Analysis of extreme heat vulnerability: Scales of spatial analysis

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Local government responses to climate change: Survey of 264 cities (Aylett A, 2014)

**Figure 1: Focus of Climate Change Planning and Action**

- **Global**: 73% Mitigation, 24% Adaptation, 3% Both
- **Canada**: 81% Mitigation, 13% Adaptation, 6% Both
- **USA**: 58% Mitigation, 41% Adaptation, 1% Both
- **Latin America**: 83% Mitigation, 17% Adaptation
- **Europe**: 82% Mitigation, 15% Adaptation, 4% Both
- **Africa**: 77% Mitigation, 15% Adaptation, 8% Both
- **Asia**: 81% Mitigation, 16% Adaptation, 3% Both
- **Australia & New Zealand**: 91% Mitigation, 9% Adaptation
City Climate Hazard Taxonomy

C40’s classification of city-specific climate hazards

March 2015 – C40 Launches City Climate Hazard Taxonomy for Public Comment
stakeholders, assess concerns, and determine the broad outlines and objectives of the planning process (Figure 2 below). Identification and mapping of community assets that may enhance resilience, and vulnerable populations, is a key pre-condition to a broader stakeholder involvement and prioritization of possible interventions based on criteria selected by the stakeholders (Ebi & Semenza, 2008, p.504). After creating plans for implementation and associated mobilization of resources, the implementation of selected activities occurs. As adaptive planning is always an iterative process, the process concludes with monitoring and evaluation processes, with feedback from community members engaged in the process. As such, this process aims to develop social capital through discussion within communities, and may help to address some of the vulnerabilities suggested by the ecological research presented in Chapter 4 – the inadequate access to resources and assets (economic, institutional, biophysical and social) that underlies population vulnerability to climate-health impacts.

Figure 7.2: Framework for community-based adaptation planning (Ebi & Semenza, 2008)
## Heat-health vulnerability mapping

Reid et al., 2009. *Env Health Perspect*; DOI:10.1289/ehp.0900683

### Table 1. Heat-health vulnerability data, 39,794 U.S. census tracts.

<table>
<thead>
<tr>
<th>Category</th>
<th>Data source (year)</th>
<th>Variable definition</th>
<th>Percent mean (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographic variables</td>
<td>U.S. Census (2000)</td>
<td>Percent population below the poverty line</td>
<td>12.57 (0.00–100.00)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Percent population with less than a high school diploma</td>
<td>19.97 (0.00–85.88)</td>
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<td>Percent population of a race other than white</td>
<td>30.20 (0.00–100.00)</td>
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<td>Percent population living alone</td>
<td>10.28 (0.00–68.86)</td>
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<td></td>
<td>Percent population ≥ 65 years of age</td>
<td>12.21 (0.00–94.28)</td>
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<tr>
<td></td>
<td></td>
<td>Percent population ≥ 65 of age living alone</td>
<td>27.38 (0.00–100.00)</td>
</tr>
<tr>
<td>Land cover</td>
<td>National Land Cover Database (2001)</td>
<td>Percent census tract area not covered in vegetation</td>
<td>61.15 (0.03–100.00)</td>
</tr>
<tr>
<td>Air conditioning</td>
<td>American Housing Survey (2002)*</td>
<td>Percent households without central AC</td>
<td>44.43 (2.10–95.13)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Percent households without any AC</td>
<td>18.47 (0.00–95.13)</td>
</tr>
</tbody>
</table>

*Data were interpolated for 2002 for counties that were surveyed in years before and after 2002 to get a larger sample of air conditioning estimates for 1 year.

Curriero et al. 2002
New York City’s Sustainability Plan: PlaNYC 2030

Released April 2007

Available at http://www.nyc.gov/html/planyc2030/
New York City’s Adaptation Planning Process

Stakeholders include:
- City Agencies
- Regional Authorities
- Private Stakeholders

Integration across Sector-specific Working Groups

Expert Panel
- Climate change Scientists
- Legal experts
- Insurance experts

Boston Consulting Group
New York City Panel on Climate Change

NYAS, April 2010
New York City’s planning response

- Surveillance
- Emergency response: Heat alerts and emergencies
- Provider education, public education and distribution of AC to needy seniors
- NYC Panel on Climate Change and Adaptation Task Force: infrastructure adaptation
- PlaNYC initiatives
Ecological analysis

What neighborhood-level characteristics are associated with heat-related mortality rates in New York City?

Examining a range of possible vulnerability factors:
* Demographic
* Socioeconomic
* Built environment (housing, neighborhood conditions)
* Biophysical (vegetation, urban heat island)
Mortality rate ratio: $\text{MRR}_{65+}$

For Warm season (May 1st – Sept. 30th) 1997-2006:

$$\text{MRR}_{65+} = \frac{(\sum \text{M}_{H65}/\text{D}_{HI100})}{(\sum \text{M}_{W65}/\text{D}_{W})}$$

- $\text{MH65}$: Natural cause deaths, age 65+, on days when HI>=100.
- $\text{D}_{HI100}$: Number of days, with HI>= 100 during warm season
- $\text{MW65}$: Natural cause deaths, age 65+
- $\text{D}_{W}$: Number of days, warm season

Aggregated from census tracts for each of 59 CDs and 42 UHF neighborhoods.
Model for Neighborhood-Health Interactions

Adapted from Morello-Frosch & Shenassa, 2006

Community-level stressors/buffers

Built environment
- Land use/zoning
- Housing quality

Social environment
- Civic engagement/
- Political empowerment
- Access to services
- Poverty concentration

Individual-level stressors/buffers

- Poverty/SES
- Working conditions
- Social support
- Diet/nutritional status
- Health behaviors
- Reproductive events
- Psychosocial stress
- Health care access

Chronic individual stress

Individual allostatic load

Pollutant source location → Exposure → Response and resilience → Health effect → Ability to recover

Community-level impact

Individual-level impact
Urban heat island & urban design

- Vegetation
- Building and surface materials: reflectivity and emittance
- Water
- Building height and density
- Transportation infrastructure
- Sky-view angle

Landsat surface temperature, 14 August 2002
Methods

• Select factors for analysis

• Ecologic analysis: Bivariate linear regression of MRR$_{65}$ with neighborhood-level characteristics

• Assess correlation of factors with each other; stratified analysis for potential modifiers.

• Multivariate regression for heat-related mortality and risk factors (UHI and AC)
Data on vulnerability factors

- “Neighborhoods” = 59 Community Districts (CD) and 42 United Hospital Fund (UHF)
- **Demographics & SES data**: Census 2000 (CD)
- **Health status**: DOHMH Community Health Survey (UHF)
- **Built Environment**: PLUTO from NYCDCP; NYC Dept of Housing Preservation & Development; NYC Dept. of Finance
- **Biophysical**: Emerge (US Forest Service) and satellite data from NASA
Senior’s AC access by UHF area

Percent of seniors (age 65+) who do not have or do not use air conditioning

- 5 - 14%
- 14 - 25%
- 25 - 43%
- Insufficient data *

* Data are not provided due to small sample size and imprecise estimates.
Intra-urban vulnerability

Mortality rate ratios comparing Heat Advisory Days (HI ≥ 100°F) to all warm season days, 1997-2006, in New York City

Klein Rosenthal et al., 2014
Regression models with the mortality rate ratios

<table>
<thead>
<tr>
<th>Predictor variables</th>
<th>$R^2$</th>
<th>Adj. $R^2$</th>
<th>Pr &gt; F</th>
<th>Unstandardized coefficient</th>
<th>Standardized coefficient</th>
<th>$t$</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>B</td>
<td>Std. Error of B</td>
<td>95% CI for B (lower, upper)</td>
<td>$\beta$</td>
</tr>
<tr>
<td><strong>UHF-neighborhood models</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>1. Homeownership (percent)</td>
<td>0.17</td>
<td>0.15</td>
<td>0.007</td>
<td>-0.003</td>
<td>0.001</td>
<td>(-0.004, -0.001)</td>
<td>-0.413</td>
</tr>
<tr>
<td>2. Deteriorating or dilapidated buildings*</td>
<td>0.159</td>
<td>0.138</td>
<td>0.01</td>
<td>0.013</td>
<td>0.005</td>
<td>(0.003, 0.023)</td>
<td>0.399</td>
</tr>
<tr>
<td>3. Percent below poverty</td>
<td>0.156</td>
<td>0.135</td>
<td>0.01</td>
<td>0.004</td>
<td>0.002</td>
<td>(0.001, 0.007)</td>
<td>0.395</td>
</tr>
<tr>
<td>4. Impervious cover*</td>
<td>0.23</td>
<td>0.186</td>
<td>0.008</td>
<td>0.003</td>
<td>0.001</td>
<td>(0.0005, 0.006)</td>
<td>0.346</td>
</tr>
<tr>
<td>Hypertension*</td>
<td></td>
<td></td>
<td></td>
<td>0.004</td>
<td>0.0016</td>
<td>(0.001, 0.007)</td>
<td>0.376</td>
</tr>
<tr>
<td>5. Air conditioning access, age 65+</td>
<td>0.117</td>
<td>0.094</td>
<td>0.027</td>
<td>-0.004</td>
<td>0.002</td>
<td>(-0.008, -0.001)</td>
<td>-0.341</td>
</tr>
<tr>
<td>6. Homes near structures rated good or</td>
<td>0.168</td>
<td>0.147</td>
<td>0.007</td>
<td>-0.003</td>
<td>0.001</td>
<td>(-0.006, -0.001)</td>
<td>-0.409</td>
</tr>
<tr>
<td>excellent</td>
<td></td>
<td></td>
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<tr>
<td><strong>Community District models</strong></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Property tax delinquencies*</td>
<td>0.112</td>
<td>0.096</td>
<td>0.01</td>
<td>0.01</td>
<td>0.004</td>
<td>(0.003, 0.018)</td>
<td>0.334</td>
</tr>
<tr>
<td>2. Serious housing violations*</td>
<td>0.104</td>
<td>0.089</td>
<td>0.013</td>
<td>0.001</td>
<td>0.0005</td>
<td>(0.0003, 0.002)</td>
<td>0.323</td>
</tr>
<tr>
<td>3. Percent below poverty</td>
<td>0.065</td>
<td>0.049</td>
<td>0.051</td>
<td>0.003</td>
<td>0.001</td>
<td>(0.000, 0.006)</td>
<td>0.255</td>
</tr>
<tr>
<td>4. Percent Asian population</td>
<td>0.093</td>
<td>0.077</td>
<td>0.019</td>
<td>-0.005</td>
<td>0.002</td>
<td>(-0.008, -0.001)</td>
<td>-0.305</td>
</tr>
</tbody>
</table>

Note: $N = 42$ UHF-neighborhoods and 59 Community Districts. The dependent variable is the mortality rate ratio for age 65+ (MRR65+).

* Percent of households, 2002; influential point UHF 501 removed (Port Richmond, Staten Island).

* Influential point UHF 101 removed (Kingsbridge-Riverdale, the Bronx).

* Five-year mean, 2000–2003 and 2006. The share of 1–3 residential unit properties (Tax Class 1) with over $500 in unpaid property tax.

* Six-year mean, 2000–2005. The number of class C (immediately hazardous) housing code violations issued by the NYC HPD per 1,000 rental units.
Results

• Built environment/housing quality metrics have the strongest correlation with MRR$_{65+}$:
  • Property tax delinquencies
  • Residential Air Conditioning access/use 65+
  • Housing violations
  • Rates of homeownership
  • Poverty rates at UHF-level

• Weaker correlations with:
  • SES measures: poverty concentration at CD-level, educational attainment
  • Health status: hypertension prevalence, diabetes
  • Surface temperature and percent of land-cover that is trees or impervious cover, averaged to UHF-neighborhoods

• Marginal correlations with:
  • Other Biophysical measures: vegetative cover of residential tax lots

• Neighborhood poverty rates and relative income levels modified of the association between these characteristics and mortality rates
Conclusions

• The findings affirm the importance of neighborhood characteristics and social determinants in climate-health effects.

• Poverty, disparities in AC access and poor quality housing are associated with heat-mortality rates in NYC, as are proxy measures of heat exposure in neighborhoods.
Hazard reduction potential of UHI mitigation, and active and passive cooling measures on the room scale.

Oliver Buchin, Marie-Therese Hoelscher, Fred Meier, Thomas Nehls, Felix Ziegler

Evaluation of the health-risk reduction potential of countermeasures to urban heat islands

Energy and Buildings, 2015, Available online 21 June 2015
Planners, designers and architects are challenged not only to integrate ecology and climate science in their work, but also to engage the public in understanding (and undertaking) research to foster a climate literate public.

GSD student Naz Beykan and Bronx resident during urban heat island field research, July 2012
Municipal climate adaptation programs

- **Urban design** interventions (e.g., the use of water, vegetation and plazas to reduce the urban heat island effect)
- **Technological innovation** (new materials)
- Changes in **behavior and public education** (neighborhood watch programs and heat-alert programs)
- While generally **not yet incorporating social policies** such as supportive housing.
Mitigation

- Renewable energy
- Energy conservation and efficiency measures that reduce fossil fuel use
- Combined heat & power systems
- More active transportation (cycling and walking)
- Expand transit use
- Fuel efficient & electric vehicles
- Reduced air travel
- Compact urban form

Adaptation

- More permeable surfaces
- Enhanced planning for extreme weather events
- Heat response systems
- West Nile & Lyme Disease Programs
- Identification & control programs for invasive species
- Ecological infrastructure: bioswales, upgrades to sewers, culverts, and flow routes or collection for extreme rainfall
New York City DOH *Take Care New York*

- Have a regular doctor or health care provider
- Be tobacco free
- Keep your heart healthy
- Know your HIV status
- Get help for depression
- Live free of dependence on alcohol and drugs
- Get checked for cancer
- Get the immunizations you need
- Make your home safe & healthy

San Francisco Department of Public Health, *Strategic Plan*

Advocate for policies such as:
- Living wages
- Employment development/ full employment
- Results-based employment training
- Adequate supply of high-quality child care
- Improve quality & quantity of housing
- Strong social safety net
- Improved public transportation
- Increased public participation in social and political organizations

*Corburn, 2009*