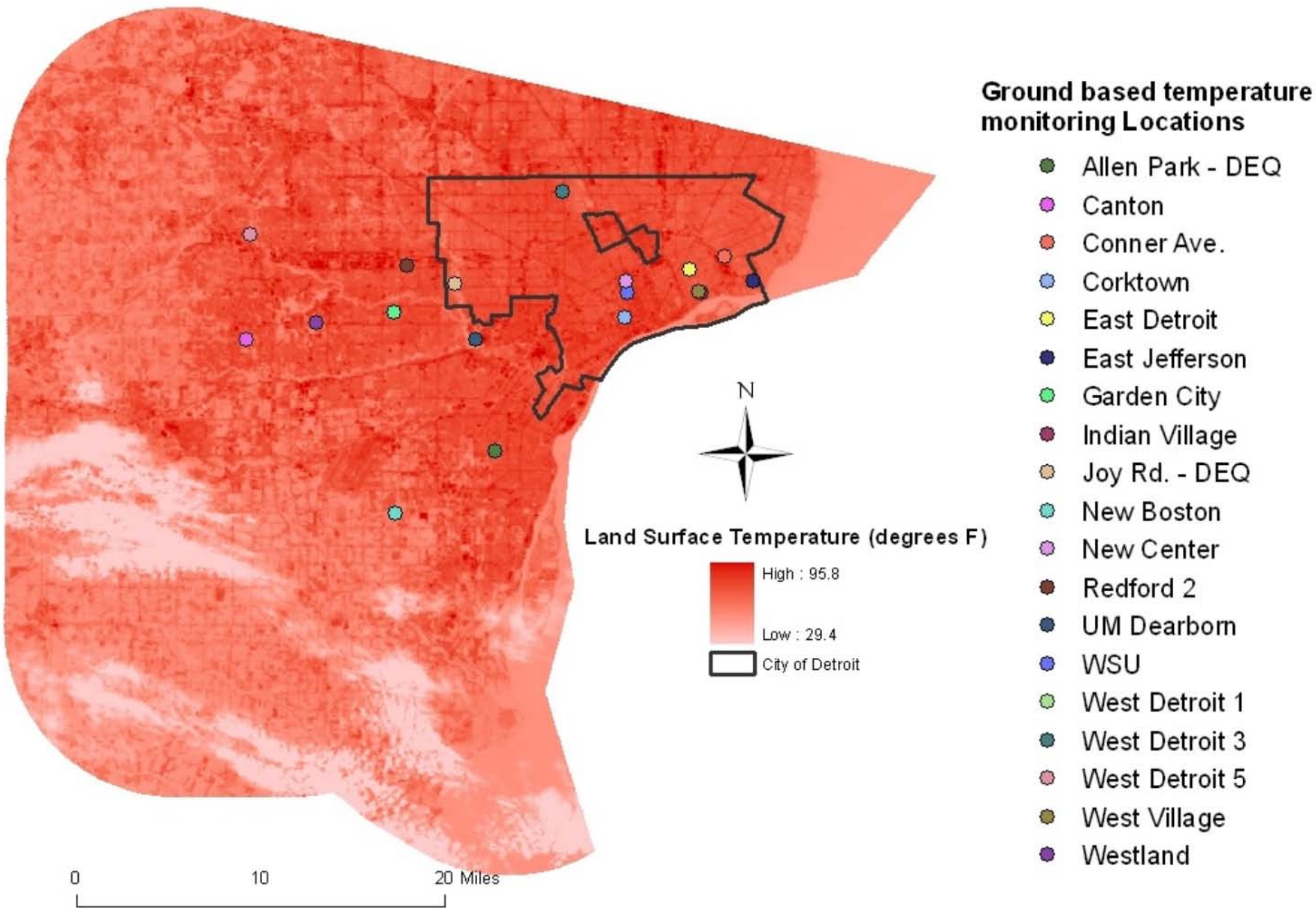


Figure 4-2 The final processed Landsat TM-5 satellite image that displays the satellite dervied land surface temperatures (LSTs) for the study area of Wayne County, Michigan. The city of Detroit is outlined. The 19 locations of the ground-based temperature monitoring network are also displayed.

Table 4-3: Spearman Rank Correlation Coefficients and corresponding p-values quantifying the relationship between satellite-derived land surface temperatures (LST) – from a Landsat TM-5 image captured on August 19, 2009 – compared with percent surface imperviousness (SI) for the study area of Wayne County, Michigan. Both LST and SI were calculated at 6 concentric radii around each monitoring points: 0, 100, 300, 400, 500, 800 meters.

Land Surface Temperature (LST) vs. Surface Imperviousness (SI) calculated at the following concentric radii:	Spearman Rank Correlation Coefficient (r) and p-value
0 meter (at the point)	0.31 (0.201)
100 meter	0.59 (0.0073)
300 meter	0.76 (0.0002)
400 meter	0.82 (<0.0001)
500 meter	0.86 (<0.0001)
800 meter	0.91 (<0.0001)

Chapter 5
Conclusion

5.1 Overview

The overall goal of this dissertation was to understand the structural, environmental and behavioral factors that can make the elderly and other vulnerable populations more susceptible to extreme heat and hot weather conditions in Detroit, Michigan. Figure 1 shows the factors evaluated in this study that can characterize and be attributed to populations that are most vulnerable to heat – housing, weather, environment, and personal adaptation practices. The results of this dissertation can provide information to create targeted interventions, build a sustainable heat response plan for urban areas, serve as a research model for other similar urban centers, identify the usability of tools for emergency response planning and serve as a research model.

Mathematical modeling, behavioral data, and the development of spatial maps were used to understand and quantify the factors that influence the indoor temperatures to which elderly residents of Detroit, Michigan are exposed. There have been limited studies related to indoor heat exposure and adaptation in general and specifically for the elderly (i.e. over 65 years of age). Additionally, there has also been limited research on examining validation methods for land surface temperatures to determine hot spots in urban area.

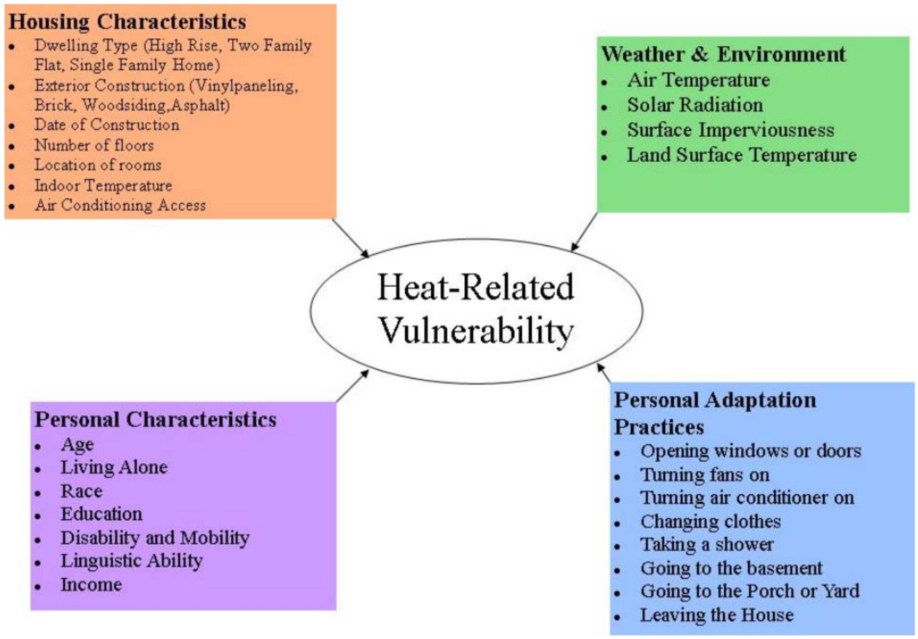


Figure 1: Characteristics that impact heat-related vulnerability that were studied in this dissertation

The outcomes of this research can be used by care givers, public health practitioners, urban planners, and emergency preparedness agencies to better prepare the elderly for extreme heat events.

5.2 Chapter 1: Indoor Temperature Modeling and Prediction

Understanding indoor temperatures that the elderly are exposed to is important from a health perspective. A large number of senior citizens spend the majority of their time inside their homes because they are not easily mobile, they are concerned about health and safety, they have no means of transportation, and/or they are not engaged in many activities outside of the home. Indoor temperature monitors were installed and monitored temperatures in two rooms of 30 participant homes in the city of Detroit during the summer of 2009. The two rooms chosen were rooms that were most frequently used by the occupant. No studies, to our knowledge, have recorded indoor temperature of occupied residences for a 3 month period to evaluate indoor temperatures for a health-based, epidemiological purpose.

We created a mathematical model that was used to better understand which homes would put senior citizens more at risk during extreme heat events. Our statistical model generated effect estimates for each of the four prediction parameters included in the model: solar radiation, outdoor temperature, previous indoor temperature and dew point. Basically, the larger the effect estimate, the more likely indoor temperatures will change based on a change in one of the prediction parameters. Our findings show the following: 1) Effect estimates for homes with an exterior construction of vinyl paneling or wood-siding were more sensitive to outdoor temperatures changes and internal heat gains; 2) Homes without central air conditioning were more sensitive to outdoor temperatures and solar radiation; 3)The highest temperatures were seen in homes that were surrounding by other residences, versus being surrounding by concrete, yards and urban areas, like business districts and 4) Single family homes and two-family flats were more sensitive to outdoor temperatures than high rise apartments. The latter is a surprising finding because historically, elderly persons living in high rise apartments were more likely to die from heat in the Chicago heat wave of 1995 and the heat wave in Europe of 2003.

5.2.1 Research Application and Translation

Although the indoor temperature model was developed and tested using data captured from homes in the city of Detroit, this model can be applied to any urban area to explore the relationship between ambient and indoor temperature exposure. The model can be used to meet the unique characteristics of different urban areas. For example, to model indoor temperatures of homes in the city of Detroit, we used the following prediction parameters: ambient temperature, solar radiation, dewpoint temperature and previous indoor temperature. However, in a place like Denver, Colorado, other prediction variables might need to be included in the model, such as elevation, which could affect the temperatures experienced by different homes.

Using the data acquired during our study, we were able to create realistic and accurate predictions of indoor temperature based on the principles of building physics and a home energy balance. The ability to predict indoor temperatures of residences can provide the information needed to create interventions and planning for extreme weather events. For example, federal government financial resources are being used to help make homes better suited to handle extreme cold and extremely hot temperatures, called weatherization.   Weatherization consists of making residences energy efficient, which includes adding insulation, weather stripping, replacing windows and glass and energy audits. Some weatherization programs are targeted to be implemented in the homes of the elderly, the handicapped and the low-income. Consequently, our prediction model could be used to identify those homes that should be weatherized, especially those occupied by the elderly, that continue to exceed the typical indoor comfort temperature range of 70- 75°F.

From an urban planning perspective, geographic information systems (GIS) can be used to create maps with layers of data that will inform urban planning policies and decisions. For example, a map could graphically depict the locations of homes that need to be weatherized, along with other demographic data (age, race, income) and environmental data (surface imperviousness, weather, electricity use). The completed map would be a resource for future development options as well as future heat mitigation efforts, such as landscaping, tree planting and other means of naturally minimizing the urban heat island effect.

5.2.2 Enhancing the Research

While the full indoor temperature exposure model resulted in a strong correlation between actual and predicted temperatures, there are many ways that this model could be expanded. With a larger sample size, more independent variables related to environmental factors could be included, such as wind speed, and surface imperviousness. Additionally, various home characteristics such as insulation, roof type and window coverings could be helpful in getting a better understanding of the influence of the built structure. More predictor variables could enhance prediction power, as well as evaluate how different heat mitigation strategies can reduce indoor temperatures.

The goal of the first part of this study was to fill gaps in knowledge about how the built environment and meteorological factors may affect indoor heat exposure among elderly and at risk populations. We believe that this modeling approach can serve as the foundation for future studies that are working to quantify exposures due to extreme weather conditions, as well as understand the characteristics of specific homes that can enhance the potential negative health impacts on vulnerable populations.

5.3 Chapter 2: Assessing heat-adaptive behaviors

This chapter explored the predominant behaviors that elderly people used to adapt to hot indoor temperatures, and described the relationship between the use of these adaptive behavior and two characteristics: percent surface imperviousness and residency type (high rise, two-family flat, and single family). Overall, this study showed that there were fewer adaptive behaviors being used at indoor temperatures above 90°F. However, residents living in high rise buildings used more behaviors, compared to residents living in single family homes and two family flats. More behavior use was also evidenced in homes located in highly impervious (areas with a higher percentage of surfaces impenetrable by water) areas of the city. Additionally, the odds of the residents engaging in adaptive behavior were found to be higher during the 81-85°F temperature range, compared to the reference temperature range of 70-75°F. The 99th percentile and mean temperatures for the summer of 2009 (including the months June 1 – August 31, 2009) were 31.11°C and 20.98°C, respectively, slightly cooler than the 99th percentile temperature and mean temperature from the years 1979 to 2008, which were 32.77°C and 21.83°C, respectively. However, we believe that the use of adaptive behaviors might have increased if the summer of 2009 was significantly warmer.

One of the challenges with this specific investigation was depending on the residents for accurate and frequent coding of their adaptive behaviors in the daily activity log. However, this challenge made this study unique, in that personal activity data was collected over a 3 month period, longer than for any other heat-related epidemiological study, to our knowledge. A complete understanding of these heat-adaptive behaviors can help direct interventions for certain populations, as well as address mitigation strategies (e.g. tree planting, home weatherization) for certain urban areas.

5.3.1 Future research questions

While it was important to understand the frequency and type of behaviors an elderly population engaged in to keep cool in their homes, this research uncovered other important questions that need investigation. The first question involves understanding and documenting the type of heat-generating activities the elderly engage in their homes, as well as when they decide to engage in those activities. For example, we witnessed some of the participants cooking food and/or cleaning during the warmest times of the day. These types of activities can increase indoor temperatures and increase the risk of unhealthy heat exposure. Having an understanding of these activities can provide useful information for public health practitioners and other senior service providers to help craft education around the healthy habits seniors should engage in (e.g. staying hydrated, keeping the home ventilated) – or what they should not do (e.g. cooking, cleaning, dusting, using intense lighting) during extremely hot weather.

Another extension of this research would involve surveying participants about their pre-existing medical conditions and physiological reactions to heat. Capturing personal physiological data would fill a large knowledge gap that could aid medical health professionals, visiting home physicians, public health practitioners and caregivers with data that could directly address the special needs of elderly, isolated, less-mobile populations to facilitate intervention and education during heat waves.

What motivates people to adapt or not adapt is an area of study that has been little explored in public health and environmental epidemiology. I recommend that future studies on adaptation and behaviors delve deeper into what motivates people to engage in those adaptive behaviors – is it physiological (sweating, dehydration), or driven by other non-physiological factors, such as outdoor temperature, motivation from family or a caregiver, lack of resources or access to resources for cooling (e.g. fans, air conditioning), or public health messages and warnings from the media.

The understanding of health and health behavior we have gained from our elderly sample population for heat-related health effects could be translated into understanding behavior or the lack of engagement in other areas of public health – such as seeking medical attention, taking medication, and engaging in other health-promoting activities. The findings from our characterization of adaptive behaviors used by the elderly can inform how public health practitioners, caregivers and those in the medical field should approach and educate the elderly population on general health issues.

5.4 Chapter 3: Using satellite data to characterize urban hot spots

The main objective of the third chapter was to perform a ground-truthing exercise in the city of Detroit by comparing temperatures derived from satellite images (LST), percent surface imperviousness (SI) and temperatures logged by a ground-based temperature monitoring network (GBT network). All three items have been used historically to characterize the potential for urban heat islands or "hot spots" in an urban area. We calculated correlation coefficients to compare the strength of the relationship between each of the following measurements: 1) LST temps vs. GBT network; 2) LST temps vs. SI, and 3) SI vs. GBT network. While we expected that the data would have shown stronger correlations between all three parameters, that was not the case. This ground-truthing exercise was important because if we can capture information on the spatial, ground-level heat structure of a heterogeneous environment like a city with a publicly available, free data source like downloaded satellite thermal images from the Landsat TM-5 satellite, it would eliminate the need to deploy hundreds of temperature monitors around a city. This measure of ground level exposure could be useful for quantifying urban hot spots at a finer spatial scale. As mentioned before, understanding the amount of exposure is key to developing heat response plans to protect vulnerable populations. This again, could be another data layer added to a GIS generated map used by emergency response planners, public health practitioners and others.

Before satellite derived land surface temperatures are used for exposure studies, some limitations need to be addressed. The small number of high quality images and coarse resolution of the Landsat TM-5 satellite images limit the amount data available for processing. This was a significant limitation for our study, as only 1 out of 21 images were usable. Additional ground-truthing exercises are needed to prove that the satellite images can provide a true picture of ground –level exposure, specifically for urban areas. Our research provides the motivation to fill these research gaps so we can arrive at a better measure of temperature exposure for the field of environmental epidemiology.

The remote sensing community, along with the public health community, should discuss how satellite data sources and similar technology can be useful in public health practice. We also recommend that access and the frequency of spatial data be improved.

This study shows that there are several needs for public health practitioners to utilize this data source. First, satellite images with a finer resolution (< 30 meters) are needed to compare exposure at the home-level, versus the neighborhood level. There is also a need to capture images of the earth at a higher frequency than every 16 days. Capturing an image twice a day (night and day image) could provide a useful comparison of night-time lows and daily high temperatures that are usually indicative of oppressive weather conditions that exacerbate heat related morbidity and mortality, especially in urban areas.

Our findings suggest that further evaluation of the usefulness of satellite-derived LST images, corrected for atmospheric effects and emissivity is needed. Furthermore, our findings indicate that one image would not be suitable to use as an indicator of air temperature for heat exposure studies in the Wayne County, Michigan. The one image we used to evaluate fine scale spatial variations in heat exposure across such an urban area might not be sufficient to draw conclusions on whether this data sources is suitable for widespread use. Therefore, knowledge gaps need to be filled with future studies on the use of satellite images, mapping heat exposure and ground-truthing in urban areas.

5.5 Strengths and Limitations

The major strength of this research is that no studies, to our knowledge, have evaluated indoor temperature exposure during the summer time, in the field of environmental (heat) epidemiology, over a three month period. Especially for the Detroit-area, the use of demographic data sources as well as data that provides an understanding of potential urban heat islands, has not been examined, using a spatial analysis platform. While there were limitations with data sources and availability, overall, the results of this study will help guide public health interventions and programming directly related to those populations who are homebound, isolated, poor and/or old; and our research may inform building design strategies and policies to improve the comfort and care for our elderly populations.

5.6 Implications and conclusions for public health practice

This dissertation added new insight on indoor heat exposures among senior citizens, provided a localized perspective on issues unique to the Detroit area, used multi-disciplinary methods to understand new dimensions of heat-health issues and strengthened the science to document the potential climate justice concerns in the Detroit metropolitan area.

We have learned that senior citizens and their caregivers would benefit from general information on how to stay healthy in hot weather, inclusive of the proper nutrition and eating habits and adaptive behaviors (i.e. showering, changing clothes, etc.). For example, increasing education and understanding when your body is ‘too hot’, or understanding how certain medications can increase your heat-related health risks is needed. Also, educating people on how to use stand-alone fans correctly for cooling in the home (i.e. use when the windows are open in temperatures below 90°F) is critical.

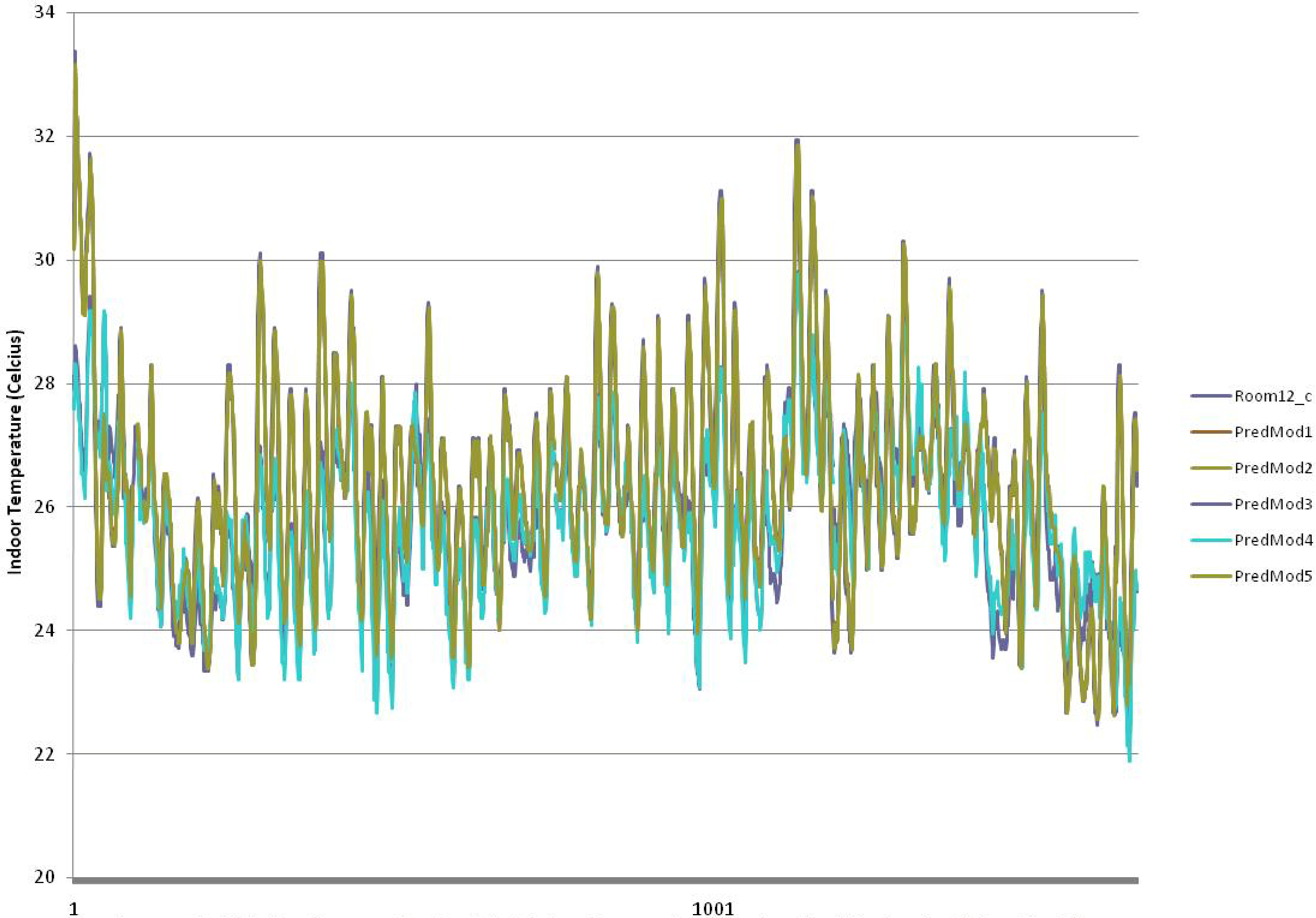
Building collaborations with senior service agencies and other institutions that serve vulnerable populations – such as churches, community centers and shelters – would be a useful conduit to deploy general heat/health educational resources and tools to these communities. Sharing the findings from this study, as well as other studies, could encourage community leaders to advocate for policies that can increase the weather-resilience of the current building stock, especially for senior citizens. Weatherization programs for seniors' housing – high rise apartments, as well as single family homes – would help mitigate some of the effects of the urban heat island.

Additionally, financial concerns (affording electricity for cooling), security concerns (i.e. not opening windows for fear of a break-in, etc.) are other factors that policy and programs can start to address. In terms of direct intervention and planning efforts, coupling geographic information systems and multiple data sets can provide a powerful tool that can be used to target vulnerable populations. Having a central portal of timely demographic, socioeconomic, structural and environmental data for use by practitioners can be helpful for creating strategies to protect the most vulnerable populations in an urban city. While some of the satellite derived data could be helpful, access and functionality might limit its usefulness for a public health practitioner. However, this data, when available and processed correctly, could be powerful and helpful for identifying city hot-spots. While resources at the city and county health department level might be limited to apply some of these data sources to heat related health planning, we hope that our study will also encourage useful collaborations between academia and the public sector that can better serve the populations in need.

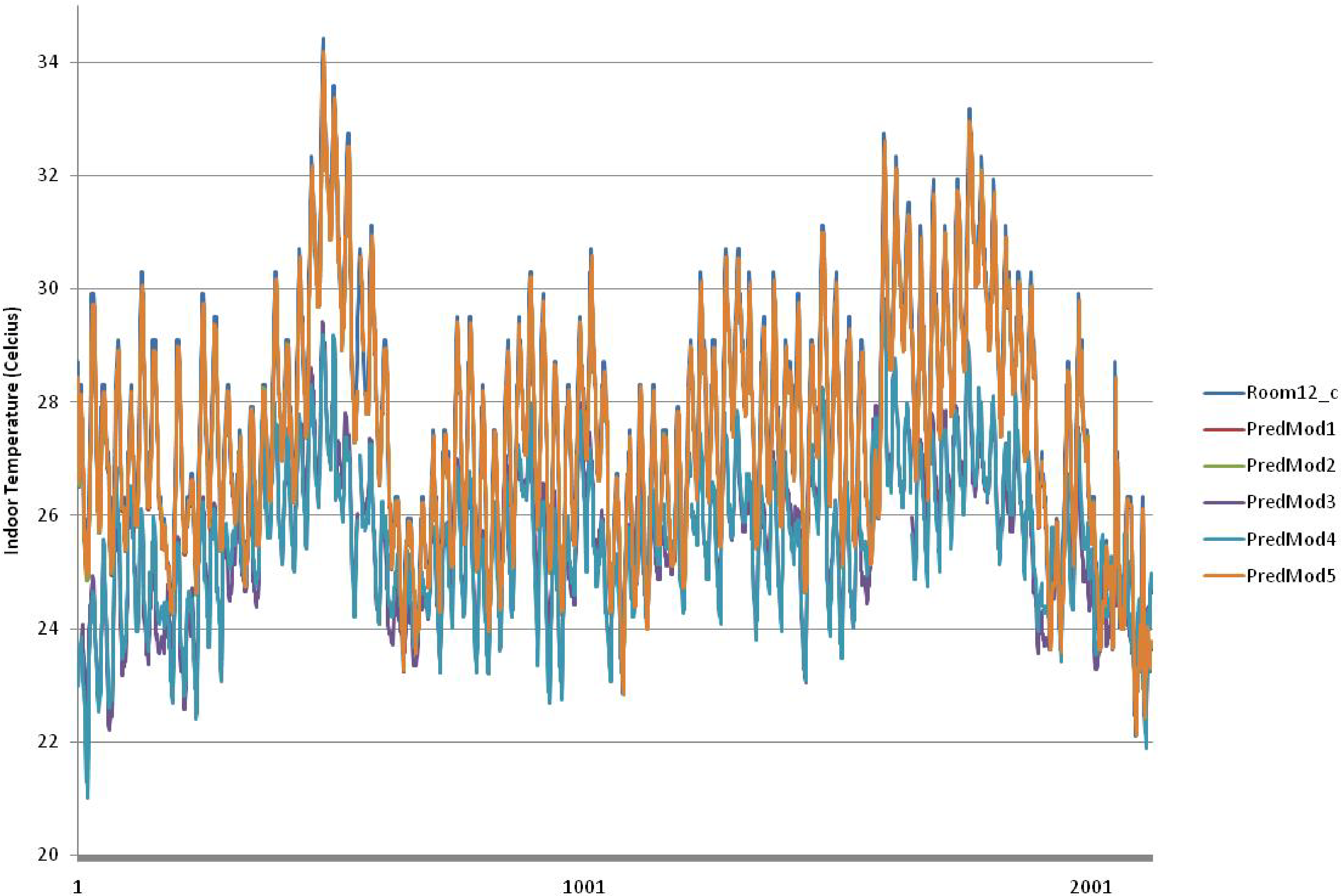
Appendices

Appendix 2.1 – 2.6

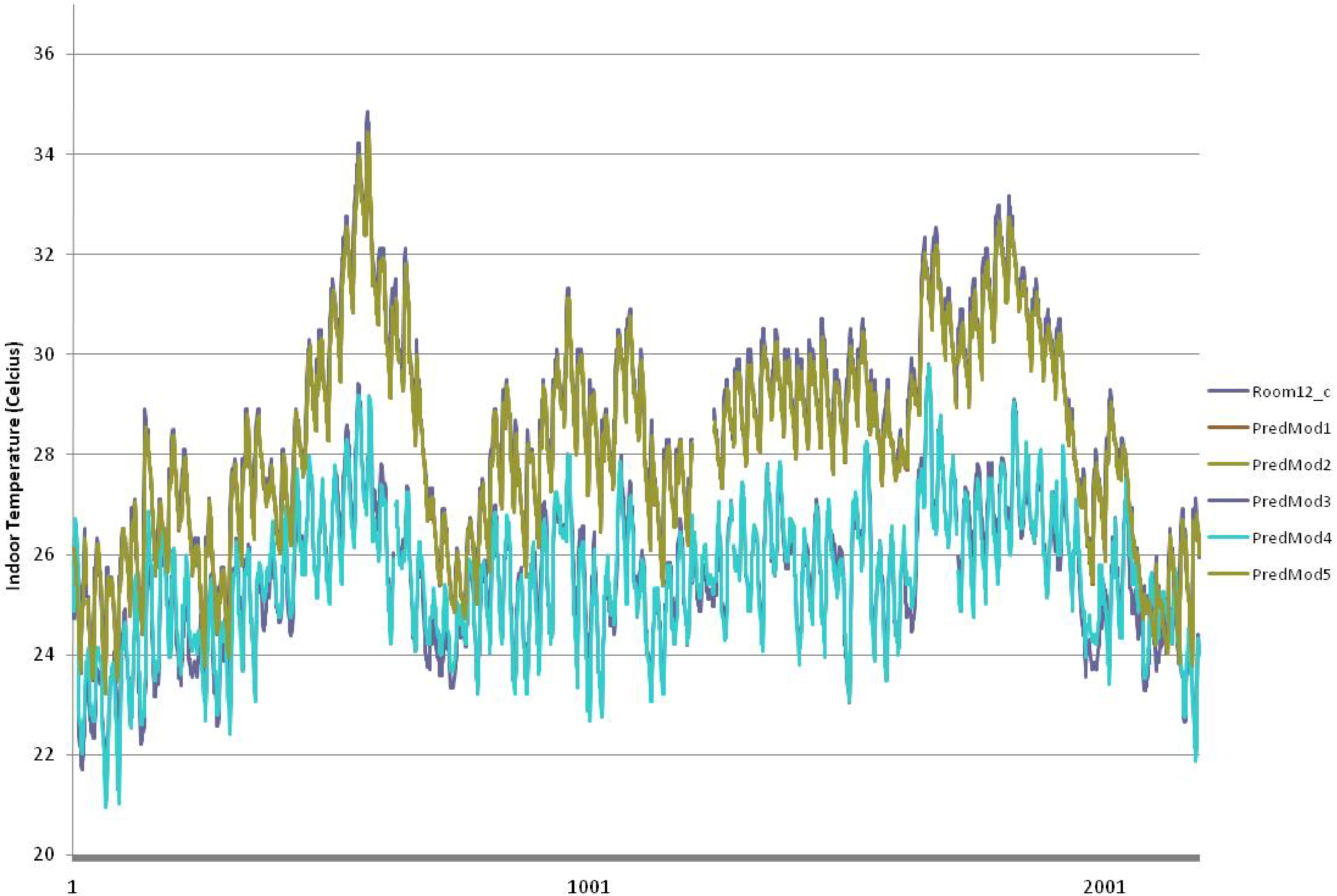
Graphs comparing predicted indoor temperatures for various volunteer locations using prediction modeling equations



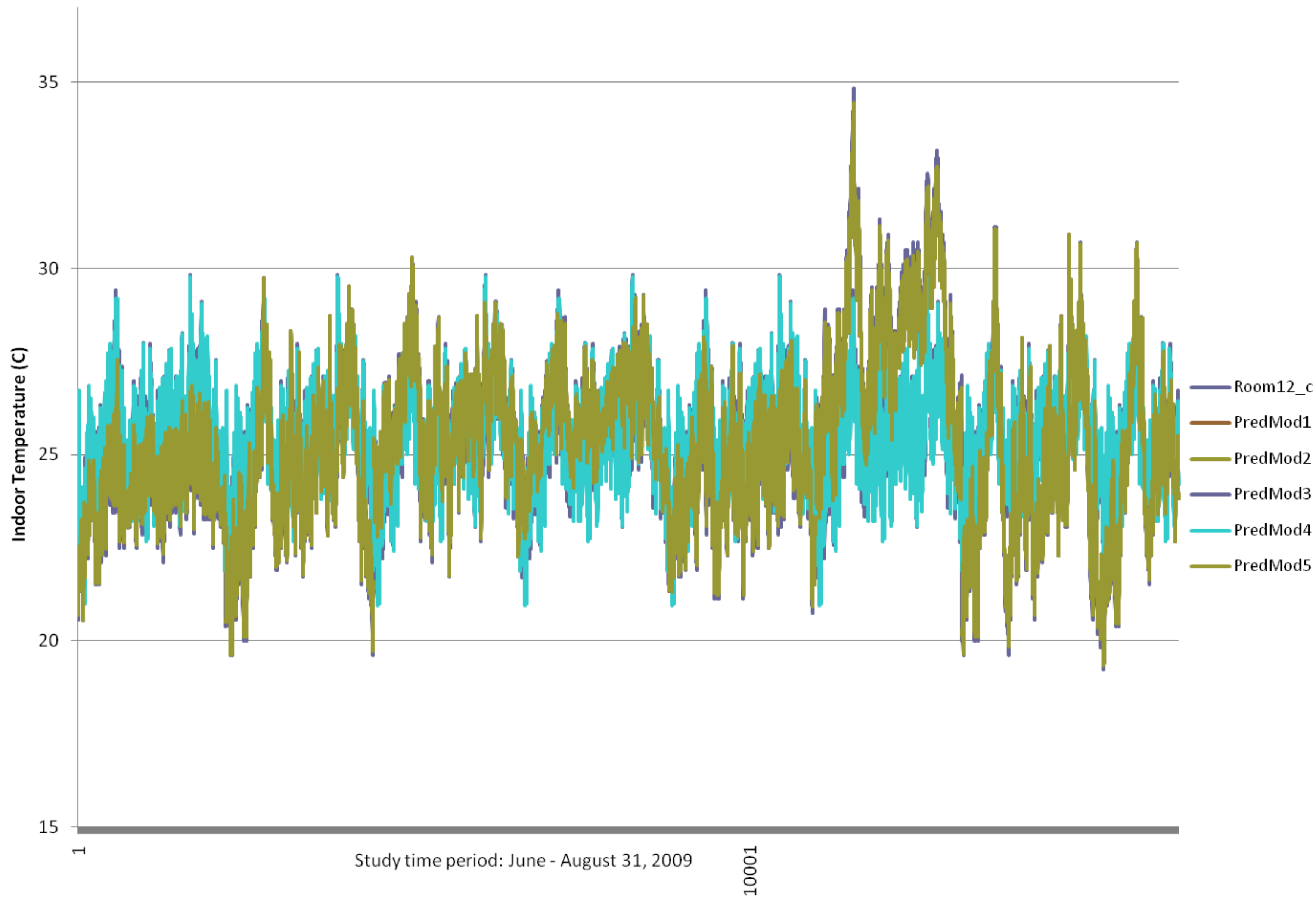
Apppendix A2.1: Graph comparing Predicted Indoor Temperatures for Location 26 using Prediction Modeling equations



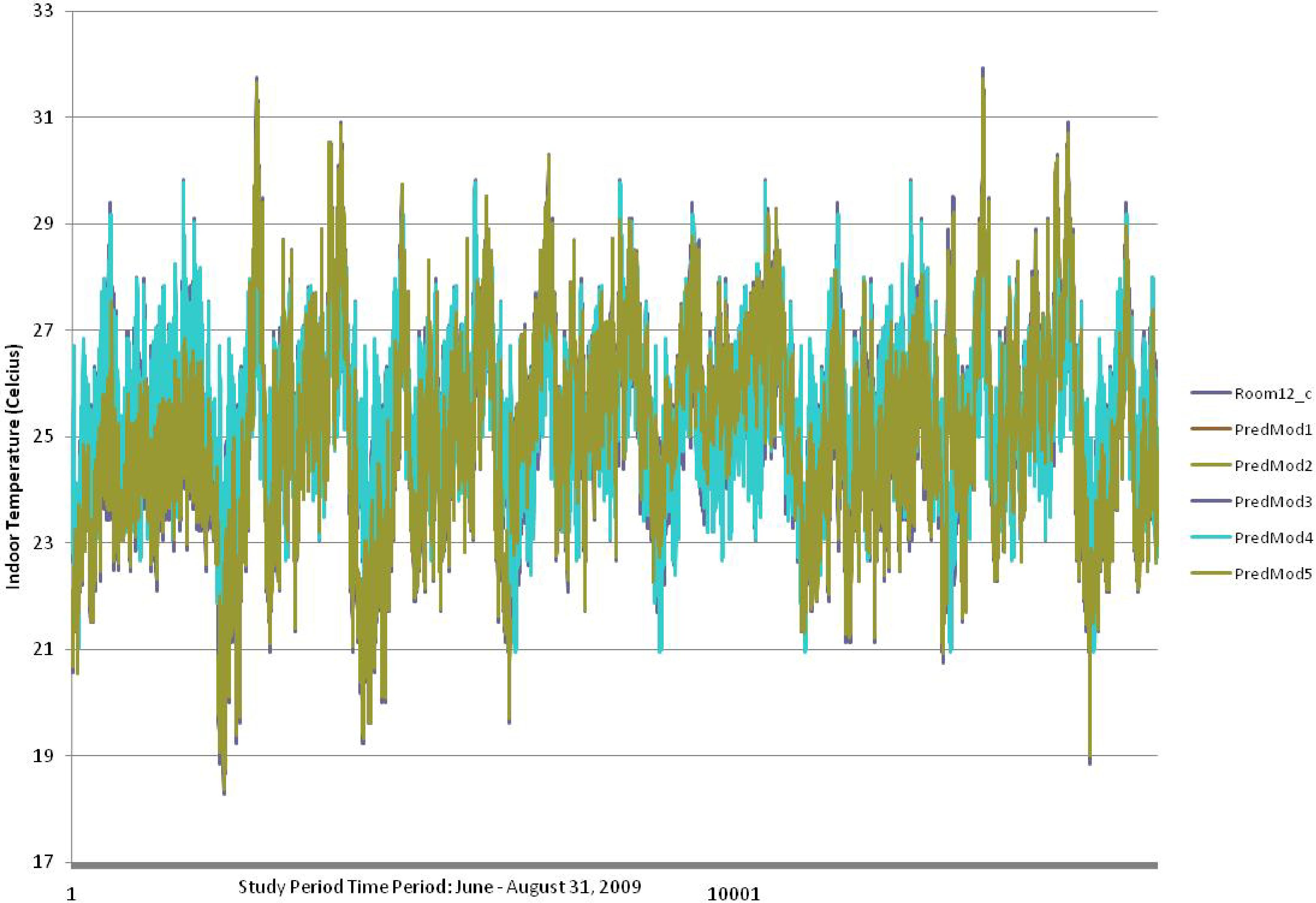
Appendix A2.2: Graph comparing predicted indoor temperatures for Location 13 using prediction modeling equations



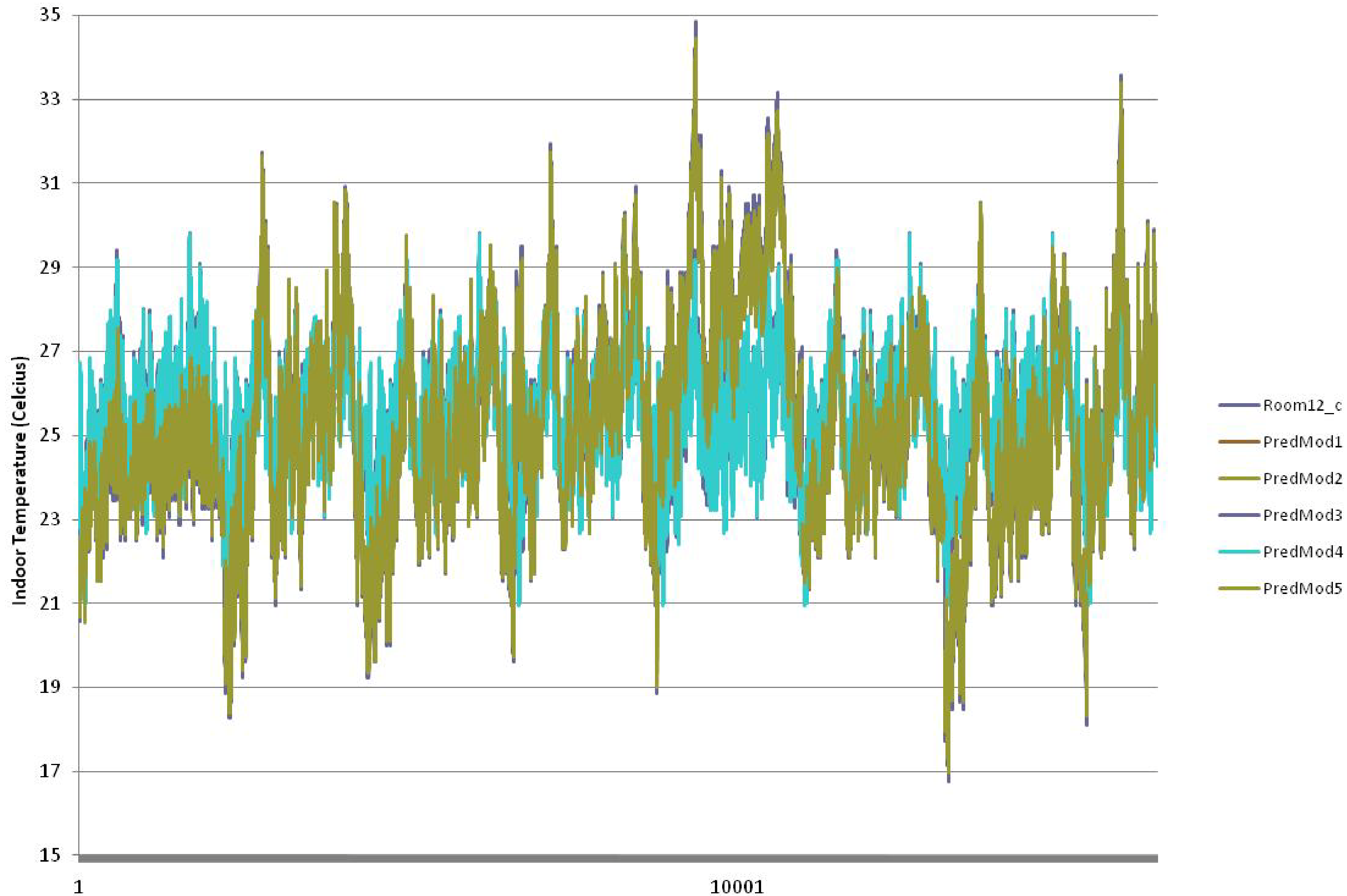
Appendix A2.3: Graph comparing predicted indoor temperatures for Location 8 using prediction modeling equations



Appendix A2:4 Graph comparing predicted indoor temperatures for locations with Air conditioning using prediction modeling equations



Appendix A2.5 Graph comparing predicted indoor temperatures for locations constructed of brick using prediction modeling equations.



Appendix A2.6: Graph comparing predicted indoor temperatures for non-high rise type homes using prediction modeling equations

Appendix 2.7 Indoor Heat Exposure Protocol Handbook

Climate change and assessment of Indoor Heat Exposure of the Vulnerable and Elderly Populations in Wayne County, Michigan
Protocol Handbook

July 13, 2009

Table of Contents

1.0 Project Summary

The purpose of this project is to determine if a robust model can be developed to determine indoor temperatures, during hot weather, based on building stock, ecological characteristics (how much land is covered by vegetation versus concrete, buildings or paving) and weather conditions in Southeastern Michigan. I propose to answer this question by conducting an exposure assessment to evaluate determinants of heat exposure during the summer months (approximately three months) from June – September 2008 for elderly residents of Wayne County, Michigan. The assessment will use direct measurements from environmental monitoring of selected dwellings that represent a variety of dwelling types found in Wayne County. HOBOS, which are automatic continuous temperature monitors, will be placed inside as well as outside each home. Each device will be pre-tested to determine accuracy before being deployed in the field.

I will compare outdoor temperature measurements and housing characteristics including as date of construction, type of insulation, and number of floors for each dwelling. I am interested in understanding what building features can increase the risk of overheating for vulnerable populations. This type of information can aid in intervention by recognizing what building types to target in addition to targeting population groups (elderly, shut-ins, etc) already considered to be vulnerable to heat.

Anticipated Results

This study will provide initial insight into dwelling and environmental factors that affect indoor heat exposure in the region of southeastern Michigan. Based on the sample dwellings that I anticipate will be included in the study, I believe that indoor temperatures will be higher in areas of the county that are more dense (with population and buildings) despite the modified effect from housing factors. I believe that the older the housing stock will have higher thermal mass and hold in more heat. This increased heat capacity will result in a higher 3 day average temperature than housing stock that was constructed more recently. I expect the model to reveal that indoor temperatures will be highly correlated with outdoor temperatures, level of insulation, # of floors and poverty level.

Conclusion

Variations in and determinants of indoor heat exposure in private residences is a facet of environmental epidemiology that has not been well studied. Being able to create a robust model that can provide better insight into parameters – meteorological, ecological and building characteristics – that can affect exposure is useful. This type of information would be especially useful for targeting public health interventions directly related to those elderly populations that are homebound, lonely and isolated, poor and/or old. Studies of the European heat wave of 2003 and the Chicago Heat Wave of 2005 have shown that the elderly can be more susceptible to heat related illnesses and death. Although this proposed exposure assessment study in Southeastern Michigan does not incorporate any health related endpoints, the results may inform building design strategies, improve our understanding of current exposure in residences, as well a provide data to refine our targeting of vulnerable populations for heat related illnesses and mortality.

2.0 Background and Significance

A significant number of deaths are caused by heat in the United States. Excessive heat, extreme heat or heat waves can be generally defined as "extended periods of unusually high-atmospheric related heat-stress, which causes temporary modification in lifestyle and which may have adverse health consequences for the affected population."(Robinson 2000) Heat exposure has caused 8,015 deaths in the United States from 1979-2003(Centers for Disease Control and Prevention 2003) During this same time period, "more people in this country died from extreme heat than from hurricanes, lightning, tornadoes, floods, and earthquakes combined." (Centers for Disease Control and Prevention 2008) Numerous heat waves have occurred in the Midwestern United States, including Illinois in 1995 and 1999; Ohio in 1999; Wisconsin in 1995 and Missouri in 1998.(Centers for Disease Control and Prevention 1996; Centers for Disease Control and Prevention 1999; Centers for Disease Control and Prevention 2000; Centers for Disease Control and Prevention 2003) Due to the large numbers of heat related deaths, public health researchers and scientists have realized that long term climate change could be important for future risk assessments as the average temperature of the globe increases.

Research Rationale

Heat related mortality and its prevention have not been adequately studied in Southeastern Michigan. A total of seven studies found involve Detroit and heat-related mortality.(Chestnut, Breffle et al. 1998; Kalkstein and Davis 1998; Braga, Zanobetti et al. 2001; O'Neill, Zanobetti et al. 2003; Davis, Knappenberger et al. 2004; O'Neill, Zanobetti et al. 2005; Kalkstein, Greene et al. 2008) From these eight studies relevant to the southeastern Michigan region, the key findings include:

1) Access to air conditioning, and/or correlated socioeconomic conditions, may explain the differences in heat related mortality amongst various racial groups, (O'Neill, Zanobetti et al. 2005)
2) the risk of dying on hot days for elderly persons in Wayne County is greater among people who are nonwhite and have pre-existing medical conditions, especially diabetes (Schwartz 2005)
3) climate change will more than double the average of heat related deaths in Detroit by the middle of the 21st century (Kalkstein and Greene 2007)

A recent literature review showed that risk factors for heat wave vulnerability include age, disability, poverty and housing. (Kovats and Hajat 2008) The travel-restricted elderly are a special population at risk. Being confined to bed, not leaving home daily, and being unable to care for oneself were found to be associated with the highest risk of illness during a heat wave. One study of an August 2003 French heat wave reviewed the risk factors for death of elderly persons (age 65 or older) living at home. In addition to the aforementioned characteristics, other risk factors identified as significant include housing conditions, environmental factors (lack of green space around the housing complex or amount of impervious surfaces (i.e. concrete) and behavioral factors, such as not dressing lightly, and not using cooling devices.(Vandentorren, Bretin et al. 2006) Additionally, according to the Environmental Protection Agency, people spend approximately 90 percent of their time indoors. (Environmental Protection Agency 2009)

Groups of people, including the young, the elderly, and the chronically ill, especially those suffering from respiratory or cardiovascular disease, that spend more time at home, could be at a higher risk of health affects from not only air pollution, but the inability to adapt or recognize the potential of heat related illnesses.

Benefits to Society

Indoor heat exposure is a facet of environmental epidemiology that has not been well studied as it relates to personal residences. Being able to create a robust model that can provide better insight into parameters – meteorological, ecological and building characteristics – that can affect exposure is useful. This type of information would be especially useful for targeting public health interventions directly related to those elderly populations that are homebound, lonely and isolated, poor and/or old. Studies have shown, as evidenced by the European heat wave of 2003 and the Chicago Heat Wave of 2005 that the elderly can be more susceptible to heat related illnesses and death. Although this assessment does not incorporate any health related endpoints, it is my hope that this exposure assessment provide a technique that can be used to impact building design strategies, assess current exposure in residences, as well a provide a method to target vulnerable populations for heat related illnesses and mortality.

3.0 Overview of Aims

I will have three directed aims in order to answer my research question.

<u>Aim 1: Study site and volunteer selection</u>
20 – 25 homes in the population dense area of Wayne County will be targeted for the exposure assessment and must meet at least one the three main selection criteria: (1) that each dwelling is occupied by a person over 64 years of age, (2) that each dwelling has no or limited air conditioning, and (3) that each dwelling has more than two floors and/or considered a high rise.

Volunteers selection will be handled using a convenience sampling method, which depends on leveraging existing relationships and collaborations with local agencies on aging, as well as family, friends, and existing organizations or clubs where the targeted membership are those over 64 years of age.

<u>Aim 2: Collection of Temperature Data</u>
Automatic temperature loggers will be placed inside each home and in participant yards (where feasible) to continuously collect temperature data. Each logger will record temperatures every 30 minutes. Each logger will be positioned according to a standard protocol that will be used for each study site. I will use this temperature data to estimate the peak exposure (peak exposure: the highest temperature of the week and take a three day average to determine the highest indoor temperature based on readings) of individuals in different home settings.

At least one temperature logger or more will be placed inside the home. Where possible, temperature loggers will be placed (1) in the room that is most used by the resident, (2) in one of the bedrooms, (3) in a room with direct sunlight into the room, and (4) on all floors of the residence, not including the first floor and the basement.

Aim 3: Collection of Behavioral Data and Home Characteristics
Two additional survey tools will be used to gather the data: (1) A Time-Activity Log, (2) Housing & Ecological Characteristics Survey. Each tool will capture other useful data that can be used to build the model to estimate indoor temperatures.

Behavioral data on how people behave and adapt to hot weather will be captured in a time activity log. Each resident will record, during the entire study period, the ways they use to alleviate any discomfort due to hot temperatures inside the home. This will be recorded per event.

Characteristics of the home will also be captured at the beginning of the survey period. The age of the home, number of rooms, color of the walls, and other data will recorded.

4.0 Project Team

Jalonne White-Newsome, Principal Investigator
Jalonne White-Newsome is a 2nd year doctoral candidate in the School of Public Health. She has completed all required coursework for environmental health sciences curriculum as well as has helped with regional projects , related to heat related mortality, lead by Dr. O'Neill. She conducted field work related to a similar grant during the Summer of 2008 related to heat and health in Southeastern Michigan

Dr. Marie O'Neill, Faculty Advisor
Dr. Marie O'Neill's is a jointly appointed professor in Environmental Health Sciences and Epidemiology departments of the School of Public Health. O'Neill leads several collaborative project groups on heat and health related research. She has published articles and presented significant findings on heat related epidemiology. Her research interests include health effects of air pollution, temperature extremes and climate change (mortality, asthma, hospital admissions, and cardiovascular endpoints); environmental exposure assessment; and socio-economic influences on health.

Dr. Edith Parker, Co-Investigator
Dr. Parker's research focuses on the development, implementation and evaluation of community-based participatory interventions to improve health status. Her current research is focused primarily in Detroit, Michigan, where she is involved in community-based participatory research projects focusing on women's and children's health and on childhood asthma and issues of environmental justice. Dr. Parker's work also focuses on methods of better understanding and operationalizing measures of community social dynamics, such as community capacity an community competence.

Dr. Joseph Dvonch, Co-Investigator
Dr. Tim Dvonch work focuses on the exposure assessment, source identification, and health effects of air pollutants. He collaborates on several other large multi-disciplinary projects focused on environmental exposures and their related effects on health.

Miatta Buxton, Study Coordinator/Project Manager
Ms. Miatta Buxton is currently working as a project coordinator working with Dr. O'Neill for two grants, one specifically focused on a qualitative review of heat and health in four cities. Miatta is an epidemiologist that has provided insight and organization to several projects within the School of Public Health.

Jacquelyn Hayes, Research Assistant
Recent graduate of the School of Public Health Master's program in Environmental Health Sciences.
Melissa Seaton, Research Assistant
Undegraduate student studying Environmental Sciences.

Ardele Stewart, Materials Assistant

5.0 Project Resources

The Graham Environmental Sustainability Institute provides financial support for the following;

- Monitoring equipment and supplies
- Time and labor for research assistants
- Mileage reimbursement for volunteer visitation
- Volunteer compensation

The actual temperature monitoring devices were borrowed from Dr. Audrey Smargiassi of the Quebec Institute of Public Health/University of Montreal, Montreal, QC, Canada

6.0 Recruitment

Potential study subjects will be recruited by members of the study team immediately after IRB approval is received. For this study, I am particularly interested in the indoor exposure to heat experienced by persons over 64 years of age, particularly in homes that do not have air conditioning. However, I will not exclude homes with air conditioning because there could still be exposure that needs to be measured due to the inefficiency of air conditioning or spot-cooling used in some homes, especially without a central air conditioning unit.

Volunteer recruitment will be handled using a convenience sampling method, which depends on leveraging existing relationships and collaborations with local agencies on aging, as well as family, friends, and existing organizations or clubs where the targeted membership are those over 64 years of age. The recruitment strategy involves

3 steps: a) targeting existing agencies and organizations, b) utilizing existing personal and professional contacts, and c) grass roots campaign handing out fliers in neighborhood locations.

As a first step, I will contact the following organizations – Meals on Wheels Program for Wayne County, Detroit Area Agency on Aging and Adult-Well Being Services. I will identify a possible contact and set-up a face-to-face meeting to discuss the study objectives and goals. Based on that meeting, I will provide a hard-copy of the project description as well offer to talk to a focus group of seniors if that can be arranged. I will next target community centers with senior citizen programs and possibly 4 to 5 local churches in the dense areas of the county, or located near a senior high rise building or a community center. The outreach will be conducted in the same manner.

The PI or a designated team member will conduct all recruitment efforts. The recruitment methods described above will take place over the phone, email or face to face with the target agencies. Because the study period will begin June 1, 2009, the recruitment period will end on June 1st as well.

The target population for this study is senior citizens over 64 years of age, and residing in Wayne County, Michigan, in a home, apartment building or any type of dwelling that may or may not have air conditioning. The recruitment strategy involves using existing agencies that provide services and resources for senior citizens in Wayne County as a center for pooling volunteers. This strategy allows us to target the population needed for our study, as well provide an equitable arrangement for anyone willing to participate in the study.

Participant contact information will only be used by one member of the study team. This is to protect privacy.

Participant Benefits

Upon the completion of the study, volunteers will receive fact sheets and a list of local resources related to heat and health awareness. A member of the research team will also review the study data as well as any significant findings related to the study population with the participants. The results of this study will also be shared with local agencies to help direct programming and interventions to those that are most vulnerable in the population.

Volunteers will also receive a $10 gift card after completing two weeks of the study period. Every two weeks a member of the research team will be checking on the monitors, downloading data and reviewing that the activity log is being completed daily.

Upon completion of the study and once the data has been analyzed, a follow-up thank you letter, as well as the significant findings and recommendations will be shared with each participant (in person when possible).

Any articles and publications produced will be mailed to all participants.

7.0 Data Security

Every reasonable precaution will be taken to protect the confidentiality of study participants. Several procedures will be used to ensure confidentiality of information collected throughout the project. All hard copies of the survey tools will be stored in a locked file cabinet in the School of Public Health at the University of Michigan, accessible only to members of the research staff under the supervision of the Principal Investigator. Each home and participant will be assigned a code number at the beginning of the project and all temperature data will be entered under the code number in an aggregated file that is accessible only to the data manager. In addition to the data files, a hard copy of the names matching the identification numbers will be kept in a lock file drawer in the Principal Investigator's office.

The temperature data will be housed on a secure, password protected project computer for access for analysis using a statistical software package.

The name and telephone of each subject will be collected and only used as contact information during the study period to schedule visits. Once the study period is complete, this information will be destroyed and not be linked to the data that will be used for analysis (i.e. the data captured by the two survey instruments (1) Time Activity Log, and (2) Housing and Ecological Characteristics Survey.

The necessity for collecting data linked to subject identities is because the address of the dwelling will be linked to the behavioral responses collected on the Time Activity Log by the resident of that dwelling. We are not interested in personal, directly identifiable information, only general behavior information (activities) that we are studying that could be related to the housing characteristics and influence certain behaviors during hot weather.

8.0 Data Management and Quality Control

There will be several sources of data that will be used in the final analysis for the project. Some sources, summarized below, will be the original source and some will be taken from a secondary source.

Data Description	Source	Quality Control Measure
Indoor Temperature	Primary data from HOBO loggers in volunteer homes; collected every ½ hour	HOBOs tested before deployment
Behavioral Data	Primary data from Activity Logs – captures activities daily, every hour	Dual data entry by project personnel

Outdoor Temperature1	Primary data from outdoor HOBO loggers	HOBOs tested before deployment
Outdoor Temperature2	Secondary data from Detroit Metropolitan Airport	

Indoor Temperature Data

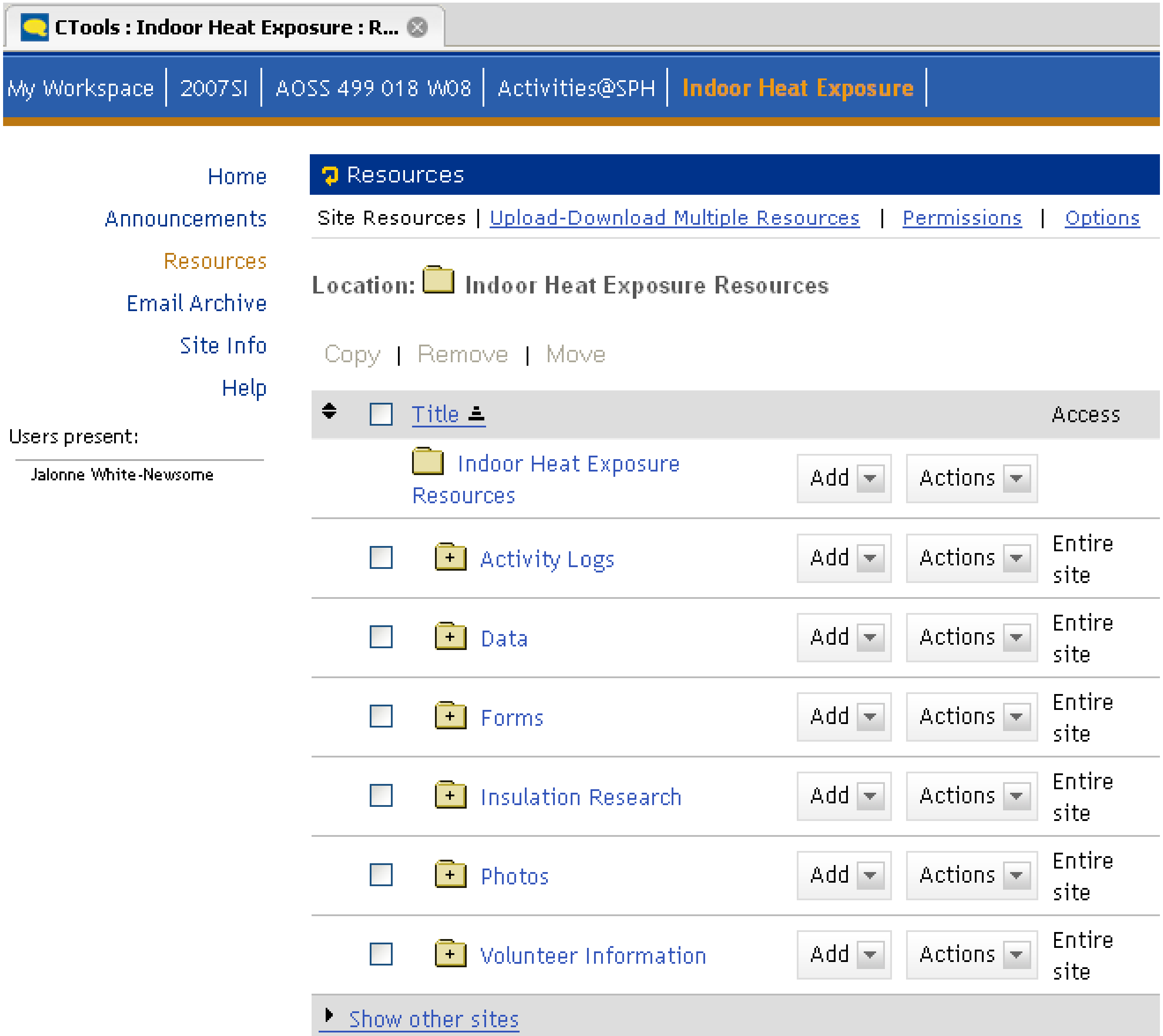
The indoor temperature data will be collected using the HOBO Indoor Temperature loggers. There will be two loggers mounted in each household (unless there is an exception). All logger data will be downloaded on-site at least once a month by either a research assistant or the principal investigator. However, all data files will be managed on the PI's computer, with copies of each file on a secured CTools site for the project. This data will be accumulated into an EXCEL spreadsheet and eventually exported to R programming console for analysis.

Behavioral Data

The purpose of collecting behavioral data is to determine what types of activities seniors engage in when they are hot. Each volunteer home will receive an Activity Log booklet for each month. Volunteers are responsible for recording their activities, every hour, of every day that are related to getting relief from the heat. Activity log data will be entered into an EXCEL spreadsheet twice, by two different members of the project team. Upon completion of a month's worth of data, each spreadsheet will be compared for accuracy. The final version will then be exported to SAS for statistical analysis.

Outdoor Temperature Data

There will be a total of three sources that can be used for outdoor temperature data. A study of outdoor temperatures in Wayne County, Michigan that is ongoing during the summer has two outdoor monitors co-located at sites with indoor monitors. A sub analysis of these two sources to see how different/similar the readings are will determine which site will be used. Temperature data from the Detroit Metropolitan airport will also be used as a comparison.



Statistical Analysis
All analysis will be performed using SAS and R. The following variables and responses will be coded as follows.

VariableName	Description	Responses
WinOrDoor	Open a Window or door in the home	1: yes 0: no . : missing
FanOn	turn a fan on	1: yes 0: no . : missing
AirConOn	turn the air conditioning on	1: yes 0: no . : missing
ClotheChg	change clothes	1: yes 0: no . : missing
Shower	take a shower	1: yes 0: no . : missing
Basement	go to the basement	1: yes 0: no . : missing
PorchYard	go to the porch or yard	1: yes 0: no . : missing
LeftHouse	leave the home	1: yes 0: no . : missing
DateCons	construction date	Numeric e.g. 2-Jul-09
Exterior	material of exterior construction	1: Brick, 2: AluminumPaneling, 3: Mix of Brick and Paneling, .: missing
ExterCol	color of exterior	1: Dark, 2: Light, . : missing
NorthSurr	immediate surroundings on the north side of the home	1: urban, 2: residential, 3: yard, 4:park . : missing
EastSurr	immediate surroundings on the east side of the home	1: urban, 2: residential, 3: yard, 4:park . : missing
SouthSurr	immediate surroundings on the south side of the home	1: urban, 2: residential, 3: yard, 4:park . : missing
WestSurr	immediate surroundings on the west side of the home	1: urban, 2: residential, 3: yard, 4:park . : missing
TotSquFt	total square footage of home (ft^{2})	Numeric e.g., 1000
Rooftype	how roof is constructed	1: Metal, 2: Built up, 3: Composition Shingles . : missing
RoofShape	the shape of the roof	1: Triangular, 2: Flat, 3:Combination, 4: Other . : missing
HomeStyl	style of home	1:Single Family, MultiLevel, 2:Single Family, Ranch, 3:Duplex, 4: Apartment, 5: HighRise (>3 flrs), .: missing
NumFlrs	number of floors in home	Numeric e.g. 5
Basemnt	is a basement in the home	1: yes 0: no
NumDrsFl1	the number of doors on the main floor of the home	Numeric
NumPeople	the number of people that live in the home	Numeric
AirCond	is there Any type of air conditioning in the home	1: yes 0: no
CentrlAir	is there Central air conditioning in the home	1: yes 0: no
Rm1AC	name of room in the house with air conditioning	1: LR, 2:BR, 3: Den, 4:other
Rm2AC	name of room in the house with air conditioning	1: LR, 2:BR, 3: Den, 4:other
StructChg	has there been any structural changes to the home	1: yes 0:no
Rm1Monitr	Room 1 that is being monitored	1: LR, 2:BR, 3: Den, 4:other
Rm1MonFl	The floor that room 1 is on that is being monitored	Numeric e.g. 5
Rm1Win	number of windows in room being monitored	Numeric e.g. 5
Rm1WinOpn	can windows in room being monitored open	1: yes 0: no
Rm1WinTyp	the type of windows in the room being monitored	1: regular glass, 2: high efficient windows, 3: film, 4: stained glass, 5: safety glass, 6: patterned glass, 7: other, .:missing
Rm1WinScr	are there screens in the window	1: yes 0: no
Rm1WinTrt	the type of window treatments on the window	1: curtains, 2: blinds, 3:plastic, 4:none, 5:other
Rm1WalClr	color of the walls	1: white, 2:off-white, 3: pink, 4: red, 5:black, 6:green
Rm1Size	size of the room (multiply length times width)	Numeric
Rm1FlrTyp	type floor in the room	1: carpet, 2:wood, 3: linoleum, 4: other
Rm1FlrClr	color of floor in the room	1: white, 2:off-white, 3: pink, 4: red, 5:black, 6:green
Rm1Height	height of the ceiling (ft)	Numeric eg. 10
Rm1AirCon	is there an air conditioner in the room	1: yes 0: no
Rm1Veg	is there any type of vegetation outside of the room windows	1: yes 0: no
HmInsTyp	type of insulation	text or numbers once I determine year

9. Outreach and Education

At each visit, the PI or research assistant will have the opportunity to share and discuss activity logs and the temperature data gathering from the last visit. This is an opportunity to engage and educate the volunteer about max temperatures reached in their home, as well as encourage them to continue documenting their behavioral patterns.
At the end of the study period, volunteers will receive a thank you card, fact sheets on heat and a project summary.
Once analysis of the data is complete, the PI will contact all referring agencies, the Health Department, Emergency planning, and the City Council to set up a time to share and present significant results and findings. The PI will collaborate with organizations, as requested, to prepare awareness materials or emergency plans.
A simplified fact sheet and personal summary will hand delivered (or mailed) to each volunteer pertaining to their home. Subsequently, copies of any publications or final materials will be provided as written.

10. Current Status of Project

As of July 9, 2009, there are 27 volunteers enrolled in the study. The following chart shows the breakdown of home type and air conditioning status. Volunteers will continue to be accepted until we reach 30 volunteers or up until July 31st.

Location	***Home***	***Highrise***	***CentralAC***	***RoomAC***	***Hybrid***	***NoAC***
1	X			X		
2	X					X
3	X					X
4		X		X		
5		X		X		
6		X		X		
7	X			X		
8	X					X
9	X					X
10	X					X
11	X					X
12	X			X		
13	X					X
14	X				X	
15	X					X
16	X					X
17		X	X			
18		X	X			
19		X		X		
20	X					X
21	X					X
22	X					X
23	X					X
24	X			X		
25	X					X

26	X		X			
27	X		X			
Total	21	6	4	8	1	14

Appendix A: References

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Appendix B: Indoor Temperature Exposure Protocol

1. Preliminary Organization
   1.1. Verification of the comparability of the measurement apparatus
      1.1.1. Program 50 monitors so they can record simultaneous temperature measurements every 30 minutes, during a period of 2 days.
      1.1.2. Calculate a coefficient of variation between each of the monitors.

2. Sampling
   2.1. For each HOBO being deployed, a member of research team will pre-program the HOBOs as necessary before visiting the home. The HOBOs will be pre-programmed to start measurements on June 1st or the day the specific HOBO is being deployed in the field. Measurements will be taken every 30 minutes, from June 1st to September 1st, 2009.
   2.2. To insure that the HOBOs will be pre-programmed at the same starting hour and for the whole time of the measurement period, the research team member will always have to check the exact hour and accuracy of the time set on the computer (Jalonne's computer) that will be used for programming the HOBOs.
   2.3. The procedure for programming the HOBOs:
      2.3.1. Open the software
      2.3.2. Connect the HOBO to the computer using the PC3.5 cable
      2.3.3. click "logger" and "launch"
      2.3.4. The screen will read "connecting"
      2.3.5. Write down the ID of the HOBO in the case description (see if ID corresponds with the ID on the HOBO device)
      2.3.6. In the cell of the EXCEL spreadsheet, set the interval duration, so each measurement is taken every 10 minutes
      2.3.7. Check the box "delayed start" and enter the date for the beginning of the measurement in the format month, day, year followed by the hour the measurement is to begin.
      2.3.8. Click on the "start" button.
      2.3.9. At this moment, "launching" will appear on the screen.
      2.3.10. Wait for a message and then unplug the logger, then unplug the cable from the computer.
      2.3.11. Put a sticker on the HOBO indicating the ID. (verify the ID matches what's on the HOBO)

3. Recruitment
   3.1. Event
      3.1.1. To prepare for the event, a member of the research team will have the following:
         3.1.1.1. extra copies of the consent form
      3.1.2. Research team members will participate by presenting basic information about the study as requested by potential partnering organizations.
      3.1.3. At each event, a short, informal presentation to potential volunteers will be prepared. Sign up sheets will be prepared for sign-up on location.
      3.1.4. Research team members will inform the potential participants that follow-up calls will be made in 48 hours to schedule a time for installation.
   3.2. By Telephone
      3.2.1. Scripts will be used by the research team to share program information.

4. Initial Visit for HOBO installation

4.1. 2 members of the research team will visit the home. The home visits will be split up by (1) date of installation, (2) location within the city. Once all HOBOs are installed, a visitation schedule will be developed.

4.2. At most, each research team will visit a site twice a month. A member of the research team will also make a reminder telephone call to each volunteer between visits to remind volunteers to fill out their daily activity log and schedule the next visit. (A reminder call will also be made the day before each subsequent visit.)

4.3. The same day as the visit, a member of the research team will make sure they have enough copies of consent forms, activity log booklets and housing surveys.

4.4. During the visit, if the person is away, the member of the research team will wait at least 20 minutes, call by phone, knock on the door, and call an alternate contact before abandoning the visit.

4.4.1. If a child less than 18 years of age answers, the research team member will ask to talk to an adult. If no adult is present, the research team member leaves the home.

4.5. When the member of the research team comes into the home, they will follow the visit and hobo installation checklist. (see attached). This includes:

4.5.1. Presentation of the project
4.5.2. Formal consent statement
4.5.3. Review of the Housing and Ecological Survey
4.5.4. Review of how to use the activity log and reminder sheet
4.5.5. Installation of the HOBO(s)
4.5.6. Set an appointment for the next visit
4.5.7. Project compensation

4.6. The research team member must read the full consent form to each participant. The person who signs the form must be the head of the household. The research team member must make sure that all the information is understood by the participant and will answer any questions. If the person accepts, she/he will sign the consent form, the research team member will sign the form and the Location ID is recorded on the consent form. One copy of the consent form remains with the participant. If the participant refuses to sign the consent, then the employee thanks the person and leaves the home.

4.7. The HOBO installation will be installed, where possible, on a coated surface, per the HOBO installation checklist (see attached)

4.8. The next day after the visit, consent forms should be filed in the PI's office.

5. Subsequent Visits

5.1. At each visit after the initial visit, a member of the research team will call the day before to remind the participant that they will be coming to check on the temperature monitor and collect the daily log. The research team member must get copies of the activity logs, gift cards and receipts.

5.2. Once arriving at the home, the member of the research team will collect the completed activity log, and leave a new activity log booklet for the participant, making sure the new log has the correct Location ID on the label. A member of the research team will also ask permission to download the data from the temperature monitors.

5.3. At the completion of the visit, the research team member will fill out the receipt page and ask the volunteer to fill out and sign the form, providing some personal information. Both the research team member will sign the form indicating that they did not take the gift card for themselves. The research team member then checks the box at the bottom of the participant tracking sheet that contact was made.

5.4. The day following the visits, the member of the research team will file the receipt and the activity logs in the PI's office. Any extra materials will be returned to the PI's office.

6. Distribution of gift cards

6.1. At each subsequent visit, participants will receive gift cards for their participation. As addressed above, participants and the research team member must sign a receipt each time a gift card is given.

6.2. If there is a chance that the activity log is not being completed by the volunteer, the research assistant will indicate to the volunteer that the log must be completed to comply with the study terms and possibly next time, will not receive a gift card. If the log is not completed in at least (2) visits (except for extenuating circumstances) the volunteer might be asked to not participate. The final decision will be made by the principal investigator.

7. Collection of equipment

7.1. At the last visit, all monitoring equipment, activity logs, reminder sheets and will be taken. The last gift card will be distributed as well. A thank you letter and a packet of information (heat resources, etc.) will be given to each participant. A member of the research team will also remind the participants that they will receive copies of any publications or report written from the data gathered during the summer.

7.2. All equipment will be returned to the PI's office.

Appendix C: Standard Operating Protocol for HOBO Temperature Monitors Placement

HOBO monitors will be used to monitor indoor and outdoor temperature and humidity to provide real-time meteorological data for use in research. All operators of the HOBO should review the operating protocol as needed.

Indoor Data Logger Equipment

(A) (B) (C) (D)

(A) HO8-002-01 HOBO Temperature Data Logger
(B) USB232 Serial Adapter
(C) HO9-003-08 HOBO Shuttle Data Transporter
(D) Interface Cable for Personal computers

Calibration of sensors and monitors

These instruments cannot be calibrated. Monitors have been tested to insure the relative difference between each monitored measurement is minimal.

Before placement of HOBO logger in field

1. Plug the shuttle into a USB port on the computer in Marie O'Neill's office (which has the Onset Corp. HOBO software loaded on it).
2. Open the HOBOware Pro software.
3. Attach the HOBO logger to the shuttle and press the lever on the shuttle.
4. Click "Device" and then click "Launch." Make the appropriate settings to the logger, e.g., time intervals to record and start time, and then launch the logger.
5. Remove the logger from the shuttle.

Mounting Instructions for Inside the Home

1. Determine best location for indoor temperature monitor. Prioritize area selection as follows (try to select a position facing the street):
   a. Wall in center of the home
   b. Wall in a common area
   c. Wall in a bedroom
2. Using a yard stick to determine height monitor will be placed at.
   a. Height: 5 feet 6 inches from the floor [average height for a man - 69.2 inches (5 feet, 9.2 inches) – average height for a woman: 5 feet ,3.75 inches
   b. Avoid the monitor being placed:
      i. Directly near a vent
      ii. Less than 1 meter away from any window or door leading to the outside
      iii. directly near any source of heat (i.e. furnace, oven)
      iv. in the following rooms: kitchen, bathroom, utility room, closets.
      v. near lights.
3. Confirm with home owner that the position selected is okay with them.
4. Attach monitor using double sided tape, or a hook mechanism.

Sampling Site Method

Sampling sites will be selected based on volunteer availability in the areas of the county that are most dense. A HOBO will be placed inside and outside the selected homes. Specific sites for HOBO deployment will be based on finding two volunteer homes for each area.

Preparing the Shuttle to go on-site

Refer to HOBO shuttle Manual in the Appendix, Document #8091B

Note: this must be done each time before the shuttle goes into the field.

1. Make sure BoxCar Pro Software is installed on computer that will be used for data downloads and storage.
2. Connect the shuttle to the computer using the interface cable and the serial adapter.
3. To make sure that all data has been logged off of the shuttle, connect the shuttle and offload the data. (HOBO shuttle readout command from the Logger menu)
4. Run the BoxCar program and select “Launch” from the Logger menu. (This will synchronize the time of the computer with the logger)
5. Check the battery level of shuttle. If it is <40%, change the batteries before going into the field.
6. Disconnect the shuttle from the computer.

Offloading the Data from the Temperature Loggers

Refer to HOBO shuttle Manual in the Appendix, Document #8091B

1. Check the battery status before going into the field. (Put in new batteries for EACH field visit.
2. Make sure that the data shuttle is completely dry.

3. Connect the logger to the shuttle by plugging the 12” cable into the shuttle jack and the 3.5 mm end into the logger.
4. The logger will automatically start off-loading data. If not, press the little black button on top of the shuttle.
    a. If while downloading the data, the shuttle continues to read “change logger battery”, disconnect the logger from the shuttle. Press the button three times to clear the battery check. Install a NEW battery in the logger, then reconnect the logger to the shuttle and press the little black button to re-do the download.
    b. If the shuttle’s battery is low and must be changed in the field and re-synchronized with the host computer.
5. The offloading is complete once the button changes to green.
6. Disconnect the cable from the logger.

Reading out data to the host computer

Refer to HOBO shuttle Manual in the Appendix, Document #8091B

1. Connect the shuttle to the host computer using the PC Interface Cable and the USB serial adapter cable.
2. Select HOBO shuttle readout from the Logger Menu.
3. Save data and disconnect cables.

Appendix D: Housing Characteristics Key

Exterior: Brick, Type: Single Family

Exterior: Brick, Roof type: asphalt shingle roofing

Roof type: flat

Glass type: Patterned glass

Glass type: Stained glass

Multi family – vinyl paneling

Exterior: brick, type: two-family flat

CHAPTER 1  brick,

ranch  asphalt shingle, brick, multi level, single family

CHAPTER 2

2.1 Different types of window glass

In addition to window style, there are also many types of glass to choose from depending on what it will be used for:

- Sheet glass
- Float glass (plate)
- Energy efficient glass
- Patterned glass (with color, patterns, etc. for privacy and decoration)
- Tempered glass (or safety glass)
- Laminated glass
- Wired glass
- Mirrors
- Picture frame glass

The following web site, sponsored by the U.S. Department of Energy's Windows and Glazings Program. provides information on windows for commercial buildings.

http://www.commercialwindows.umn.edu/index.php

Visit our Commercial Glass Page

Composition shingles are available

Composition Shingle

in 3-tab and architectural designs.

The most widely used roofing material is the composition shingle. Commonly known as asphalt shingles, they come in two types, differentiated by the base material. They consist of either an **organic** fiber mat or **fiberglass** core. Each type is impregnated with asphalt and coated with mineral granules to add color and texture. An adhesive back combined with nails, tacks or staples is the fastening method used. You will most likely find a "good/better/best" selection. Compare warranties (number of years the roof should last) when shopping. Shingles are available in the common 3-tab style or newer architectural designs that replicate other roofing materials such as wood or slate.

Corrugated Sheet

Corrugated sheet roofing is a cost-effective choice.

There are two main types:

- Sheets composed of **fiber** and impregnated with asphalt are available in many colors (or can be painted). This sheet roofing can be installed over existing roofs of other types. This is one of the easiest roofs to install for a do-it-yourselfer.
- Sheet roofing made from translucent **fiberglass** or **PVC**.

Wood

There are two types. **Shingles** are cut to a specific size and smooth finished. **Shakes** are irregular and rough-textured. Wood gives a natural look to a home. It also requires more maintenance to protect it from the elements. Wood roofing is commonly made from cedar. Fire-resistance is definitely a consideration in some areas due to local ordinances.

Metal

Metal roofs have returned from the olden days to become a popular roofing option. Once limited to low-slope structures, standing seam steel roofs can now be used on steeper roofs as well. Metal is durable, practically maintenance-free, heat reflective and nonflammable. Installed in sheets, a metal roof will actually dissipate a lightning strike rather than conduct it (a concern left over from the olden days). For real visual impact, a copper roof ages to an attractive patina.

Built-up Roofing

Built-up roofs are installed on flat or very low-sloping structures. They consist of alternating layers of felt or fiberglass treated with asphalt. These layers are topped with asphalt (tar) or aggregate. Built-up roofs are more common in commercial buildings.

Tile and Slate

These are two of the oldest roofing materials around. They are long-lasting and durable. Their weight requires a reinforced roof structure that can support them. Both can be quite expensive and neither are easy to install.

For a glossary of roofing terms, see our article on roofing repair.

Appendix D: Instructions for adding Daily Activity Log Data to Spreadsheet

The purpose of this protocol is to establish a common method for entering data from the Daily Activity Log into an EXCEL spreadsheet that will be analyzed at a later date.

Locate the Daily Activity Log that you will be using to get the data. Make sure you are able to identify the "Location #" that should be either printed or on a sticker on the front of the log. This Location # MUST be on the Log before you begin to input data.

1. Open up the data entry spreadsheet from the CTools site, located at:
    a. Indoor Heat Exposure/Data/DataEntry/DataDownload#1_SASPrep_070709
    b. The spreadsheet is laid out as follows:
        i. At the bottom of the spreadsheet, you will see different tabs labeled as such: VariableKey, Loc01, Loc02, etc.
        ii. The VariableKey worksheet explains the different "entries" you will use for each data point.
        iii. Loc01, Loc02, etc. correspond to the Activity Log information you will be inputting on that worksheet in EXCEL.

2. Data Entry
    a. The categories that you will be entering data for are located at the top of the Daily Activity Log. They are as follows:
        i. Opened Window or Door
        ii. Turn on Fan
        iii. Turned on Air conditioning
        iv. Changed clothes
        v. Took shower
        vi. Went to basement
        vii. Went outside the house to the porch/yard
        viii. Left house
    b. The date and temperature data from the logger is in ½ hour increments. However, the daily activity log is in 1 hour increments. We will assume

that whatever behavior the person marked in the activity log that this behavior was done for the entire hour.

c. Every time you see a mark on the activity log for a specific time and behavior, this should be recorded as a "1" in the spreadsheet. If a specific behavior was not done, at any time, this should be recorded as a "0".

d. Some other points:

   i. If "evening", put a "1" in the fields for 11:00 pM and 11:30 pm

   ii. If "bedtime" is marked, put a "1" in the fields from midnight up to 6 AM the next morning.

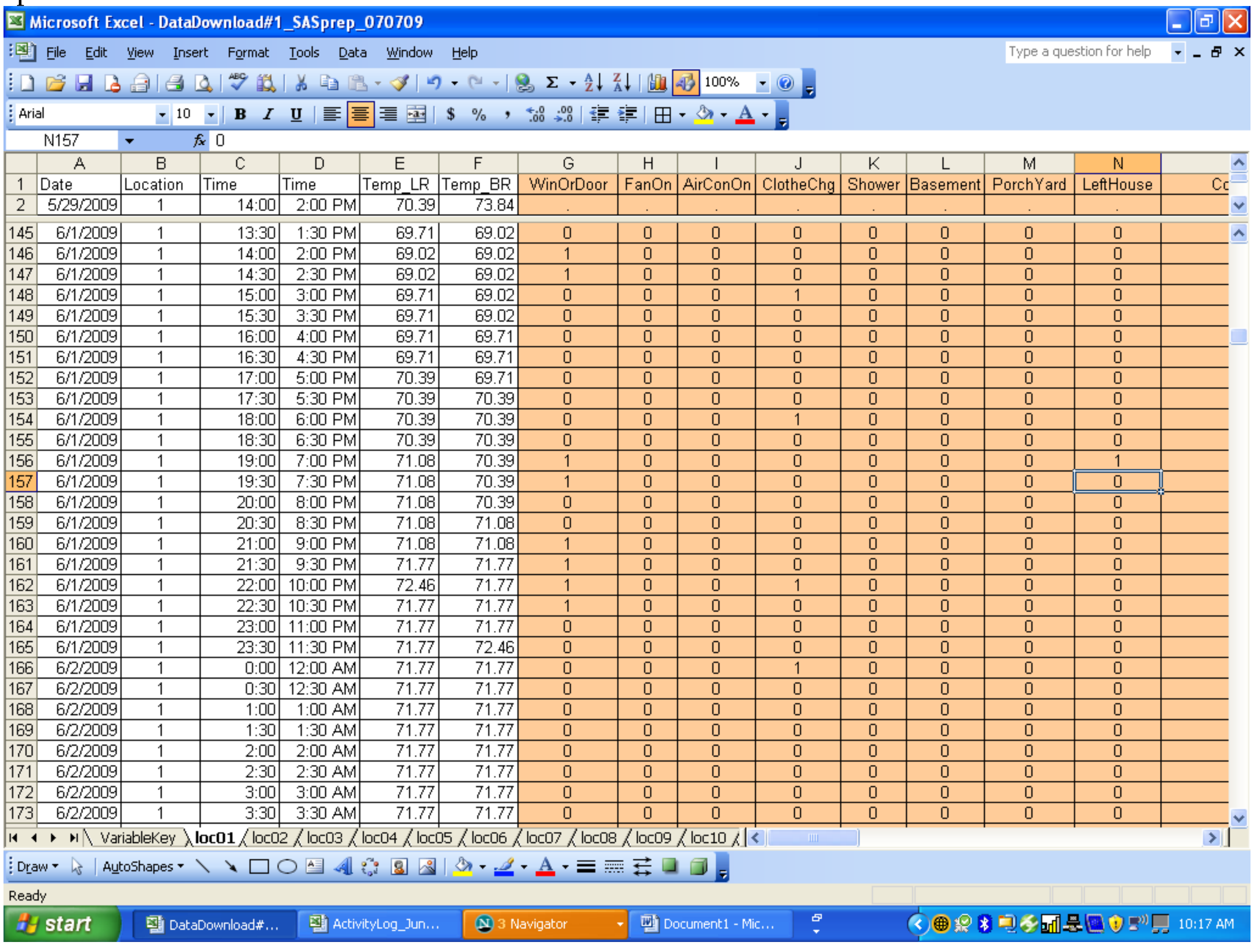
   iii. If the person has written a comment in the spreadsheet, add this comment in "comment column" (i.e. the last column after Left House" in the spreadsheet)

e. See example below.

Sample page from a volunteer activity log:

Monday June 1, 2009	Opened Window or Door	Turn on Fan	Turned on Air Conditioning	Changed Clothes	Took Shower	Went to Basement	Went Outside the house to the Porch/Yard	Left House	Comments
Before 6:00 AM									
7:00 AM	X								
8:00 AM									
9:00 AM				X	X				
10:00 AM	X							X	
11:00 AM	X								
12:00 noon									
1:00 PM									
2:00 PM	X								
3:00 PM				X					
4:00 PM									
5:00 PM									
6:00 PM				X					
7:00 PM	X							X	
8:00 PM									
9:00 PM	X								
10:00 PM				X					
Evening	X								
Bedtime				X					

Sample spreadsheet filled out correctly to document the volunteer behavior in the spreadsheet:



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	
1	Date	Location	Time	Time	Temp_LR	Temp_BR	WinOrDoor	FanOn	AirConOn	ClotheChg	Shower	Basement	PorchYard	LeftHouse	Cc
2	5/29/2009	1	14:00	2:00 PM	70.39	73.84	.	.	.	.	.	.	.	.	
145	6/1/2009	1	13:30	1:30 PM	69.71	69.02	0	0	0	0	0	0	0	0	
146	6/1/2009	1	14:00	2:00 PM	69.02	69.02	1	0	0	0	0	0	0	0	
147	6/1/2009	1	14:30	2:30 PM	69.02	69.02	1	0	0	0	0	0	0	0	
148	6/1/2009	1	15:00	3:00 PM	69.71	69.02	0	0	0	1	0	0	0	0	
149	6/1/2009	1	15:30	3:30 PM	69.71	69.02	0	0	0	0	0	0	0	0	
150	6/1/2009	1	16:00	4:00 PM	69.71	69.71	0	0	0	0	0	0	0	0	
151	6/1/2009	1	16:30	4:30 PM	69.71	69.71	0	0	0	0	0	0	0	0	
152	6/1/2009	1	17:00	5:00 PM	70.39	69.71	0	0	0	0	0	0	0	0	
153	6/1/2009	1	17:30	5:30 PM	70.39	70.39	0	0	0	0	0	0	0	0	
154	6/1/2009	1	18:00	6:00 PM	70.39	70.39	0	0	0	1	0	0	0	0	
155	6/1/2009	1	18:30	6:30 PM	70.39	70.39	0	0	0	0	0	0	0	0	
156	6/1/2009	1	19:00	7:00 PM	71.08	70.39	1	0	0	0	0	0	0	1	
157	6/1/2009	1	19:30	7:30 PM	71.08	70.39	1	0	0	0	0	0	0	0	
158	6/1/2009	1	20:00	8:00 PM	71.08	70.39	0	0	0	0	0	0	0	0	
159	6/1/2009	1	20:30	8:30 PM	71.08	71.08	0	0	0	0	0	0	0	0	
160	6/1/2009	1	21:00	9:00 PM	71.08	71.08	1	0	0	0	0	0	0	0	
161	6/1/2009	1	21:30	9:30 PM	71.77	71.77	1	0	0	0	0	0	0	0	
162	6/1/2009	1	22:00	10:00 PM	72.46	71.77	1	0	0	1	0	0	0	0	
163	6/1/2009	1	22:30	10:30 PM	71.77	71.77	1	0	0	0	0	0	0	0	
164	6/1/2009	1	23:00	11:00 PM	71.77	71.77	0	0	0	0	0	0	0	0	
165	6/1/2009	1	23:30	11:30 PM	71.77	72.46	0	0	0	0	0	0	0	0	
166	6/2/2009	1	0:00	12:00 AM	71.77	71.77	0	0	0	1	0	0	0	0	
167	6/2/2009	1	0:30	12:30 AM	71.77	71.77	0	0	0	0	0	0	0	0	
168	6/2/2009	1	1:00	1:00 AM	71.77	71.77	0	0	0	0	0	0	0	0	
169	6/2/2009	1	1:30	1:30 AM	71.77	71.77	0	0	0	0	0	0	0	0	
170	6/2/2009	1	2:00	2:00 AM	71.77	71.77	0	0	0	0	0	0	0	0	
171	6/2/2009	1	2:30	2:30 AM	71.77	71.77	0	0	0	0	0	0	0	0	
172	6/2/2009	1	3:00	3:00 AM	71.77	71.77	0	0	0	0	0	0	0	0	
173	6/2/2009	1	3:30	3:30 AM	71.77	71.77	0	0	0	0	0	0	0	0	

3. After data is entered, please re-save the file with the following naming scheme: "JuneActivityLogUpdate_##/ ## /09".
    a. Upload the file to the folder in Ctools at the path:

       Indoor Heat Exposure/Data/DataEntry/Completed/

This most recent file will ALWAYS be used for uploading more temperature logger data, as well as activity log data. It is important that the file is saved with the MOST recent date.

Appendix F: Organizational contacts for Recruitment

Current Volunteer Contact Updates

Name	*Organization/Relationship*	*Status*
Jerry Springs (referred by Sara Gleicher, AWBS, sgleicher@awbs.org, 313.924.7860)	Adult Well Being Services 313.819.7200 (cell)	**Forwarded outreach materials on 5/12/09; need to confirm date to present to senior citizen knitting class**
Ms. Freeman	Virginia Park Senior Association 313.894.6428	**Meeting with on 5/14/08; forwarded materials as well**
Patricia Baldwin	Hannan Foundation 313.833.1300 x15	**Forwarded materials via email on 5/12/09**
Olivia Ramsey	Social Work Office, Dept. of Health and Wellness	**Collaborative on aging will not be meeting until June due to new administration. Suggested contacting the senior services division.**
Brenda Miner	Special Events and Grant coordinator for Senior citizens Department of Detroit (313) 224-4904 off (313) 952-3804 cel	**Sent materials on 5/12/09. checking with her director to see if they can help.**
Members of the Elder Care directory	See attached	**Not contacted. Need to focus on a couple of groups and move forward with contacts.**
Deanna Myrie, M.Ed.	Health Coordinator Detroit Area Agency on Aging	**Suggested using the elder care directory**
Harold Massengille	Service coordinator at Brush Park and Harmony Manor; 313.934.4000x3 (Mon, Wed) 313.832.1576 (Tu, Th, Fri) His boss: Ms. Scott 313.832.9922	**Talked with Harold; did not get response from boss. Will resend flyers on 5/13/09.**
Emory Jones	Resident council for Harriet Tubman apartments	**Contacted; no response. Sent need to resend information to Ashanti, am@harriettubmanapts.com**

Rec. Departments	Based on Melissa's list	**Take flyers**
Service providers for the City of Detroit	Based on a list from Janice of Henry Ford health systems Teresa Pembroke: 313.224.9174 Anthony Smith: 313.224.4494 Jannie Warren 313.224.6525	**Contacted 2 months ago; no response. Need a re-contact**
Sheridan Homes Sojouner Truth Homes Smith Homes	Need contact	
Meals on Wheels of Wayne County	Need contact.313.446.4444	
Nanci Grasty	Service provider for 2 senior buildings, 313.378.5908	**Speak to seniors on 5/20 after fire drill at the Willa complex; speak on 5/27 at the Delta complex at ceramics class (confirmed on 5/13/09)**
Ms. Miree of Silver Saints 861.1089		
Rehoboth Plaza 313.898.8576 Latisha McGhee		

Additional Volunteer Agency contacts

	Contact Person	Telephone
The Senior Citizens Department		(313) 224-1000
Senior Outreach and Assistance		(313) 224-5444
Akwaaba Community Center		(313) 871-2428
St. Raymond Community Center		(313) 372-0437
Arab Community Center		(313) 871-2603
Latino Mission Society		(313) 841-2377
Jewish Community Center of Metro Detroit		(248) 967-4030
Coleman Young Recreation Center		(313) 877-8008
Joy- Southfield Health and Education Center		(313) 581-7773
Detroit East Community Mental Health Center		(313) 921-4700
Clark Park Recreation Center		(313) 297-9328
Detroit Recreation Center		(313) 297-9211/ (31
Kronk Recreation Center		(313) 224-6574
Neighborhood Club		(313) 885-4600
Renaissance Bowling Center		(313) 368-5123
Community Service Center		(313) 633-0811
Kemeny Recreation Center		(313) 628-0957
8330 On The River		(313) 331-7780
Resources for Seniors		(313) 342-2100

From Directory of Elder Care Services:

1. Care Management for the Elderly (pg. 3)
2. Disease Prevention and Health Promotion (pg. 4-5)
3. Nutrition Services (pg. 9)
4. Outreach and Assistance (pg.10)
5. Food and Friendship Listing (spreadsheets on back page)
    a. Split up list

Jackie's contact at CLOSUP. (School of Public Policy); Project Coordinator Bonnie Roberts
http://closup.umich.edu/

Appendix G: Proposed Timeline

Tuesday, May 12	Received IRB approval Sent recruitment materials to possible partnering organizations
May 13-May 15	Make calls to recruit volunteers Prepare plan for the summer Team meeting with all helpers Meeting with Ms. Freeman, Virginia Park Ass. Order additional HOBO materials w/ help of Margaret Email Canada researcher about protocol and forms they used to capture data
May 18-22	Test HOBOs in office- compare to NIST probe or other HOBO; Test protocol (if software and supplies are available) for collecting and downloading data Call backs to other volunteer agencies to help with volunteer selection Print out daily logs and documents for field use
May 25-29	Install HOBOs in volunteer homes that are ready (use weekend if necessary) Develop installation schedule based on volunteer availability
June 1-5	Final installation of all HOBOs
	See what is in the property tax assessment database at the county bldg. related to housing characteristics.
TWO WEEK HOBO checks based on initial deployment data	
Retrieve all HOBOs from the field by September 2, 2009	

Appendix H: HOBO Operating Instructions

HOBO™ Shuttle Operating Instructions

The Shuttle's internal clock

The time set in the Shuttle is only as accurate as the time on the computer it was connected to. The Shuttle's time is used to set the logger's launch timer. If accurate time is important, you may want to use a utility that sets the PC clock to a time standard, and readout or launch the Shuttle just before going into the field.

Replacing the HOBO Shuttle batteries

Important: Replace all batteries at the same time and observe correct polarity when inserting them into the battery holder.

The host computer displays the Shuttle's battery status when you launch or read out the Shuttle. If the batteries are low (32% or less), you should replace them before going into the field. The data stored in the Shuttle is retained when you remove the batteries; however, as a data safety measure, a Shuttle with low batteries prohibits you from offloading additional loggers.

To change the Shuttle's batteries:

1. Open the case by unsnapping the latch and lifting the lid. Work over a desk or table to provide a safe platform for the disassembly.
2. Gently pull the tab on the label to remove the circuit board from the case.
3. Unwrap the label from the circuit board and remove the batteries from their holder.
4. **Be sure to install the new batteries in their correct orientation.** When the last battery makes proper contact, all of the Shuttle's LEDs light in sequence from top to bottom, then from bottom to top.
5. After new batteries have been installed, the Shuttle's clock must be synchronized before it can offload a logger. To do this, connect the logger to the host computer and run BoxCar. Select Launch... from the Logger menu. The software synchronizes the Shuttle's clock and displays the battery status.

⚠ **WARNING:** Do not install backwards, recharge, put in fire, expose to extreme heat, or mix with other battery types, as the batteries may explode or leak. Contents of an open or leaking battery can cause chemical burn injuries. **Replace all used batteries at the same time.** Recycle or dispose of the battery according to all applicable federal, state, and local regulations.

Service and Support

HOBO products are easy to use and reliable. In the unlikely event that you have a problem with this instrument, contact the company where you bought the logger: Onset or an Onset Authorized Dealer. Before calling, you can evaluate and often solve the problem if you write down the events that led to the problem (are you doing anything differently?) and if you visit the Technical Support section of the Onset web site at www.onsetcomp.com/support.html. When contacting Onset, ask for technical support and be prepared to provide the product number and serial number for the logger and software version in question. Also completely describe the problem or question. The more information you provide, the faster and more accurately we will be able to respond.

Onset Computer Corporation
470 MacArthur Blvd., Bourne, MA 02532
Mailing: PO Box 3450, Pocasset, MA 02559-3450
Phone: 1-800-LOGGERS (1-800-564-4377) or 508-759-9500
Fax: 508-759-9100
E-mail: loggerhelp@onsetcomp.com
Internet: www.onsetcomp.com

Returning Products to Onset

Direct all warranty claims and repair requests to place of purchase. Before returning a failed unit, you must obtain a Return Merchandise Authorization (RMA) number from Onset. You must provide proof that you purchased the Onset product(s) directly from Onset (purchase order number or Onset invoice number). Onset will issue an RMA number that is valid for 30 days. You must ship the product(s), properly packaged to protect against further damage, to Onset (at your expense) with the RMA number marked clearly on the outside of the package. Onset is not responsible for any package that is returned without a valid RMA number or for the loss of the package by any shipping company. Products must be clean and free of any contaminants before they are sent back to Onset or they may be returned to you.

Repair Policy

Products that are returned after the warranty period or that are damaged by the customer as specified in the warranty provisions can be returned to Onset with a valid RMA number for evaluation.

Optional Services

Please contact Onset for more information and prices on:

- ASAP Repair. Onset will expedite the repair of a returned product.
- Data-back™ Service. HOBO data loggers store data in nonvolatile EEPROM memory. Onset will, if possible, recover your data to a disk.
- Tune Up Service. Onset will examine and retest any HOBO data logger.

Warranty

This warranty is void if the product has been damaged by the purchaser as a result of improper maintenance, abuse, misuse, mishandling, misapplication, error or negligence of Purchaser, or if there has been an unauthorized alteration, attachment or modification.

THERE ARE NO WARRANTIES BEYOND THE EXPRESSED WARRANTY AS PROVIDED IN THIS DOCUMENT. IN NO EVENT SHALL ONSET BE LIABLE FOR LOSS OF PROFITS OR INDIRECT, CONSEQUENTIAL, INCIDENTAL, SPECIAL OR OTHER SIMILAR DAMAGES ARISING OUT OF ANY BREACH OF THIS CONTRACT OR OBLIGATIONS UNDER THIS CONTRACT, INCLUDING BREACH OF WARRANTY, NEGLIGENCE, STRICT LIABILITY, OR ANY OTHER LEGAL THEORY.

LIMITATION OF LIABILITY. The Purchaser's sole remedy and the limit of Onset's liability for any loss whatsoever shall not exceed the Purchaser's price of the product(s). The determination of suitability of products to the specific needs of the Purchaser is solely the Purchaser's responsibility. THERE ARE NO WARRANTIES BEYOND THE EXPRESSED WARRANTY IN THIS DOCUMENT. EXCEPT AS SPECIFICALLY PROVIDED IN THIS DOCUMENT, THERE ARE NO OTHER WARRANTIES EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO, ANY IMPLIED WARRANTIES OF MERCHANTIBILITY OR FITNESS FOR A PARTICULAR PURPOSE. NO INFORMATION OR ADVICE GIVEN BY ONSET, ITS AGENTS OR EMPLOYEES SHALL CREATE A WARRANTY OR IN ANY WAY INCREASE THE SCOPE OF THE EXPRESSED WARRANTY OFFERED WITH THE SALE OF THIS PRODUCT.

INDEMNIFICATION. Products supplied by Onset are not designed, intended, or authorized for use as components intended for surgical implant or ingestion into the body or other applications involving life-support, or for any application in which the failure of the Onset-supplied product could create or contribute to a situation where personal injury or death may occur. Products supplied by Onset are not designed, intended, or authorized for use in or with any nuclear installation or activity. Products supplied by Onset are not designed, intended, or authorized for use in any aeronautical or related application. Should any Onset-supplied product or equipment be used in any application involving surgical implant or ingestion, life-support, or where failure of the product could lead to personal injury or death, or should any Onset-supplied product or equipment be used in or with any nuclear installation or activity, or in or with any aeronautical or related application or activity, Purchaser will indemnify Onset and hold Onset harmless from any liability or damage whatsoever arising out of the use of the product and/or equipment in such manner.

LEGAL REMEDIES. This warranty gives you specific legal rights. You may also have other rights which vary by jurisdiction. The remedies provided herein are in lieu of all other remedies, express or implied.

Appendix I: RECRUITMENT FORM

ID#	NAME	ADDRESS (street,zip code)	PHONE #	BEST TIME TO CONTACT: AM or PM	Air Conditioning?	FAVORITE STORE
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

APPENDIX Ia: Telephone Script

Telephone Script to recruit volunteers for summer heat study on indoor heat exposure

Good afternoon.

My name is _______________.I am a student at the University of Michigan School of Public health and I am working on a project that might be of interest to your residents/program participants that are aged 64 and over.

Hot weather can be more intense for elderly people – especially when people do not have a way to cool off and they are in their homes the majority of the time. What I am calling for today is to try and identify any volunteers that you may know that fit any of the following criteria (1 or more):

1) elderly (64 and over)
2) living in a home that is not air conditioned or has limited air conditioning (i.e. only window air conditioning units in a certain part of the home)
3) living in a high rise building
4) living in Wayne County, Michigan

Once we identify potential volunteers, we are asking them to help with a study that will start on June 1st and end on September 1st. We are asking that all volunteers will be able to help with the following:

1. First, allow us to put up small thermometers (temperature loggers) inside and outside of their home for the summer. All this logger will do is record temperatures and requires no work on their part. The only thing is we would need to check on the logger every couple of weeks to make sure it is working properly. The loggers will be in place from June 1 through September 1, 2009.
2. Secondly, we would like the volunteers to write down daily what they do when they get too hot. So, if it's turning on the air conditioning, opening a window or turning on a fan, all they would have to do is write it down in a notebook that we will provide each of the volunteers.
3. The last thing would involve helping us fill out a short questionnaire that will give us information about their home – how old the home is, how many floors, just some basic information.

We will have to visit volunteer homes every two weeks to download data and check that the activity log is being filled out correctly. We will be providing all volunteers with a $10 gift card at every visit (total of 6 visits) as compensation for their participation during the study period.

Participant information will not be shared and confidentiality will be maintained by keeping all identifying information on a password, protected computer. Also, this is a chance for people to really be involved, on a new project, related to climate change that can influence policy and community programs on the local area. Of course, all of the results will be shared with anyone that participates. We also plan on sharing the results with agencies that can help make a difference in the lives of these seniors.

If you have any more questions, or need more details, we would be happy to meet with you in person as the heat is on it's way! Also, if you have a group of seniors that you work with, or can specifically identify someone that might be interested, that would be helpful as well. We would be willing to meet you at your convenience.

Please feel free to contact me at via email at jalonne@umich.edu, or by phone at 734.223.5331. If not, we will follow-up with you before the study period officially begins. If you have someone else we could contact that might be interested, we'd appreciate that information as well.

Thank you for your time.

Appendix Ib: Recruitment Email

To: Agency Contact/Network
From: Jalonne White-Newsome
University of Michigan School of Public Health
Environmental Health Sciences Department
Doctoral Candidate
Phone: 734.223.55331
Email: jalonne@umich.edu

Date: May 2009
Re: Summer study on heat and health

I hope this email finds you all well. I am a doctoral candidate at the University of Michigan School of Public Health and I am studying heat related mortality in Southeastern Michigan. My advisor is Dr. Marie O'Neill, associate professor in Environmental Health Sciences and Epidemiology in the University of Michigan School of Public Health. I am especially interested in the risks of our elderly population when it comes to handling hot weather.

As I have explained in previous meetings of the Health Aging Collaborative, I have been working with the Detroit Extreme Heat Task Force to try and identify specific senior high rise apartments that might be interested in learning more about heat awareness and illness prevention.

However, this summer I am embarking on a study to assess the level of heat exposure on senior citizens, especially those that are over 64 years of age and living in a dwelling without air conditioning or limited cooling, and in Wayne County. I would appreciate your help in trying to identify seniors that would be willing to participate in this study. The study will start on June 1st and end on September 1, 2009.

The first part of the study is to install at least one automatic thermometer to record temperatures inside the home, and one automatic temperature thermometer to record temperatures outside of their homes (where possible). The seniors will also need to be willing to fill out a quick activity log on a daily basis that describes their activities.

Because we will be visiting the volunteer homes every two weeks (a total of 6 visits during the study period) to download data and check that the activity log is being filled out correctly, at each two-week visit, each volunteer will receive a gift card. We will be providing all volunteers with a $10 gift card at every visit (total of 6 visits) as compensation for their participation during the study period.

Seniors will also receive valuable information on how to reduce their risk during hot weather.

Because you are connected with the Healthy Aging Collaborative, I am sure that you have some connections, either professionally or personally, to seniors that would be willing to participate. I am willing to talk over the phone or meet with you in person to adequately review all of the details of the project. Feel free to pass this information on to other senior resource agencies or personal contacts. I can be reached via phone or email at the contact information above. Your prompt response would be appreciated, as I would like the study to begin on June 1st. Thank you for your time.

Appendix Ic: Volunteer Flyer

Looking for volunteers!!

Are you a senior citizen living in Wayne county?

Do you spend more than 5 hours a day in your home?

Are you interested in public health?

Do you live in a high rise building or a home with no air conditioning?

What is the purpose of this study?

As the temperatures rise from year to year, we will experience more weather events that are more extreme –more cold days, or more hot days. Specifically, during the summertime, temperatures can get hot and more people are at risk for heat related illnesses.

The purpose of this study is to identify what types of buildings and homes that hold onto heat and do not cool down as fast, especially those buildings without air conditioning. By setting up an automatic thermometer in your home, we can track indoor temperatures for the entire summer and compare these temperatures to different buildings.

What do volunteers have to do?

* Allow us to put a thermometer in your home or apartment from June 1— September 1.

- Keep a log during the summer of what you do when it gets hot
- Allow us to collect general information about your home

This is an important study that can help identify those people that are more at risk for heat related illnesses in the summer months.

If you are interested, please contact your building manager or contact Jalonne Newsome at 313.575.0413, or jalonne@umich.edu. Volunteers will be given a $10 gift card for every two weeks they participate.

Appendix Id: Volunteer Letter

May 2009

Dear Potential Volunteers:

My name is Jalonne White-Newsome and I am a doctoral student at the University of Michigan in Ann Arbor studying climate change and heat. Climate change is part of the reason why our weather has been extreme – really cold during the winter, and really hot during the summer.

When the weather gets hot, certain people can be at a greater risk of getting sick or dying. Especially some senior citizens that are isolated, bedridden or have a hard time moving around inside their homes, or living in homes without air conditioning.

In order to better understand how hot different homes can get, I am asking for volunteers to help with a study. The volunteers need meet the following criteria:

1) elderly (over 64 years of age) and living in Wayne County

2) living in a home or apartment building with no air conditioning, or limited air conditioning (i.e. air conditioning in one room)

Once we identify potential volunteers, we are asking them to help with a study that will start on June 1st and end on September 1st. We are asking that all volunteers will be able to help with the following:

1. First, allow us to put up small thermometers (temperature loggers) inside and outside of their home for the summer. All this logger will do is record temperatures and requires no work on their part. The only thing is we would need to check on the logger every couple of weeks to make sure it is working properly. The loggers will be in place from June 1 through September 1, 2009.
2. Secondly, we would like the volunteers to write down daily what they do when they get too hot. So, if it's turning on the air conditioning, opening a window or turning on a fan, all they would have to do is write it down in a notebook that we will provide each of the volunteers.
3. The last thing would involve helping us fill out a short questionnaire that will give us information about their home – how old the home is, how many floors, just some basic information. This information will be used for us to figure out how well homes protect or don't protect us from really hot weather. The researchers will enter study data on a computer that is password-protected and encrypted. To protect confidentiality, your real name or contact information will not be used..

The overall goal is to look at different buildings around the city to determine where public agencies might need to pay closer attention during the hot weather to make sure everyone is taken care of and we have interventions and resources ready to go.

If you are interested in participating or would like more information, we would be happy to sit and talk with you in person. Feel free to contact me at 734.223.5331 or via email. Also, if you know other buildings or volunteers in single residences that would be willing to participate, do not hesitate to pass this information on. Have a great day and we look forward to hearing from you soon.

Jalonne White-Newsome
jalonne@umich.edu
734.223.5331

Appendix L: Consent Form to Participate

Consent to Participate in a Research Study

Climate change and assessment of Indoor heat exposure of vulnerable and elderly populations in Wayne County, Michigan

Principal Investigator:	Jalonne L. White-Newsome, Environmental Health Sciences Department, University of Michigan
Faculty Advisor:	Marie S. O'Neill, Ph.D., Environmental Health Sciences Department, University of Michigan

You are invited to be a part of a research study that looks at how indoor heat exposure among seniors over the age of 64 varies by the type of house and environmental surroundings. The purpose of the study is to improve awareness and better protect the health of senior citizens during hot weather. We are asking you to participate because you are a part of this important population. This study is being funded by the University of Michigan.

If you agree to be part of the research study, you will be asked to allow us to install at least one temperature logger (automatic thermometer) inside your home, and one outside of your home (in the yard). Both loggers will be installed for the full length of the study period – from June 1st to September 1st. You will not be held responsible if the samplers are damaged or stolen. The samplers have no commercial value. We do not anticipate any risks to you or your family and community from having this equipment in your home or in your yard. The device can not cause injury and the University of Michigan or research team will not pay for any damage to the yard in the unlikely event that any occurs as a result of your participation.

At the first meeting, we will ask you some general questions about your home. An example of these types of questions could be, what type of material is your home constructed from, or how old is your home. You have the right not to answer any of these questions. During the study period, we will also ask you to fill out a daily log when you do certain activities. For example, you will write down when you do certain activities like open a window, go outside or turn on the air conditioning. We will explain how to use this checklist during our first meeting. We will also have to visit your home twice a month (at total of 6 visits during the study period) to make sure the temperature loggers are working properly, get the data and check that the activity log is being filled out correctly.

As a direct benefit from participating in this study, at the conclusion of the study period, you will receive fact sheets and brochures that contain important information about heat related illnesses and why it is a concern for senior citizens. You will also get a list of resources for programs, as well as weatherization information on how to better prepare your home. Additionally, the research team will be available to come and talk to you about the results of the study, and share any articles or other publications that result from this valuable data.

We will be providing all volunteers with a $10 gift card at every visit (total of 6 visits) as compensation for their participation during the study period.

We plan to publish in scientific journals the results of this study, but will not include any information that would identify you. The researchers will enter study data on a computer that is password-protected and encrypted. To protect confidentiality, your real name or contact information will not be used in publications.

There are some reasons why people other than the researchers may need to see information you provided as part of the study. This includes organizations responsible for making sure the research is done safely and properly, including the University of Michigan, government offices, or the study sponsor. Also, federal or state law may require the study team to give certain information to government agencies to prevent harm to you or others.

If you have questions about this research, including questions about the scheduling of your interview or your compensation for participating, you can contact Jalonne White-Newsome, University of Michigan, Environmental Health Sciences Department, 109 Observatory St., M6314 SPH II, Ann Arbor, MI 48109, (734) 223-5331, jalonne@umich.edu. You can also contact my faculty advisor, Dr. Marie O'Neill, University of Michigan, Environmental Health Sciences Department, 109 Observatory St., 6631 SPH Tower, Ann Arbor, MI 48109, (734) 615-5135, marieo@umich.edu.

If you have any questions about your rights as a research participant, please contact the University of Michigan Health Sciences Institutional Review Board, toll free, at 866-936-0933, or by mail at 540 E. Liberty St., Suite 202 Ann Arbor, MI 48104-2210, irbhsbs@umich.edu.

By signing this document, you are agreeing to be part of the study. Participating in this research is completely voluntary. Even if you decide to participate now, you may change your mind and stop at any time. You may also refuse to answer any question or not record certain items in your diary. We are asking that you participate at a minimum of at least 4 consecutive weeks. You will be given a copy of this document for your records and one copy will be kept with the study records. Be sure that questions you have about the study have been answered and that you understand what you are being asked to do. You may contact the researcher if you think of a question later.

I agree to participate in the study and grant permission to have the temperature monitoring device in my home and yard, and have read and understand the terms of the agreement as described above.

______________________________ ______________

Participant Signature Date

______________________________ ______________

Research Team Member Signature Date

Appendix M: Housing Characteristic Survey

Location ID: ______ Month:______ Researcher Initials/Date:_______________

Housing and Ecological Characteristics Survey

A Research Assistant will ask you questions about your home, listed below. Some of these questions will be answered by visual inspection by the researcher. Answer all questions to the best of your knowledge. These questions will help us better understand how the construction of your house could change how much heat you are exposed to indoors.

Item#	Description	Response
	GENERAL HOUSING	
HE1	Date of Construction	**18____ 19____ 20_____**
HE2	Material of Exterior Construction	**Brick Aluminum Paneling Other______**
HE3	Color of Exterior	**Dark Light**
HE4	Description of Immediate Surroundings (within 20 feet of home on North, East, South and West of home)	**N: urban residential yard/park concrete other** **E: urban residential yard/park concrete other** **S: urban residential yard/park concrete other** **W: urban residential yard/park concrete other**
HE5	Total square footage of home being monitored	______
HE6	Roof type	**Flat Triangular Other** **Metal Built up Composition Shingle Unknown**
HE7	Style of home	**Single Family/multi level Duplex** **Single Family/ranch High Rise Apt.(> 3 flrs)** **Apartment**
HE8	# of floors in house (not including basement)	#______
HE9	Basement	**Yes No**
HE10	# of doors on main level	#______
HE11	# of people living in home	#______
HE12	Air conditioning	**Yes No**
HE13	*Central air conditioning*	**Yes No**
HE14	*Room air conditioning (how many and what rooms)*	**Room1:______________ NA** **Room2:______________ NA**
HE15	Has there been any structural changes or remodeling done to the home? If so, what year? (changes in insulation)	**Year:____ Description of changes:** **________________________________** **________________________________**
HE16	Electricity Usage	**Month of Bill:________** **Current usage____ Last Month:____ Year Ago:___**
	ROOMS BEING	

	MONITORED	
HE17	Room(s) being monitored	**Room1:_______ Floor:____ HOBO#_____** **Room2:_______ Floor:____ HOBO#_____**
HE18	# of windows in room(s) being monitored	**Room1:________# windows_________** **Room2:________ #windows__________**
HE19	Any special window glazing Room 1:_____	 **Patterned glass Yes No** **Stained glass Yes No** **Safety glass Yes No** **Efficient Windows Yes No** **Film Yes No** **Other__________ Yes No** **Regular Windows Yes No**
	Room 2:_____	**Patterned glass Yes No** **Stained glass Yes No** **Safety glass Yes No** **Efficient Windows Yes No** **Film Yes No** **Other__________ Yes No** **Regular Windows Yes No**
HE20	Windows can open in room(s) being monitored	**Room1:________ Yes No** **Room2:________ Yes No**
HE21	Windows have screens	**Room1:________ Yes No** **Room2:________ Yes No**
HE22	Window Treatments	**Room1: curtains blinds plastic other none** **Room2: curtains blinds plastic other none**
HE23	Color of the walls in the room(s) being monitored	**Room1:_______Color:_____________** **Room2:_______Color:_____________**
HE24	Size of Room being monitored	**Room1:_______ Size(foot by foot):______** **Room2:_______ Size(foot by foot):______**
HE25	Type of floor / Color of floor in room being monitored	**Room1:______ Type: Wood carpet linoleum other Color: ________** **Room2:______ Type: Wood carpet linoleum other Color: ________**
HE26	Description of room being monitored: spacious, crowded	**Room1: crowded spacious semi spacious** **Room2: crowded spacious semi spacious**

HE27	Approximate height of ceiling in room being monitored	**Room1:________ Height: ~ _____ ft** **Room2:________ Height: ~_____ ft**
HE28	Room air conditioner in room(s) being monitored	**Room1:________ Yes No** **Room2:________ Yes No**
HE29	Any visible vegetation or structures outside of the window that shade the room	**Room1:________ Yes No** **Room2:________ Yes No**
HE30	**Assumed Insulation type/width Based on Year home built**	___________________________________

A2.6 IRB Approval

Health Sciences Institutional Review Board • 540 East Liberty Street, Suite 202, Ann Arbor, MI 48104-2210 • phone (734) 936-0933 • fax (734) 998-9171 • irbhsbs@umich.edu

To: Jalonne White-Newsome

From:

Charles	Kowalski
Richard	Redman

Cc:

Joseph	Dvonch
Miatta	Buxton
Jalonne	White-Newsome
Edith	Parker
Marie	O'Neill

Subject: Initial Study Approval for [HUM00030093]

SUBMISSION INFORMATION:
Study Title: Climate change and assessment of Indoor heat exposure of the vulnerable and elderly populations in Wayne County, Michigan
Full Study Title (if applicable):
Study eResearch ID: HUM00030093
Date of this Notification from IRB:5/12/2009
Initial IRB Approval Date: 5/7/2009
Current IRB Approval Period:**5/7/2009 - 5/6/2010**
Expiration Date: Approval for this expires at **11:59 p.m. on 5/6/2010**
UM Federalwide Assurance (FWA): FWA00004969 expiring on 4/18/2011
OHRP IRB Registration Number(s): IRB00000245

NOTICE OF IRB APPROVAL AND CONDITIONS:
The IRB Health Sciences has reviewed and approved the study referenced above. The IRB determined that the proposed research conforms with applicable guidelines, State and federal regulations, and the University of Michigan's Federalwide Assurance (FWA) with the Department of Health and Human Services (HHS). You must conduct this study in accordance with the description and information provided in the approved application and associated documents.

APPROVAL PERIOD AND EXPIRATION:
The approval period for this study is listed above. Please note the expiration date. If the approval lapses, you may not conduct work on this study until appropriate approval has been re-established, except as necessary to eliminate apparent immediate hazards to research subjects. Should the latter occur, you must notify the IRB Office as soon as possible.

IMPORTANT REMINDERS AND ADDITIONAL INFORMATION FOR INVESTIGATORS

APPROVED STUDY DOCUMENTS:
You must use any date-stamped versions of recruitment materials and informed consent documents available in the eResearch workspace (referenced above). Date-stamped materials are available in the "Currently Approved Documents" section on the "Documents" tab.

RENEWAL/TERMINATION:
At least two months prior to the expiration date, you should submit a continuing review application either to renew or terminate the study. Failure to allow sufficient time for IRB review may result in a lapse of approval that may also affect any funding associated with the study.

AMENDMENTS:
All proposed changes to the study (e.g., personnel, procedures, or documents), must be approved in advance by the IRB through the amendment process, except as necessary to eliminate apparent immediate hazards to research subjects. Should the latter occur, you must notify the IRB Office as soon as possible.

AEs/ORIOs:
You must inform the IRB of all unanticipated events, adverse events (AEs), and other reportable information and occurrences (ORIOs). These include but are not limited to events and/or information that may have physical, psychological, social, legal, or economic impact on the research subjects or other.

Investigators and research staff are responsible for reporting information concerning the approved research to the IRB in a timely fashion, understanding and adhering to the reporting guidance (http://www.med.umich.edu/irbmed/ae_orio/index.htm), and not implementing any changes to the research without IRB approval of the change via an amendment submission. When changes are necessary to eliminate apparent immediate hazards to the subject, implement the change and report via an ORIO and/or amendment submission within 7 days after the action is taken. This includes all information with the potential to impact the risk or benefit assessments of the research.

SUBMITTING VIA eRESEARCH:
You can access the online forms for continuing review, amendments, and AEs/ORIOs in the eResearch workspace for this approved study (referenced above).

MORE INFORMATION:
You can find additional information about UM's Human Research Protection Program (HRPP) in the Operations Manual and other documents available at: www.research.umich.edu/hrppp.

Richard Redman
Co-chair, IRB Health Sciences

Charles Kowalski
Co-chair, IRB Health Sciences

Appendix 2.8 2-page heat education and outreach flyer

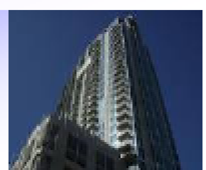
Are you a Detroit Area Senior (over the age of 65) who lives alone and...

- ☑ Spends a lot of time inside your home?
- ☑ Lives in a high rise building ?
- ☑ Lives in a home with no air conditioning?
- ☑ Has health conditions like diabetes, heart troubles or respiratory problems?
- ☑ Has difficulty walking or getting around your home without help?

Studies have shown that any of these factors listed above, in addition to personal health and type of home you live in can make you unhealthy when it's hot.

Being in a HOT home can ***cause you to sweat which can lead to dehydration and body overheating***. Too much heat can cause ***mental confusion or behavior changes, fainting, heat stroke and eventually death***.

Living in the city, having an apartment on a high floor, or living in a neighborhood that does not have a lot of trees for shade or grass can make the insides of homes harder to stay cool.



Heat can feel good, but can be dangerous, especially during multiple days of hot temperatures. Before summer comes, remember the **3P's** so you can be prepared to beat the heat.

Prepare - ***P***ay Attention - ***P***revent

Prepare

- Explore getting your home weatherized: better Insulation and windows with better sealing.
- Make sure windows can open and close easily.
- On hot days, cover windows with outdoor awnings, shades, curtains, and/or blinds to prevent direct sunlight from heating up the room.
- Make sure your air conditioner works.
- If you do not have an air conditioner, make plans for a friend or family member to let you visit their home or take you to a public place (like a recreation center, a mall or a library) during the day time.
- Cook meals early in the morning or late at night to avoid generating heat in your home during the day.
- Find a neighbor or a friend who you can call or will call you during the day to make sure that you are physically well.

Pay Attention

- Listen to the radio or the news to see if hot weather warnings have been forecasted for the day.
- Know your body. If you feel light headed or dizzy, call for help. This could be the start of a potentially dangerous reaction to the heat.

Prevent

- Drink water all day, especially when you go out. Keep a supply of bottled water in your home.
- During the daylight hours, move to a cooler part of your home — the basement, outside on the porch, or the 1st floor of an apartment building.
- Wear light, loose fitting clothes.

To find air conditioned <u>centers open to the public</u>

Dial 3-1-1 or
313-224-4636

City Recreation Department:
313-224-1100

<u>General Assistance for Seniors</u>

Detroit Area Agency on Aging:
313-446-4444

Outreach and Assistance
313-224-5444

Home Weatherization Department:
313-852-5609 ext. 1100

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Appendix 2.9 Tri-fold brochure of Indoor heat study results

What do I do now?

Anyone living in Detroit may be at risk from heat during the summer. Remember these tips to be better prepared for hot weather and reduce your risks for heat related health effects.

- Listen to the weather on the radio or TV
- Move to a cool area of your home during the day—avoid rooms or windows with direct sunlight.
- Electric fans do not help cool in really hot, humid weather (over 90 degrees)—they just blow hot air around
- Find a summer buddy—a friend, neighbor or family member that you can call for assistance
- Drink water (no alcohol), take showers, and wear light clothing
- Spend the day in a cool place: visit the mall, the movies or a friend's home if you do not have air conditioning in your home
- Try not to cook during the hottest times of the day (noon to 4 pm)
- Consider improving the insulation in your attic, walls and windows

References

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A study of indoor heat exposure in Detroit, Michigan:

2009 Study results and recommendations to stay healthy in hot weather

Last summer, you participated in a unique study by the University of Michigan Heat Study Team to determine how hot homes can get during the summertime, as well as what people do to stay cool during the summer. This brochure will provide results of the study, as well as things to keep in mind so you can stay healthy as we prepare for another summer!

The U of M Heat Study Team cares about how hot it gets in your home. Many people think they should only care about hot weather if they live in the southern United States. But, that's not true!

There have been long periods of hot weather that have caused serious illnesses and even death in cities in the Midwest, like St. Louis, Chicago and right here in Detroit, Michigan.

Risk and effects of heat

When it is hot outside, keeping your home and body at a comfortable temperature is important. There are serious health risks that can result from your body overheating.

- **Too much sweating** can lead to dehydration and the body overheating
- **Too much heat** can cause mental confusion or behavior changes, fainting, heat stroke and/or death

Risk factors of heat

Studies have shown that certain people are more sensitive to heat. *Do you have any of the following personal factors?*

PERSONAL CHARACTERISTICS

- *Are over the age of 65*
- *Live alone*
- *Have cardiovascular or respiratory conditions, diabetes*
- *Have difficulty moving around your home without help*
- *Taking certain medications (allergy, some blood pressure and heart medicines)*

While there are personal factors that can make you more susceptible to heat, the U of M Heat Study team wanted to understand what risk factors to heat could be associated ***with your home.*** After monitoring the indoor temperatures in 30 homes across the Detroit area from June 1st-August 30th 2009, some interesting trends were discovered.

Why the HOME is important

Most seniors spend the majority of their time inside their homes, so the indoor temperature is what people are actually exposed to over longer periods of time.

The U of M Heat Study Team found several trends about **how hot** homes in Detroit can get in the summertime.

- **Some homes reached 94 degrees indoors, regardless if they had air conditioning or not.**
- **Homes with an exterior made of vinyl paneling and woodsiding had higher indoor temperatures than those made of brick.**
- **Single family homes were hotter than high rise apartment buildings.**
- **Homes located in Northwest Detroit were warmer.**
- **Homes built before 1940 reached higher temperatures.**

Appendix 3.1 Picture of Activity Log book (cover and inside page)

MARK THE BOX WITH AN X DURING THE TIME YOU PERFORMED ANY OF THE ACTIVITIES PICTURED BELOW.

Wednesday July 1, 2009	Opened Window or Door	Turn on Fan	Turned on Air Conditioning	Changed Clothes	Took Shower	Went to Basement	Went Outside the house to the Porch/Yard	Left House	Comments
Before 6:00 AM									
7:00 AM									
8:00 AM									
9:00 AM									
10:00 AM									
11:00 AM									
12:00 noon									
1:00 PM									
2:00 PM									
3:00 PM									
4:00 PM									
5:00 PM									
6:00 PM									
7:00 PM									
8:00 PM									
9:00 PM									
10:00 PM									
Evening									
Bedtime									