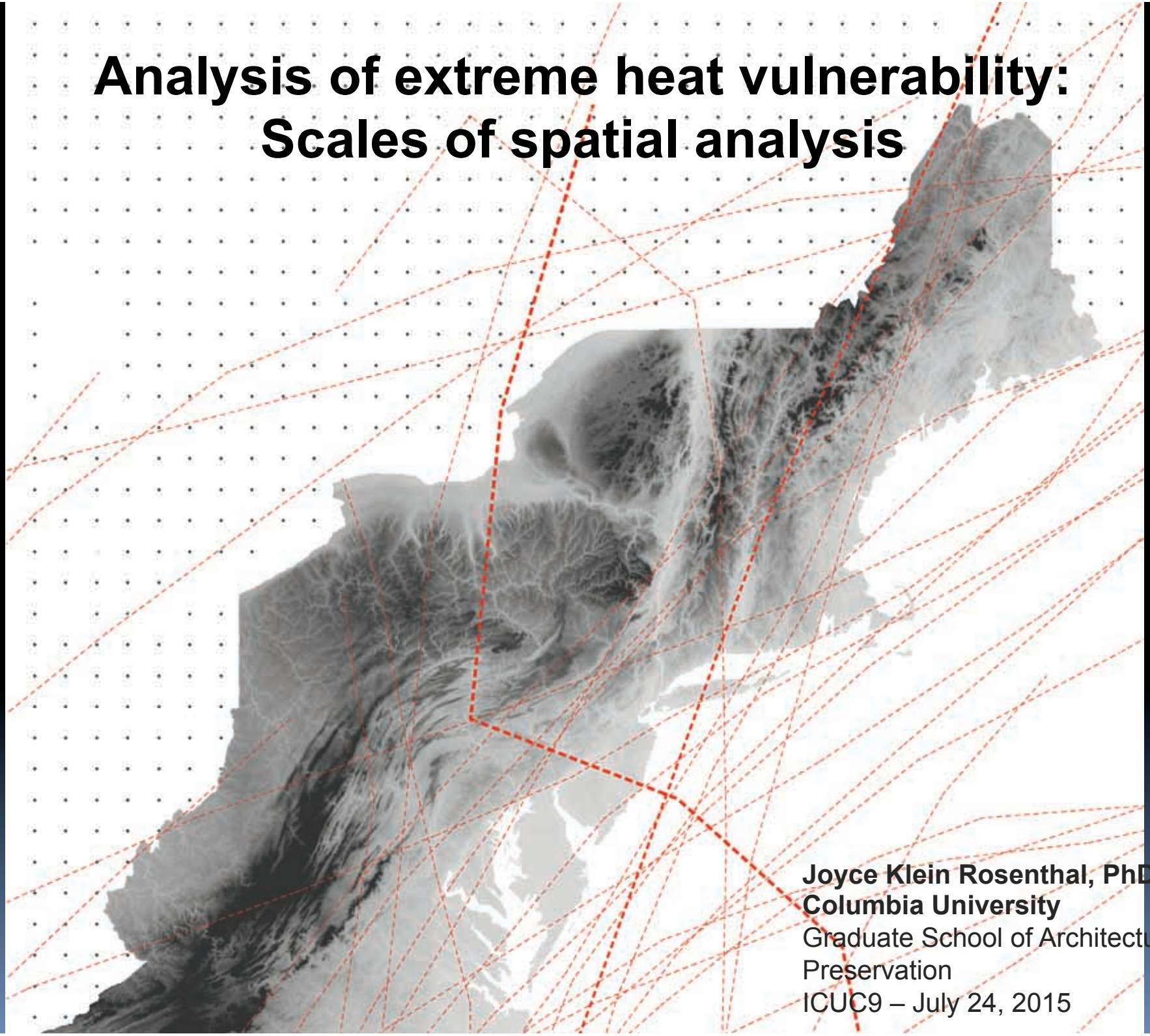
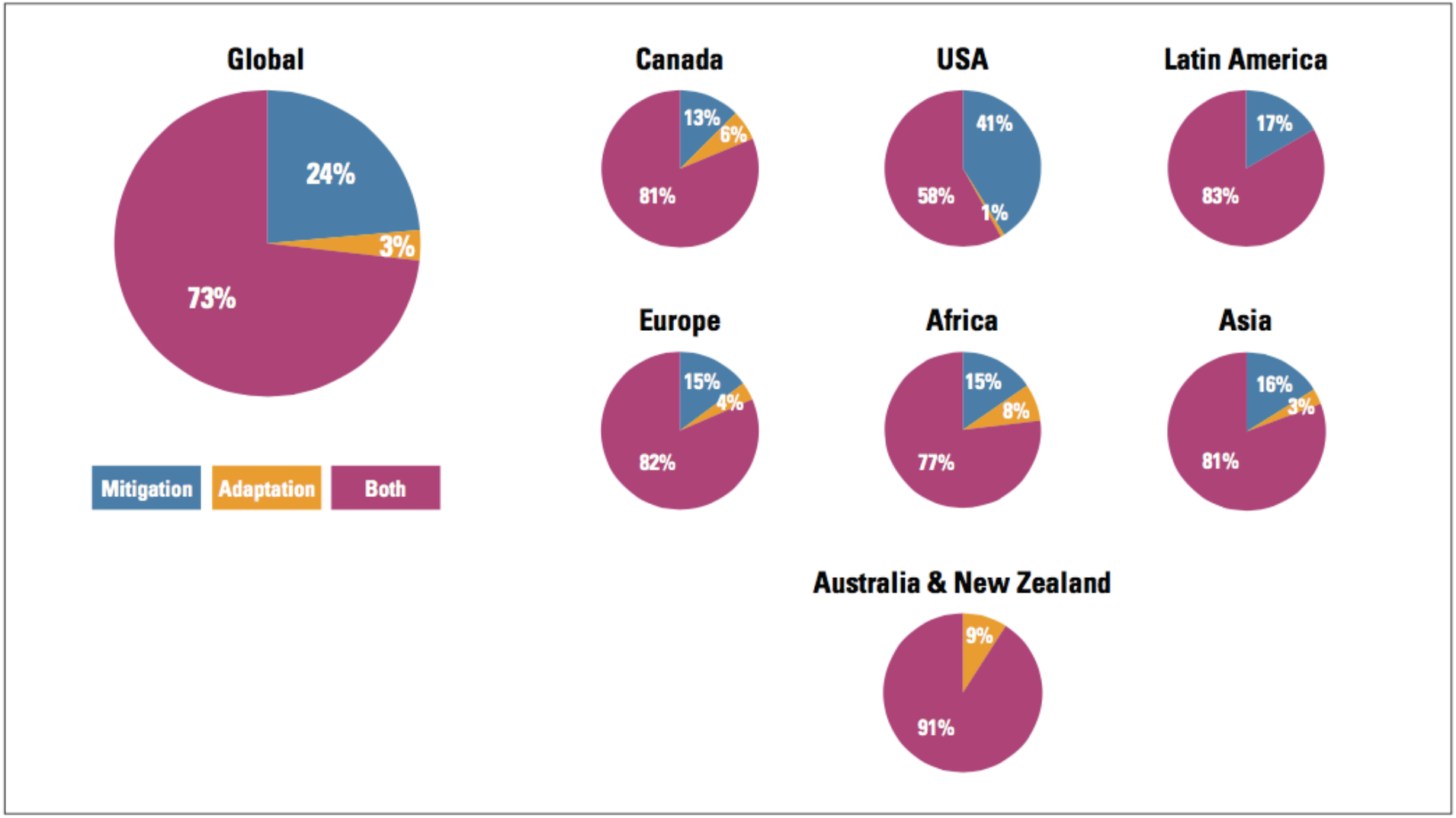
Analysis of extreme heat vulnerability: Scales of spatial analysis



Joyce Klein Rosenthal, PhD
Columbia University
Graduate School of Architecture, Planning & Preservation
ICUC9 – July 24, 2015

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

FIGURE 1 | FOCUS OF CLIMATE CHANGE PLANNING AND ACTION



City Climate Hazard Taxonomy

C40's classification of city-specific climate hazards

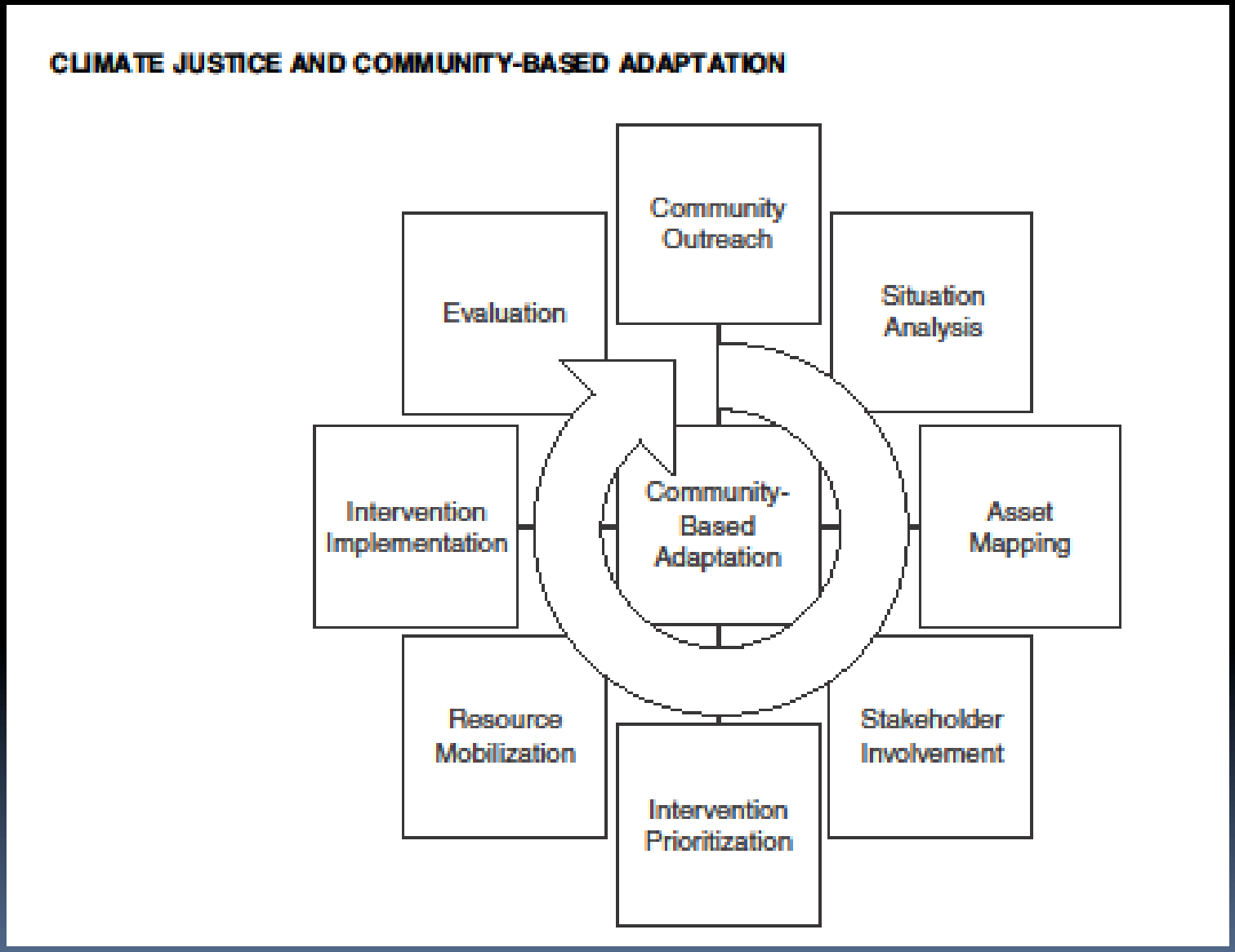
C40 CITIES

Bloomberg Philanthropies

ARUP

March 2015 – C40 Launches City Climate Hazard Taxonomy for Public Comment
http://www.c40.org/blog_posts/c40-launches-city-climate-change-hazard-taxonomy-for-public-comment

Community-based adaptation planning framework



Ebi & Semenza, 2008

Heat-health vulnerability mapping

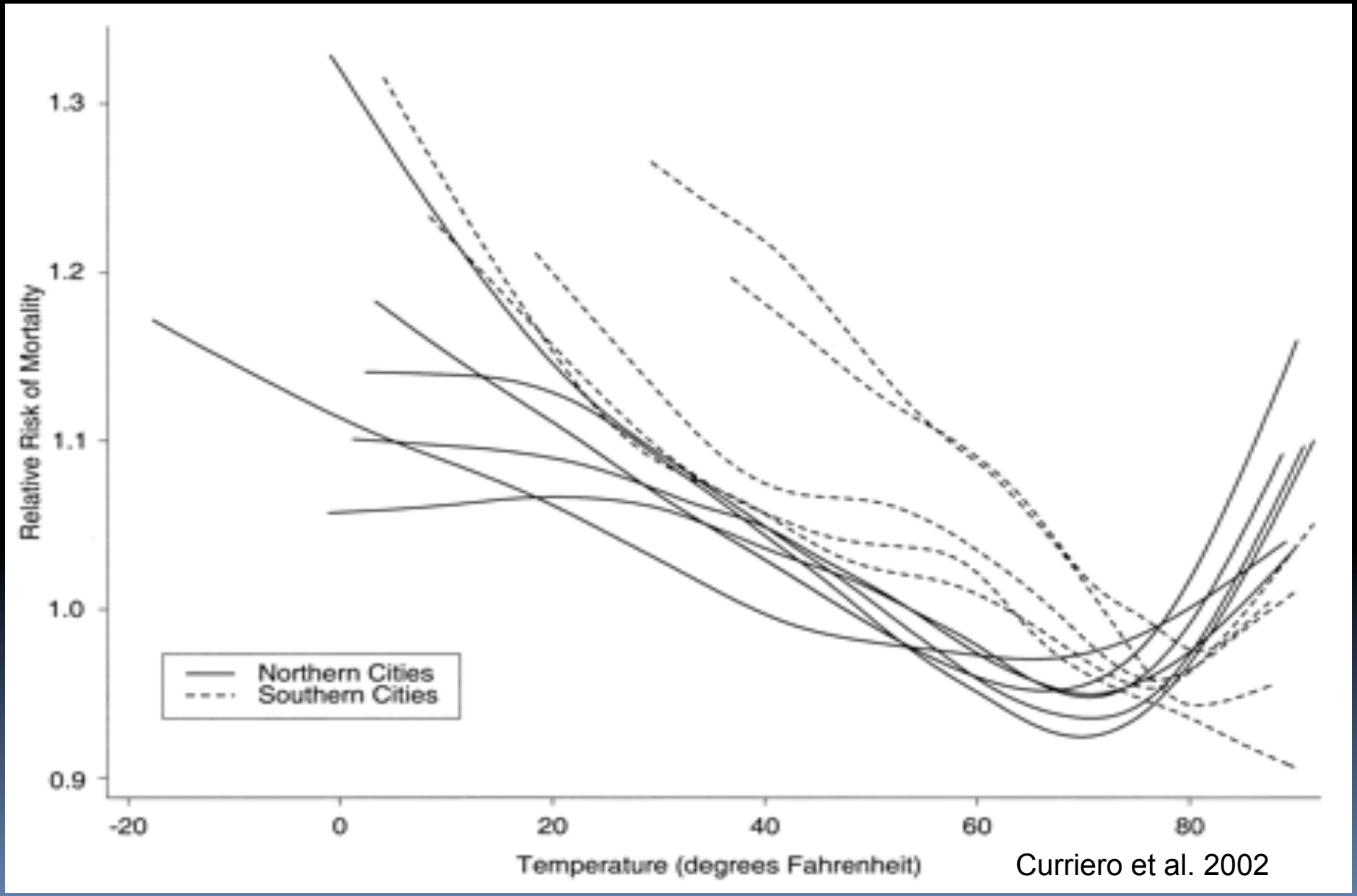
Table 1. Heat-health vulnerability data, 39,794 U.S. census tracts.

Category	Data source (year)	Variable definition	Percent mean (range)
Demographic variables	U.S. Census (2000)	Percent population below the poverty line	12.57 (0.00–100.00)
		Percent population with less than a high school diploma	19.97 (0.00–85.88)
		Percent population of a race other than white	30.20 (0.00–100.00)
		Percent population living alone	10.28 (0.00–68.86)
		Percent population ≥ 65 years of age	12.21 (0.00–94.28)
		Percent population ≥ 65 of age living alone	27.38 (0.00–100.00)
Land cover	National Land Cover Database (2001)	Percent census tract area not covered in vegetation	61.15 (0.03–100.00)
Diabetes prevalence	Behavioral Risk Factor Surveillance System (2002)	Percent population ever diagnosed with diabetes	6.95 (2.38–11.10)
Air conditioning	American Housing Survey (2002)[a]	Percent households without central AC	44.43 (2.10–95.13)
		Percent households without any AC	18.47 (0.00–95.13)

[a]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.

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

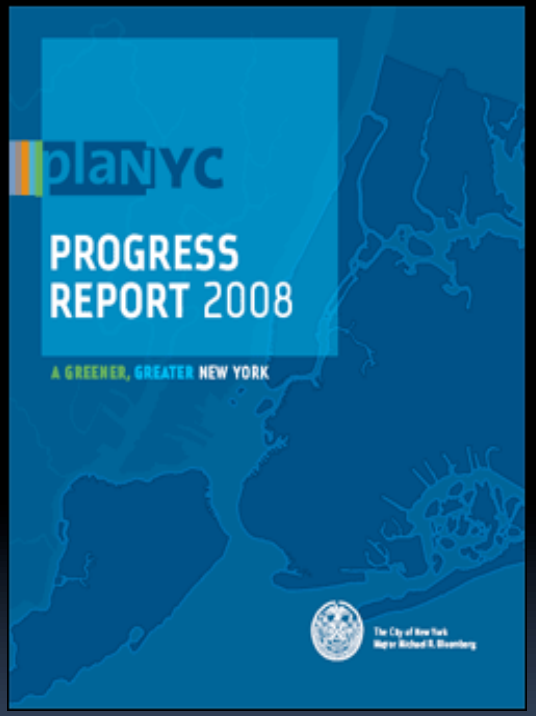
Temperature-mortality relation for 11 US cities, 1973–1994



Curriero et al. 2002

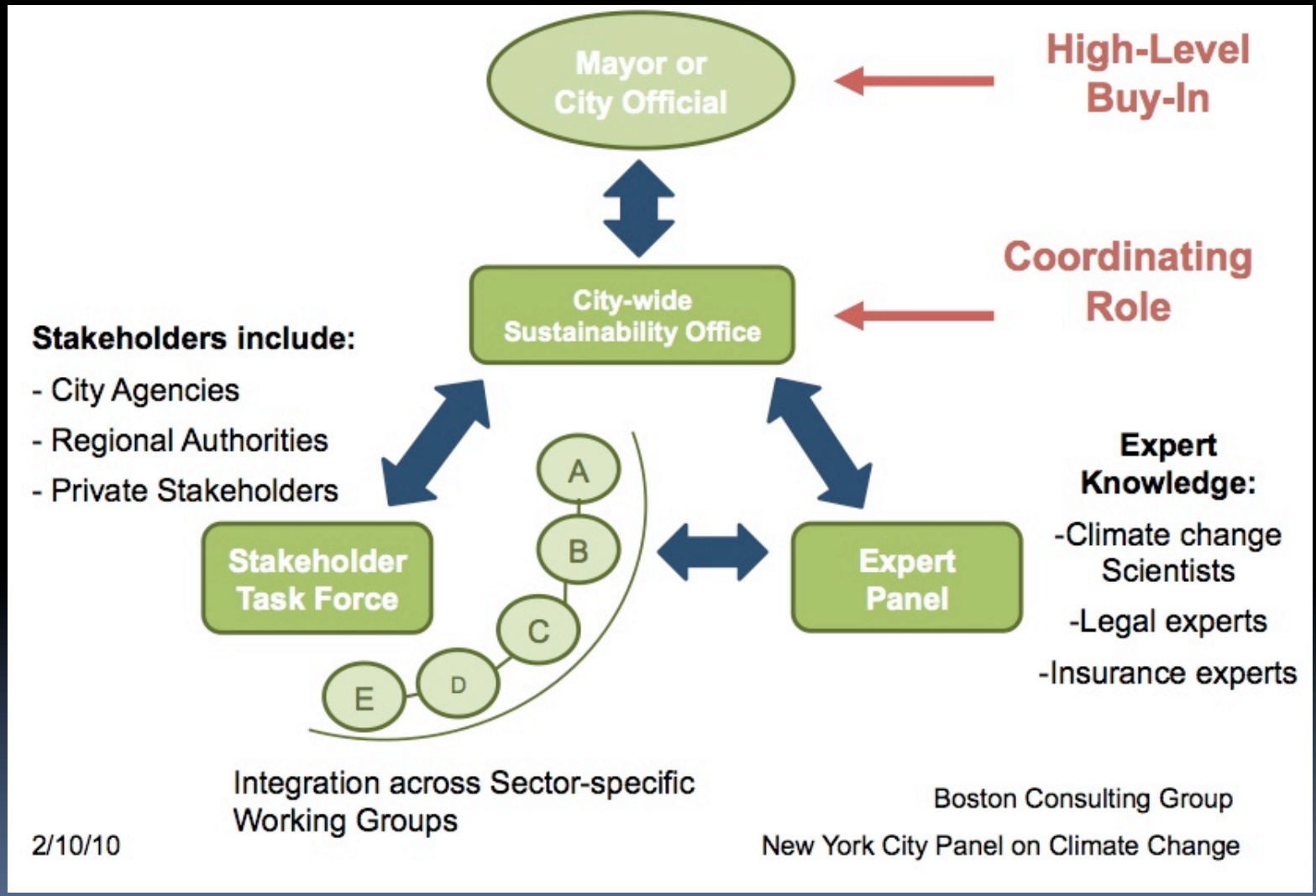
New York City's Sustainability Plan: PlaNYC 2030

Released April 2007



Available at http://www.nyc.gov/html/planyc2030/

New York City's Adaptation Planning Process



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: MRR_{65+}

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

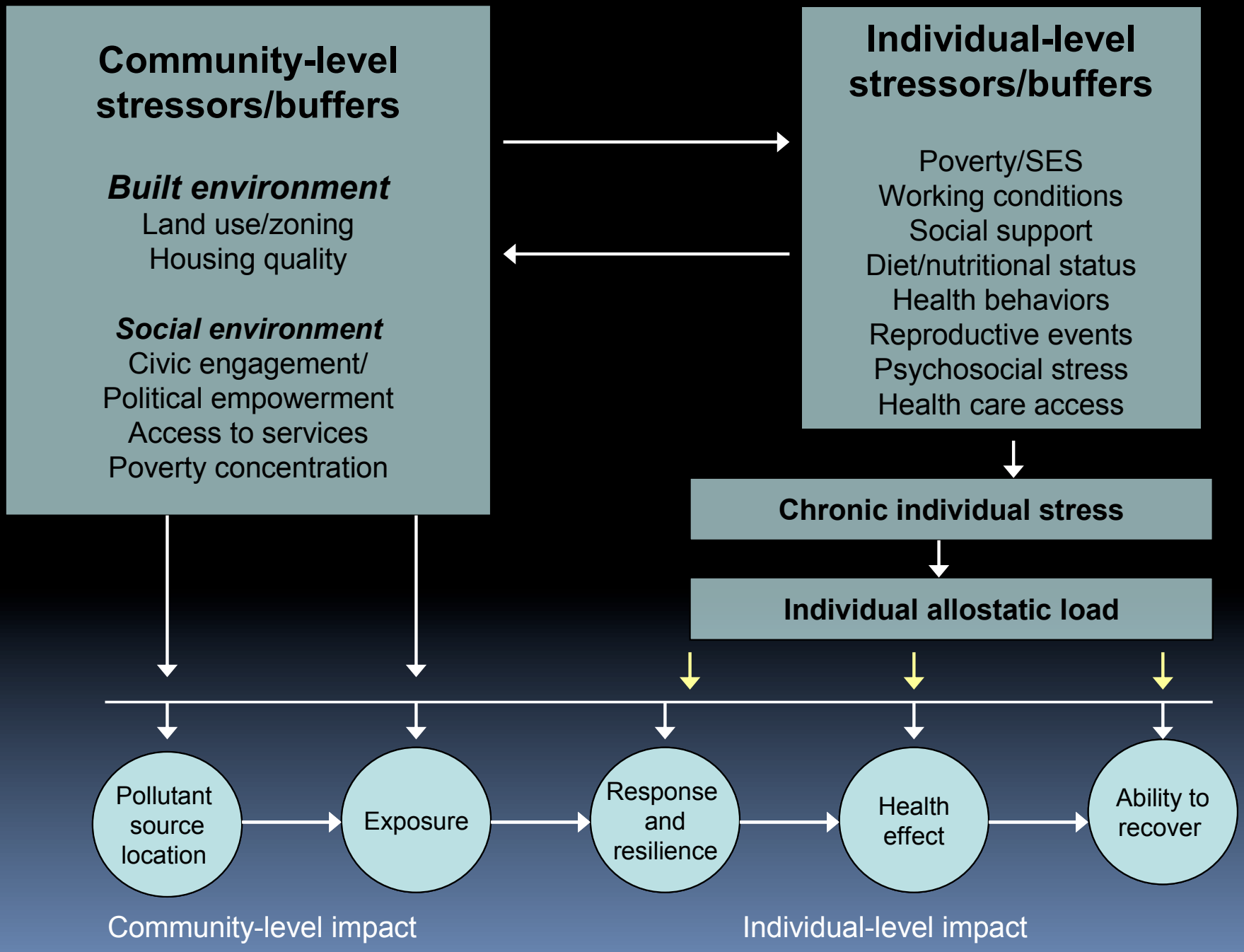
MRR_{65+} = (Σ M_{H65}/D_HI_{100})/(Σ M_{W65}/D_W)

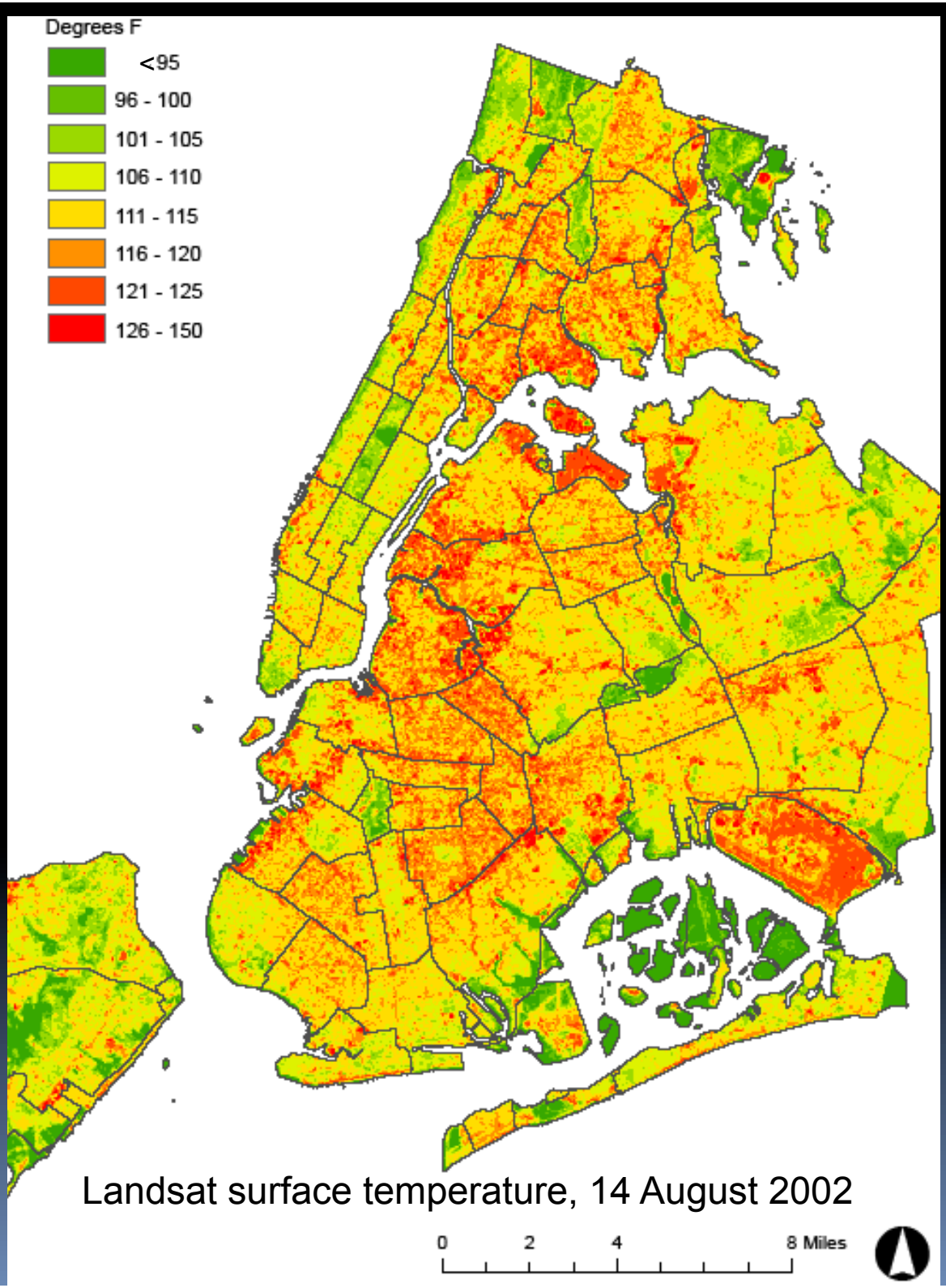
MH65	Natural cause deaths, age 65+, on days when HI>=100.
D_HI100	Number of days, with HI>= 100 during warm season
M_{W65}	Natural cause deaths, age 65+
D_W	Number of days, warm season

Aggregated from census tracts for each of 59 CDs and 42 UHF neighborhoods.

Model for Neighborhood-Health Interactions

Adapted from Morello-Frosch & Shenassa, 2006





Landsat surface temperature, 14 August 2002

Urban heat island & urban design

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

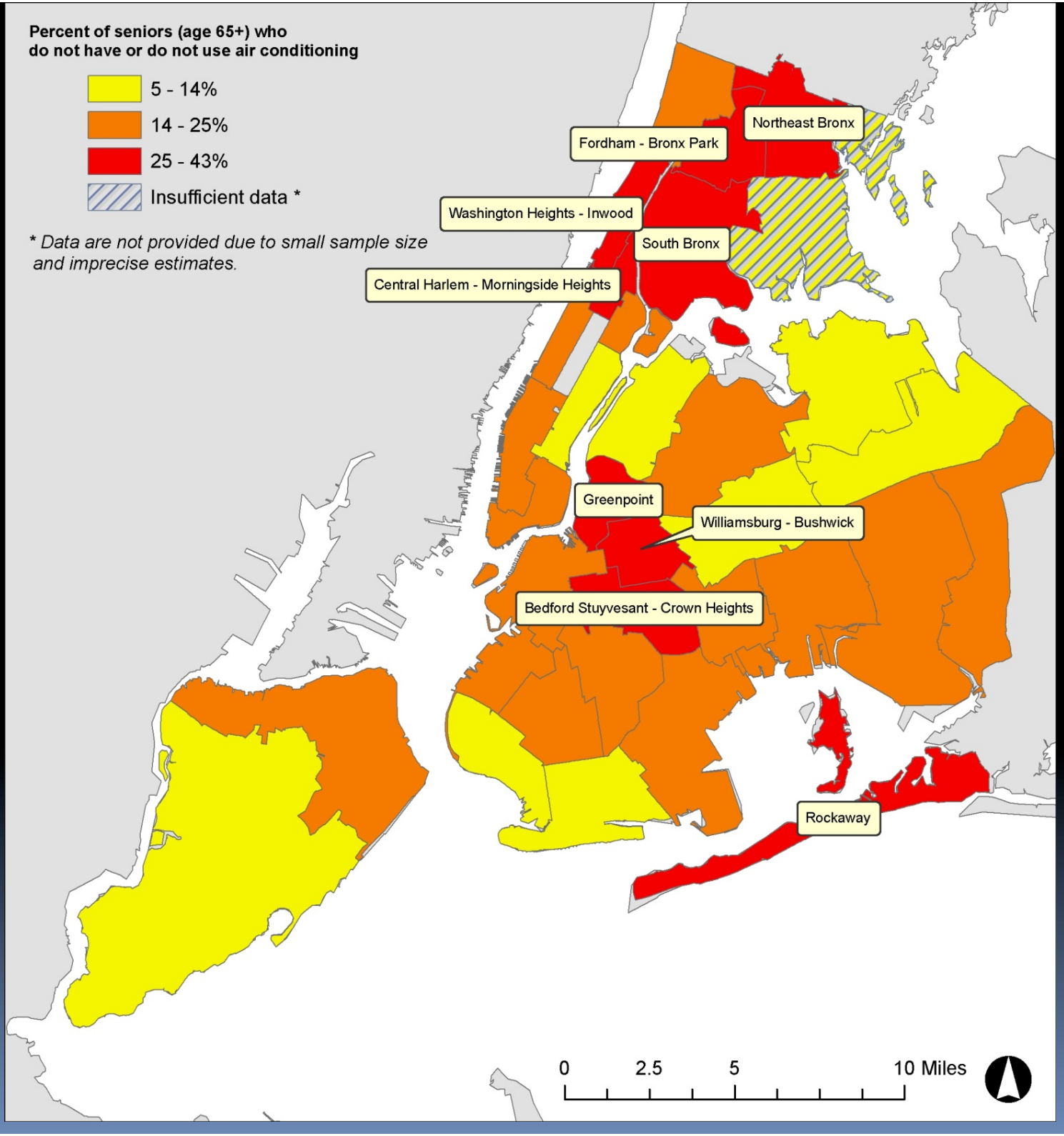
Methods

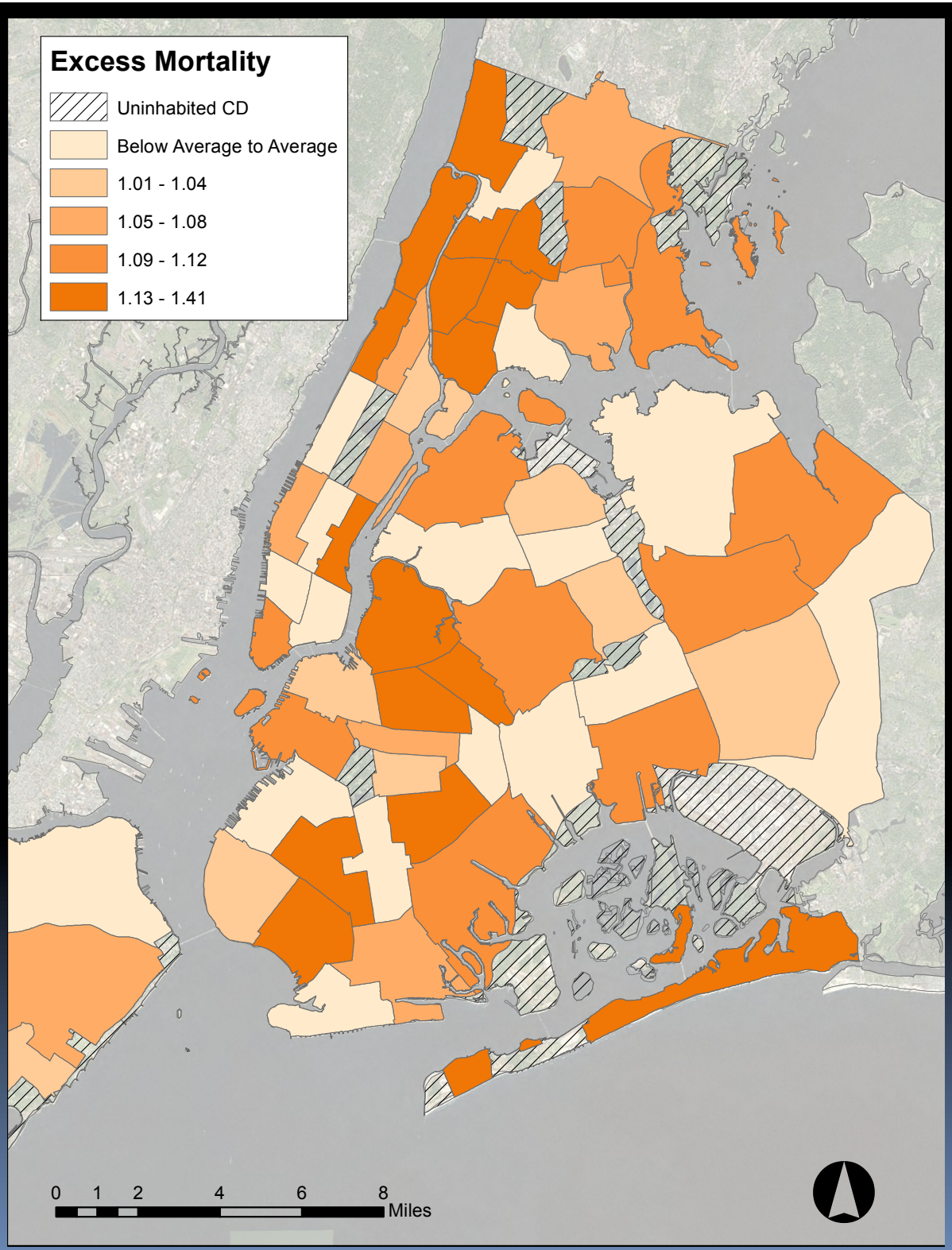
- Select factors for analysis
- Ecologic analysis: Bivariate linear regression of MRR_{65} with neighborhood-level characteristics
- Assess correlation of factors with each other; stratified analysis for potential modifiers.
- Multivariate regression for heat-related mortality and risk factors (UHI and 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





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 4
Mortality rate ratio (MRR_{65+}) models: ordinary least squares (OLS) linear regression.

Predictor variables	R^2	Adj. R^2	Pr > F	*Unstandardized coefficient*			*Standardized coefficient*		t	p-Value
				B	Std. Error of B	95% CI for B (lower, upper)	β	95% CI for β (lower, upper)		
UHF-neighborhood models										
1. Homeownership (percent)	0.17	0.15	0.007	−0.003	0.001	(−0.004, −0.001)	−0.413	(−0.704, −0.122)	−2.87	0.007
2. Deteriorating or dilapidated buildings[a]	0.159	0.138	0.01	0.013	0.005	(0.003, 0.023)	0.399	(0.102, 0.696)	2.72	0.01
3. Percent below poverty	0.156	0.135	0.01	0.004	0.002	(0.001, 0.007)	0.395	(0101, 0.688)	2.72	0.01
4. Impervious cover[b]	0.23	0.186	0.008	0.003	0.001	(0.0005, 0.006)	0.346	(0.054, 0.637)	2.4	0.021
Hypertension[b]				0.004	0.0016	(0.001, 0.007)	0.376	(0.085, 0.668)	2.613	0.013
5. Air conditioning access, age 65+	0.117	0.094	0.027	−0.004	0.002	(−0.008, −0.001)	−0.341	(−0.642, −0.041)	−2.3	0.027
6. Homes near structures rated good or excellent	0.168	0.147	0.007	−0.003	0.001	(−0.006, −0.001)	−0.409	(−0.701, −0.118)	−2.838	0.007
Community District models										
1. Property tax delinquencies[c]	0.112	0.096	0.01	0.01	0.004	(0.003, 0.018)	0.334	(0.084, 0.584)	2.677	0.01
2. Serious housing violations[d]	0.104	0.089	0.013	0.001	0.0005	(0.0003, 0.002)	0.323	(0.156, 0.830)	2.577	0.013
3. Percent below poverty	0.065	0.049	0.051	0.003	0.001	(0.00, 0.006)	0.255	(−0.001, 0.511)	1.991	0.051
4. Percent Asian population	0.093	0.077	0.019	−0.005	0.002	(−0.008, −0.001)	−0.305	(−0.558, −0.053)	−2.422	0.019

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

[a] Percent of households, 2002; influential point UHF 501 removed (Port Richmond, Staten Island).
[b] Influential point UHF 101 removed (Kingsbridge-Riverdale, the Bronx).
[c] 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.
[d] 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

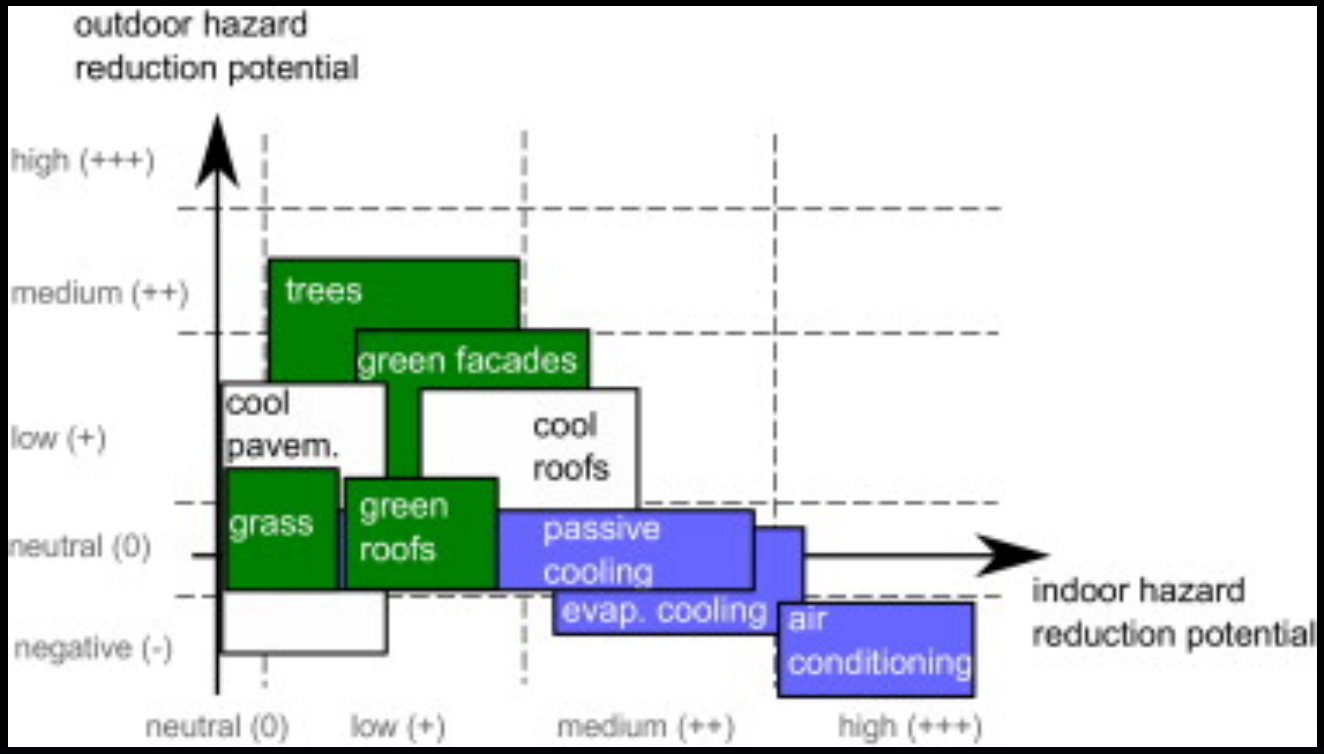
- Built environment/housing quality metrics have the strongest correlation with MRR_{65+}:
  - Property tax delinquencies
  - Residential Air Conditioning access/use 65+
  - Housing violations
  - Rates of homeownership
  - Poverty rates at UHF-level
- Weaker correlations with:
  - SES measures: poverty 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

Participatory environmental research and urban design – a new street science?

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
Reduces Emissions

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

Green and cool roofs

Urban forestry

Better insulated buildings

Water cooling systems

Adaptation
Reduces Harm

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