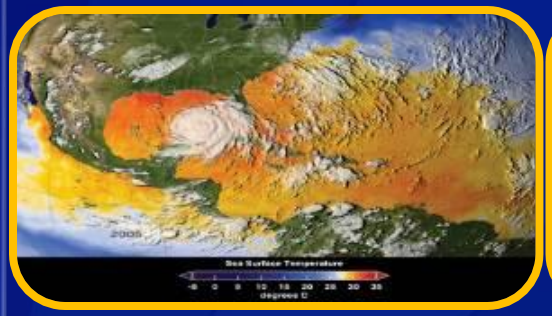
Heat-Related Morbidity and Mortality: What we know and how we can prevent it




George Luber, PhD

Chief,
Climate and Health Program

National Center for Environmental Health
Centers for Disease Control and Prevention

Presentation Outline

- An overview of the health effects of heat exposure and the epidemiology of heat waves
- A review of current and future drivers of heat morbidity and mortality
- Adaptation and mitigation actions for heat resilience.

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Overview of Heat-Related Illness

- Heat Cramps: Is a milder form of heat illness that affect people who sweat heavily during strenuous activity depleting the body's salt and fluids
- Heat Exhaustion: A milder form of heat-related illness that can develop after several days of exposure to high temperatures
  - Characterized by paleness, fatigue, muscle cramps, dizziness, headache, nausea or vomiting, and fainting. The skin is typically cool and moist.
- Heat Stroke: A severe form of hyperthermia where the body is unable to regulate its temperature
  - The sweating mechanism fails, and the body is unable to cool down.
  - Characterized by red, hot, and dry skin (no sweating); rapid, strong pulse; throbbing headache; dizziness; nausea; confusion; and unconsciousness.

Heat Waves

- **High mortality**
  - More deaths than hurricanes, lightning, tornadoes, floods, and earthquakes combined
  - From 1999–2003, total of 3,442 reported heat-related deaths. Annual mean of 688 (MMWR 2006)
- **Lack of public recognition**
  - No damage to infrastructure (silent killer)
  - Many deaths go unreported or unattributed
- **Every death is preventable**

Heat Wave Studies

1980 St. Louis

- 1st to highlight the magnitude of mortality from heat waves
- All cause mortality increased 57%

1993 Philadelphia

- Identified cardiovascular mortality as a major cause of death associated with extreme heat

1995 Chicago

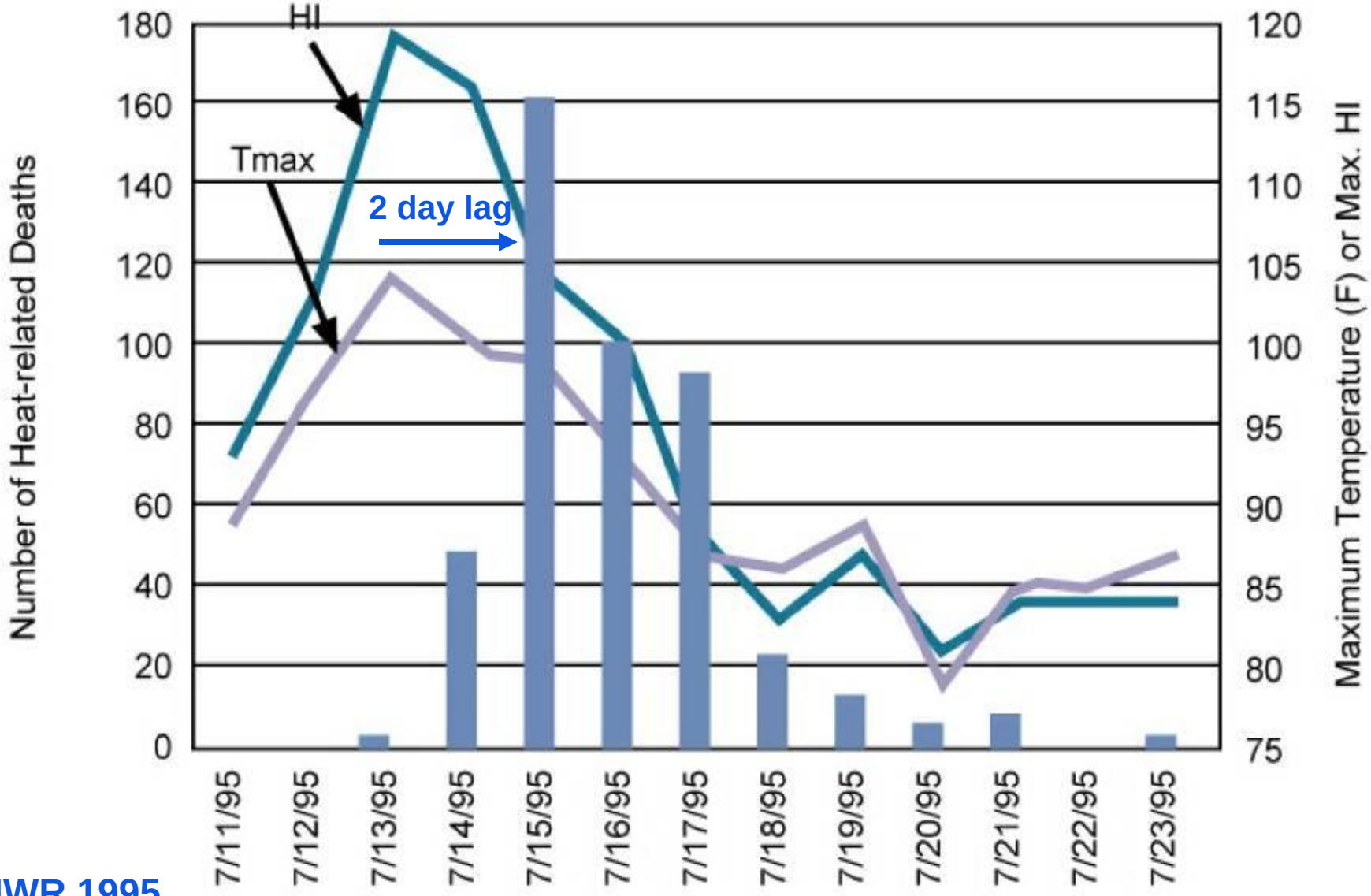
- Redefined heat-related death as used by medical examiners
- Assisted with the development of a Heat Wave Response Plan

Semenza JC, Rubin CH, Falter KH, Selanikio JD, Flanders WD, Howe HL, et al. 1996. Heat-related deaths during the July 1995 heat wave in Chicago. New England Journal of Medicine 335(2):84-90.

Wainwright SH, Buchanan SD, Mainzer HM, Parrish RG, Sinks TH. 1999. Cardiovascular mortality--the hidden peril of heat waves. Prehosp Disaster Med. 1999 Oct-Dec;14(4):222-31

Jones TS, Liang AP, Kilbourne EM, Griffin MR, Patriarca PA, Wassilak SG, Mullan RJ, Herrick RF, Donnell HD Jr, Choi K, Thacker SB. 1982. Morbidity and mortality associated with the July 1980 heat wave in St Louis and Kansas City, Mo. JAMA. 247(24):3327-31.

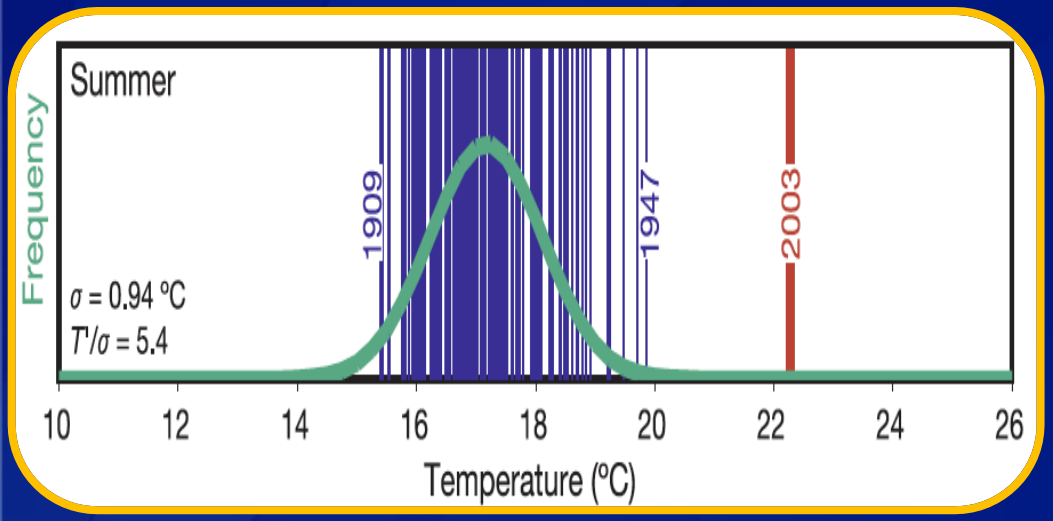
Heat Related Deaths in Chicago in July 1995



MMWR 1995

Some Extreme Events will be well beyond historical experience

European Heat Wave of 2003



Confirmed Mortality

UK	2,091
Italy	3,134
France	14,802
Portugal	1,854
Spain	4,151
Switzerland	975
Netherlands	1,400-2,200
Germany	1,410
TOTAL	29,817-30,617

Haines et al. *Public Health* 2006;120:585-96.

Vandentorren et al. *Am J Public Health 2004; 94(9):1518-20.*

Lessons Learned

Risk factors for hyperthermia:

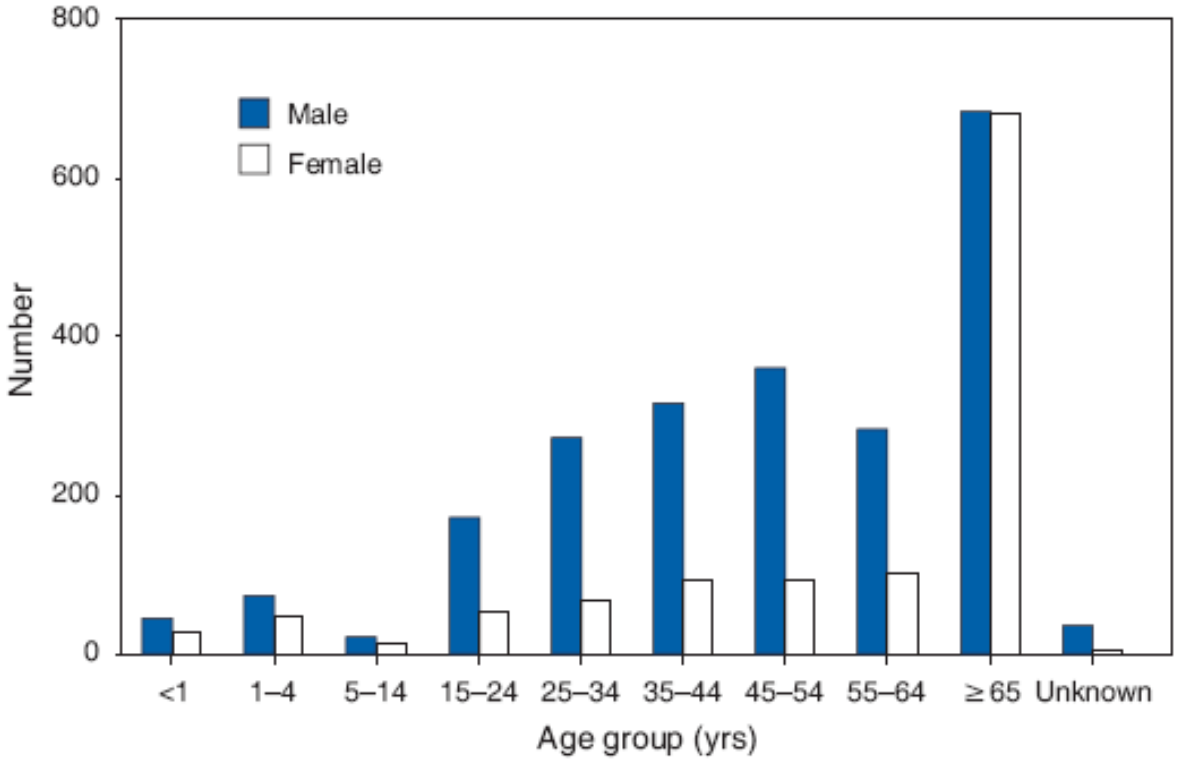
Individual

Community Characteristics

- Age
- Underlying medical conditions / mental illness
- Income and poverty status
- Homelessness
- Social isolation
- Access to health care and cooling facilities
- Neighborhood characteristics: land use/land cover, crime rate, housing type, urban heat island

Risk Factor: Age / Gender

FIGURE. Number of heat-related deaths,* by sex and age group — United States, 1999–2003



* Exposure to extreme heat is reported as the underlying cause of or a contributing factor to death (N = 3,442).

CDC. 2006. Heat-related deaths--United States, 1999-2003. MMWR - Morbidity & Mortality Weekly Report 55(29):796-798.

Risk Factor: Underlying Medical Conditions

Table 3. Medical and living conditions by case patient or control subject status,[a] Chicago, 1999

Variables	Case patients n=63 n (%)	Control subjects n=77 n (%)	OR (95% CI)
Medical/psychiatric conditions			
Heart condition	30 (62.5)	11 (15.5)	7.2 (2.5–20.8)*
Psychiatric illness[b]	23 (51.1)	13 (18.3)	5.7 (1.9–16.8)*
Depression	17 (40.5)	12 (17.1)	4.1 (1.3–12.5)*
Other mental problem	11 (26.8)	2 (2.9)	11.7 (1.5–92.2)*[c]
Living conditions			
Lived alone	35 (56.5)	23 (30.3)	5.4 (1.8–15.9)*
Did not leave home daily[d]	39 (67.2)	25 (33.8)	4.5 (1.7–11.7)*
Lived on top floor	31 (50.0)	15 (19.5)	4.0 (1.7–9.3)*
Had annual income <$10,000	26 (72.2)	25 (42.4)	3.1 (1.0–9.7)*[c]
Had working fan	56 (90.3)	67 (88.2)	0.71 (0.2–2.3)
Had working air conditioner	10 (15.9)	44 (57.9)	0.12 (0.0–0.3)*

Naughton et al. Heat Related Mortality During a 1999 Heat Wave in Chicago. AJPM **22**:4, 221-227. 1999.

Drugs that may increase risk of heat-related illness

Psychotropics (e.g. haloperidol or chlorpromazine)

Medications for Parkinson's disease

Tranquilizers (e.g. phenothiazines, butyrophenones, and thiozanthenes)

Diuretic medications ("water pills")

Important Co-Morbidities

Table 1. Conditions which increase the risk of dying in a heat-wave

	Main ICD[a] chapters
Diabetes mellitus, other endocrine disorders	E10–E14
Organic or mental disorders, dementia, Alzheimer's (mild, moderate, severe)	F00–F09
Mental and behavioural disorders due to psychoactive substance use, alcoholism	F10–F19
Schizophrenia, schizotypal and delusional disorders	F20–F29
Extrapyramidal and movement disorders (e.g. Parkinson's disease)	G20–G26
Cardiovascular disease, hypertension, coronary artery disease, heart conduction disorders	I00–I99
Diseases of the respiratory system, chronic lower respiratory disease (COPD, bronchitis)	J00–J99
Diseases of the renal system, renal failure, kidney stones	N00–N39

WHO Regional Office for Europe. 2009.. Improving public health responses to extreme weather/heat-waves. http://www.euro.who.int/__data/assets/pdf_file/0010/95914/E92474.pdf. accessed 28 Dec 2013.

Risk Factor: Social Isolation

Table 4. Social contact and behaviors during the heat wave by case patient and control subject status,[a] Chicago, 1999

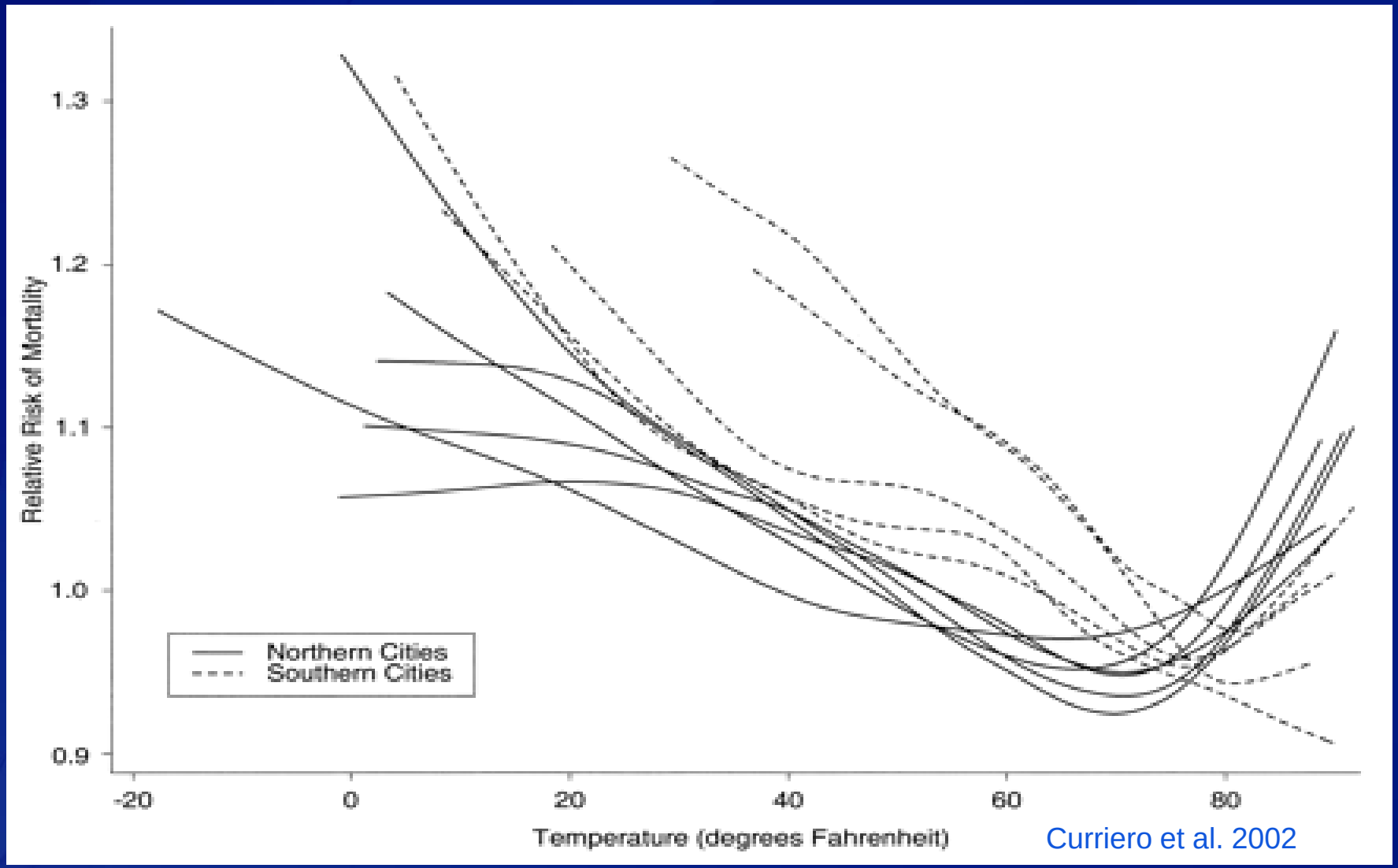
Variable	Case patients n=63 n (%)	Control subjects n=77 n (%)	OR (95% CI)
Social contacts			
Participated in group activities (clubs, religious or support)	26 (47.3)	55 (73.3)	0.3 (0.1–0.7)*
Friends in Chicago	52 (85.3)	67 (87.0)	0.9 (0.4–2.3)
Relatives in Chicago	52 (88.1)	66 (85.7)	1.3 (0.4–3.7)
Pet in home	11 (17.5)	28 (36.4)	0.3 (0.1–0.8)*
Behaviors during heat wave[b]			
Took extra baths/showers	11 (37.9)	48 (64.0)	0.3 (0.1–0.9)*
Visited cooling center(s)	1 (1.9)	7 (9.2)	0.2 (0.0–1.5)

Naughton et al. Heat Related Mortality During a 1999 Heat Wave in Chicago. AJPM **22**:4, 221-227. 1999.

Risk Factor: Crime

Risk Factor: Building Type

Location Matters:
Temperature-Mortality Relation for 11 U.S. Cities, 1973–1994



Curriero et al. 2002

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Future Drivers of Heat-Related Morbidity and Mortality

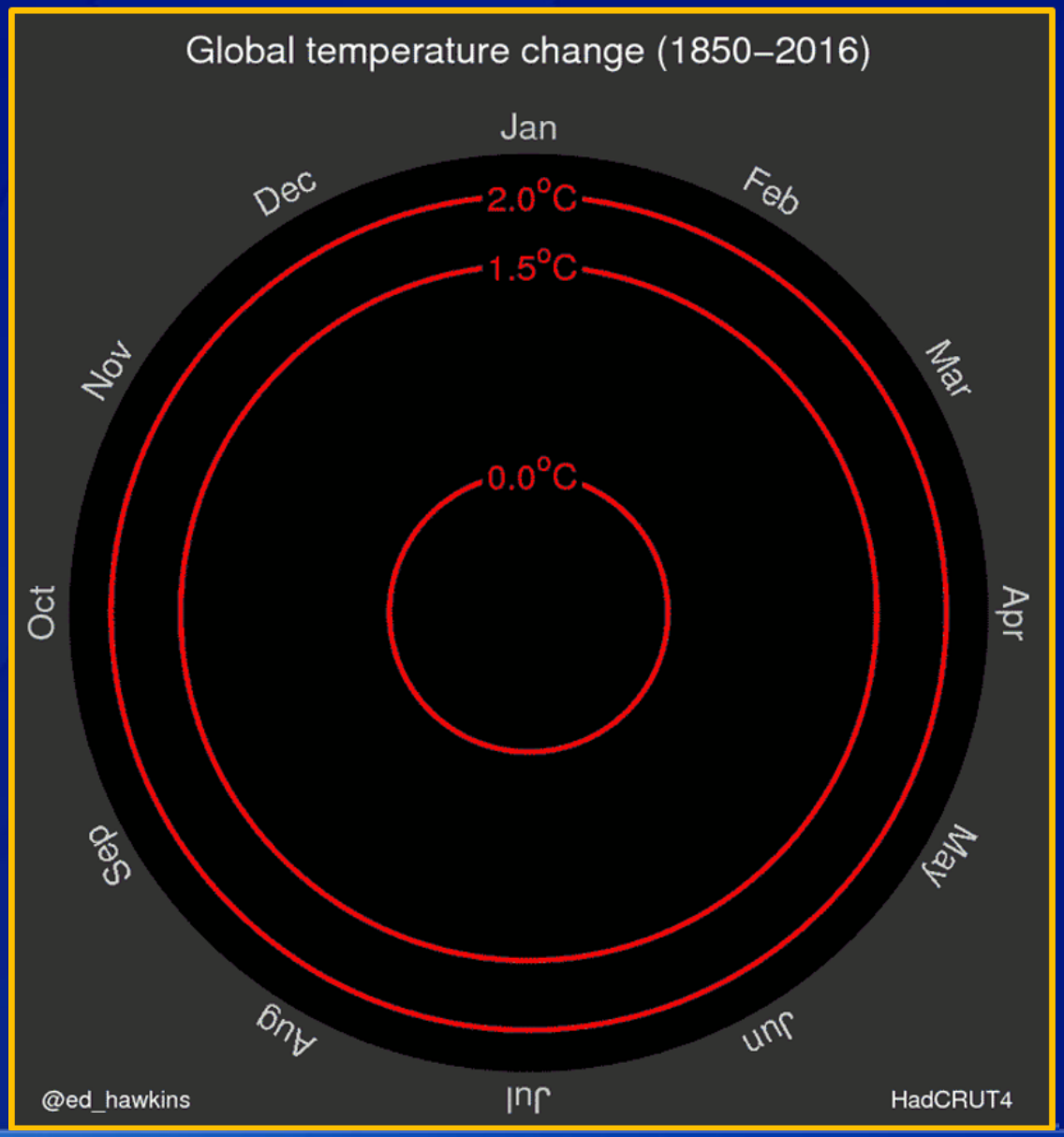
- **Climate Change**
  - Climate Variability: Frequency of extreme events
- **Demographic change**
  - Aging population
  - Urbanization
- **Built environments**
  - Urban heat island
  - Stagnant air masses

Climate Change Science: Key Findings

- Climate change is altering both the average (mean) global temperature *and* the global frequency of extremely hot temperatures (variance)

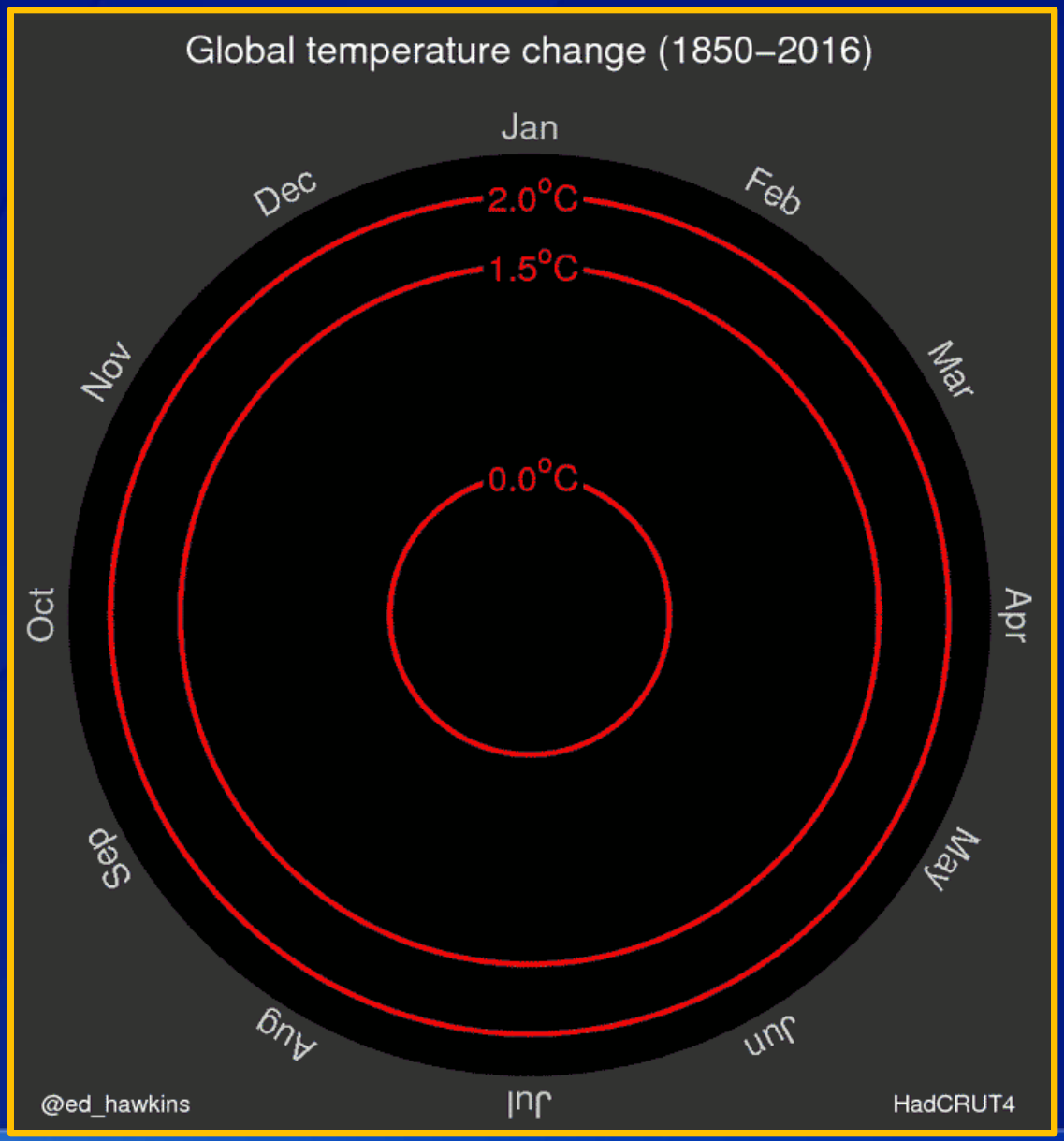
- The impacts of climate change will vary significantly by region; some places are warming faster than others.

Global Average Temperatures have been increasing



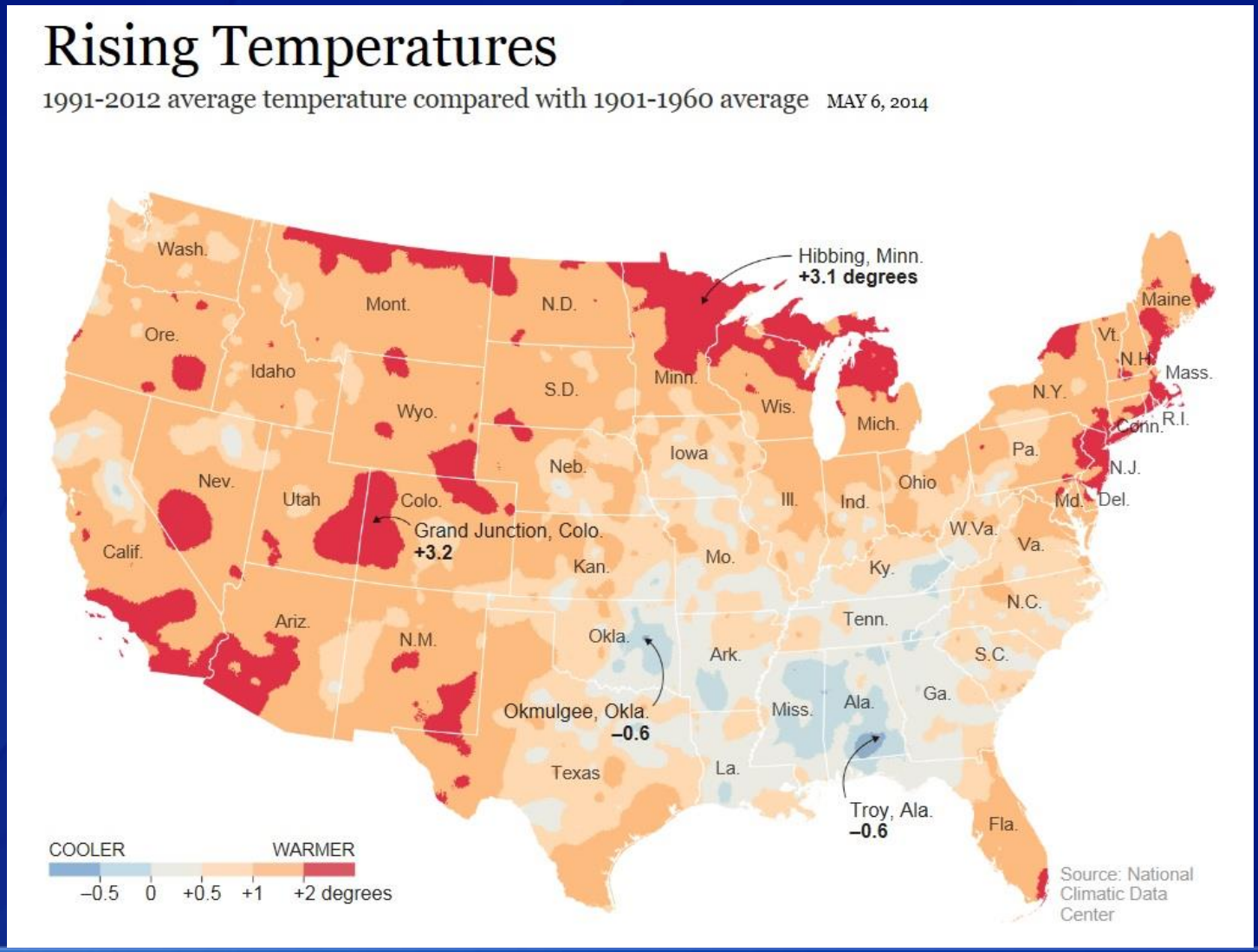
Source: http://www.climate-lab-book.ac.uk/2016/spiralling-global-temperatures/

Global Average Temperatures have been increasing

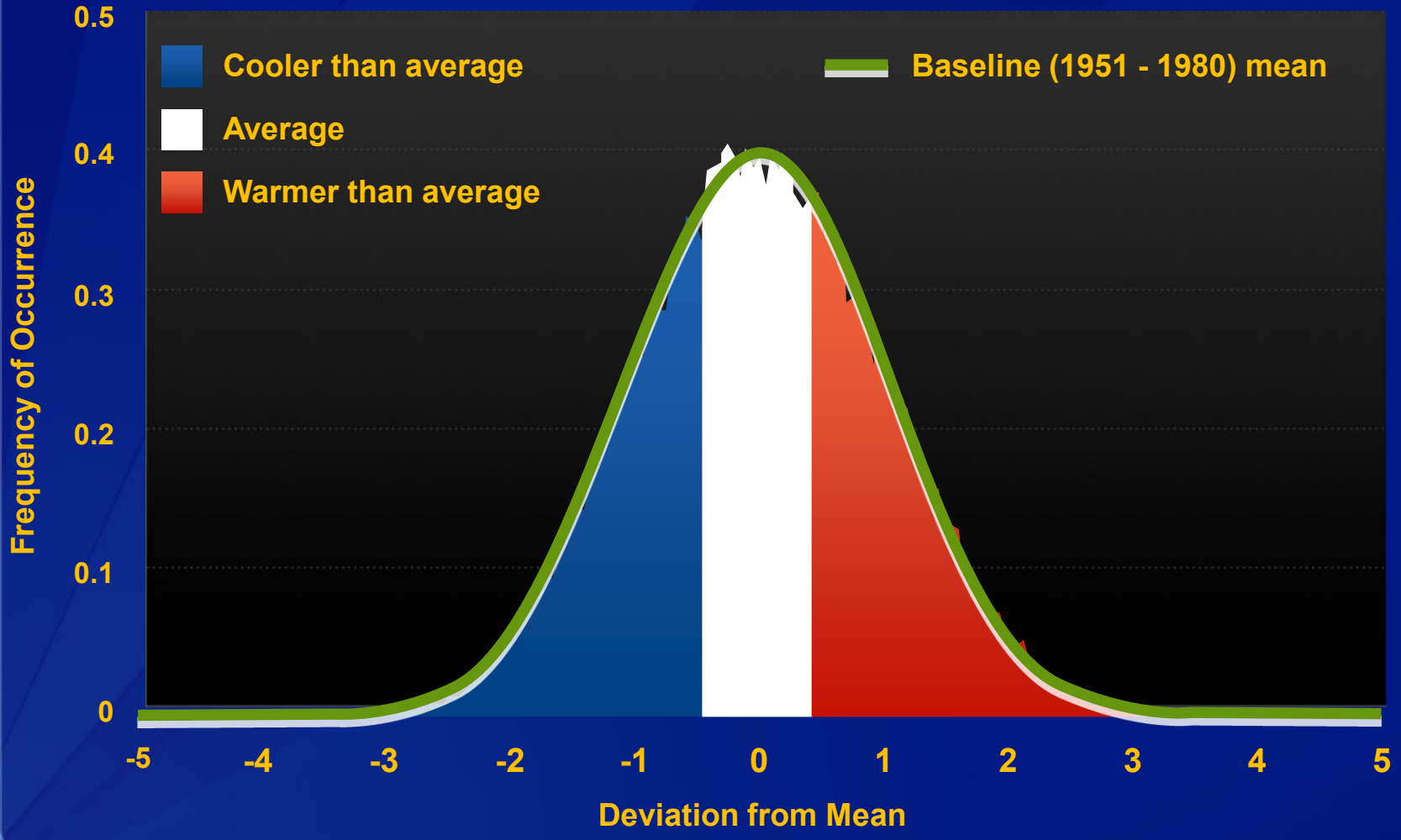


Source: http://www.climate-lab-book.ac.uk/2016/spiralling-global-temperatures/

Warming has varied significantly by region (observed record)

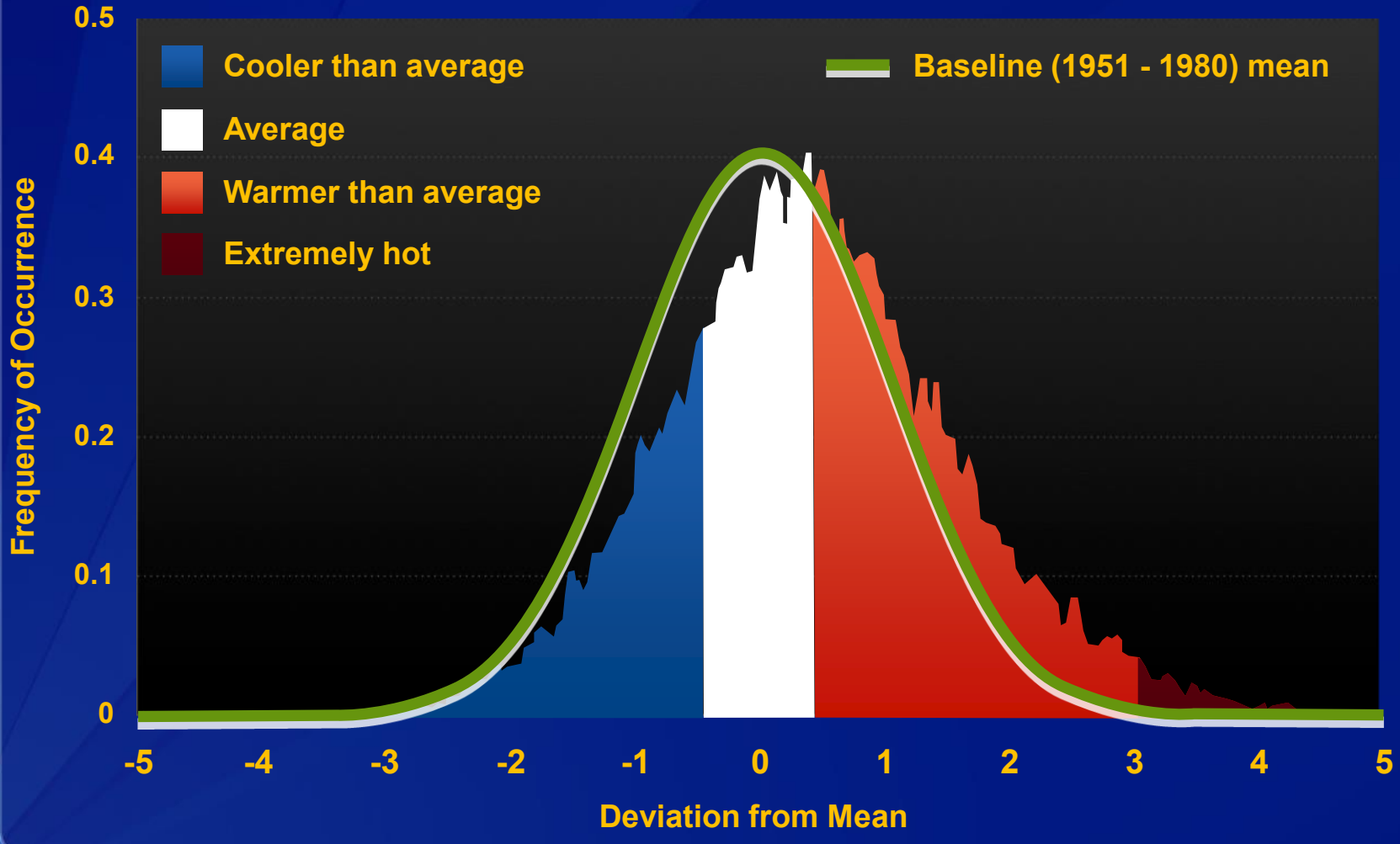


Summer Temperatures Have Shifted 1951 – 1980



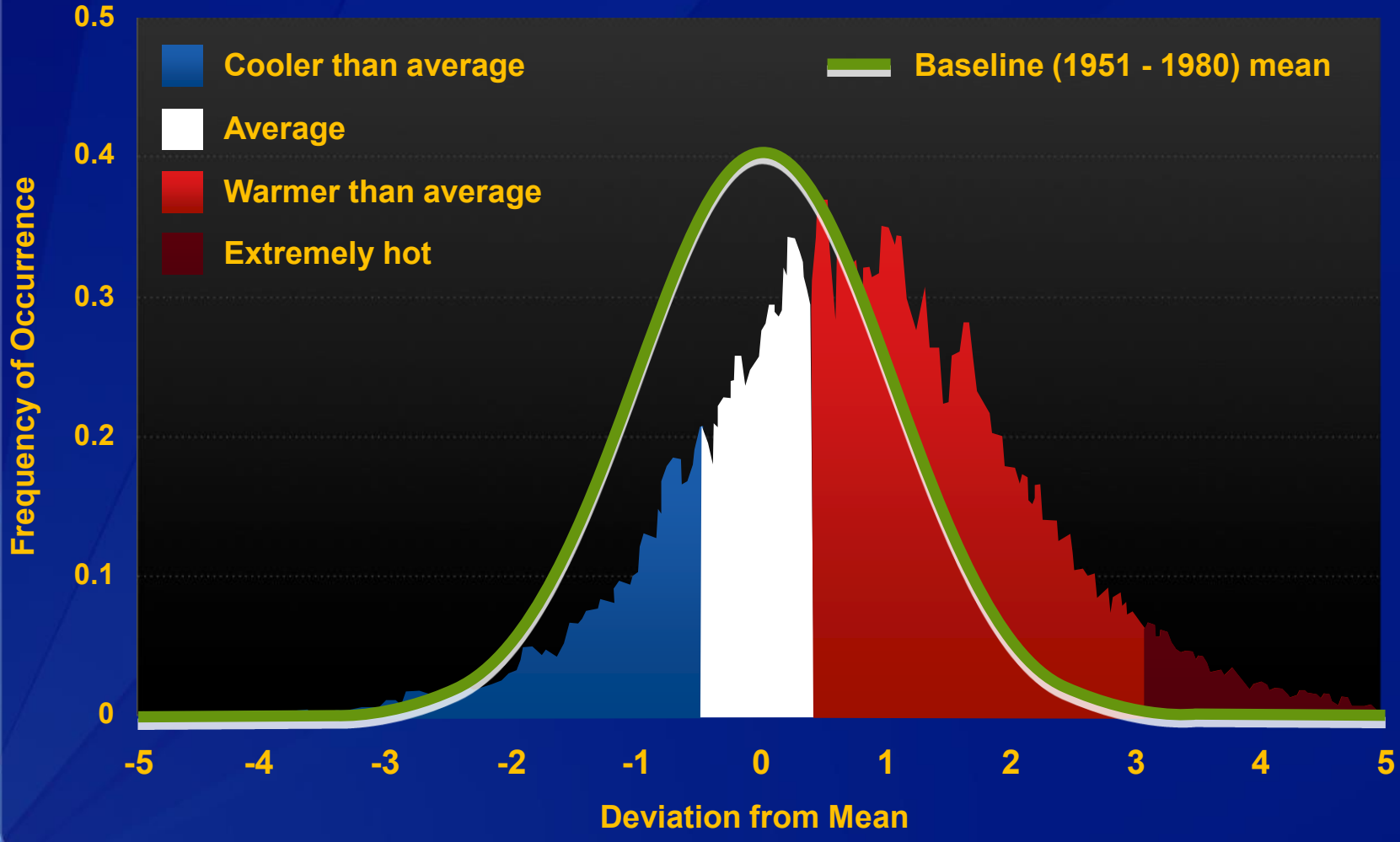
Source: NASA/GISS; Hansen, et al., "Perceptions of Climate Change," *Proc. Natl. Acad. Sci. USA* 10.1073, August 2012

Summer Temperatures Have Shifted 1981 – 1991



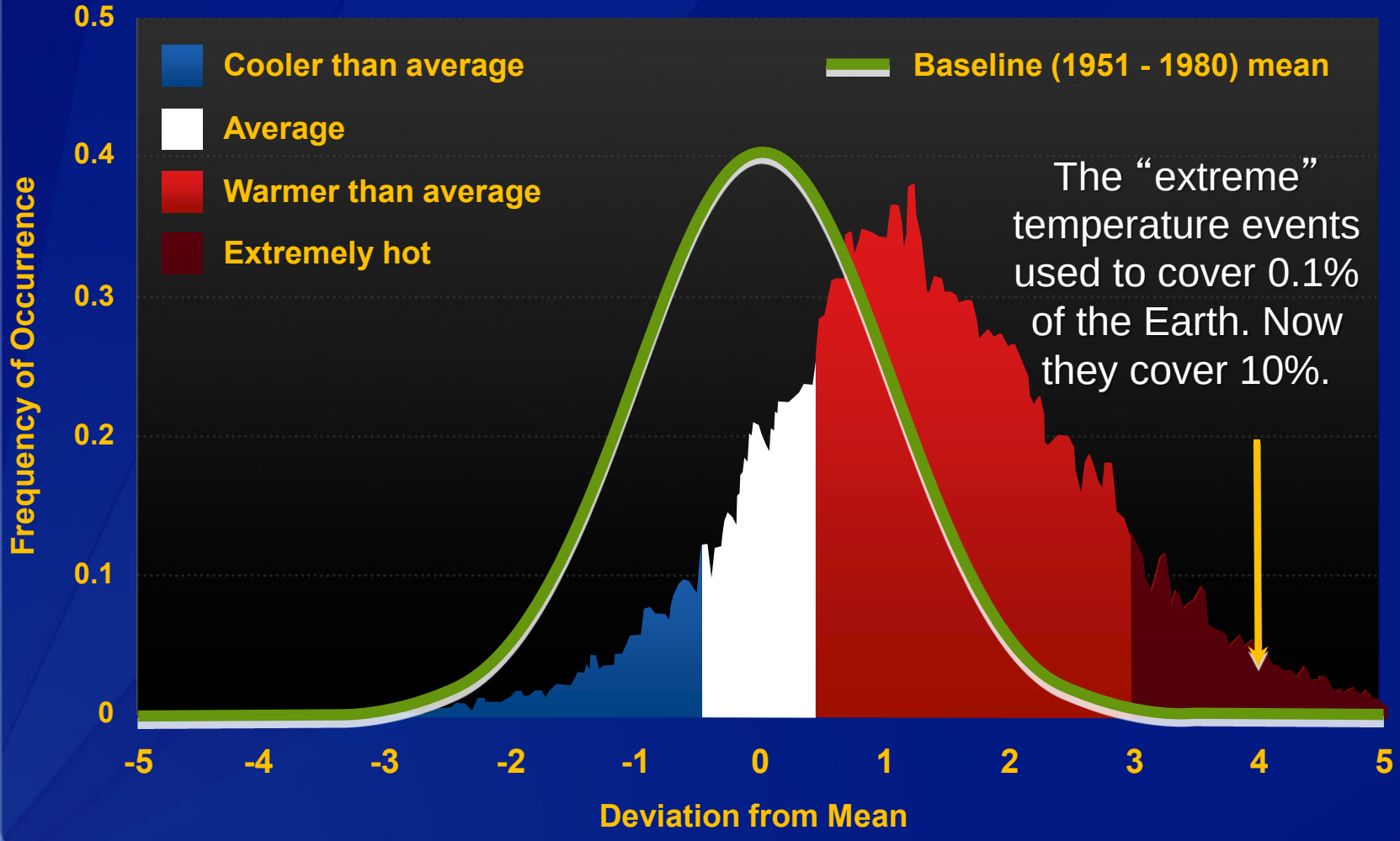
Source: NASA/GISS; Hansen, et al., "Perceptions of Climate Change," *Proc. Natl. Acad. Sci. USA* 10.1073, August 2012

Summer Temperatures Have Shifted 1991 – 2001



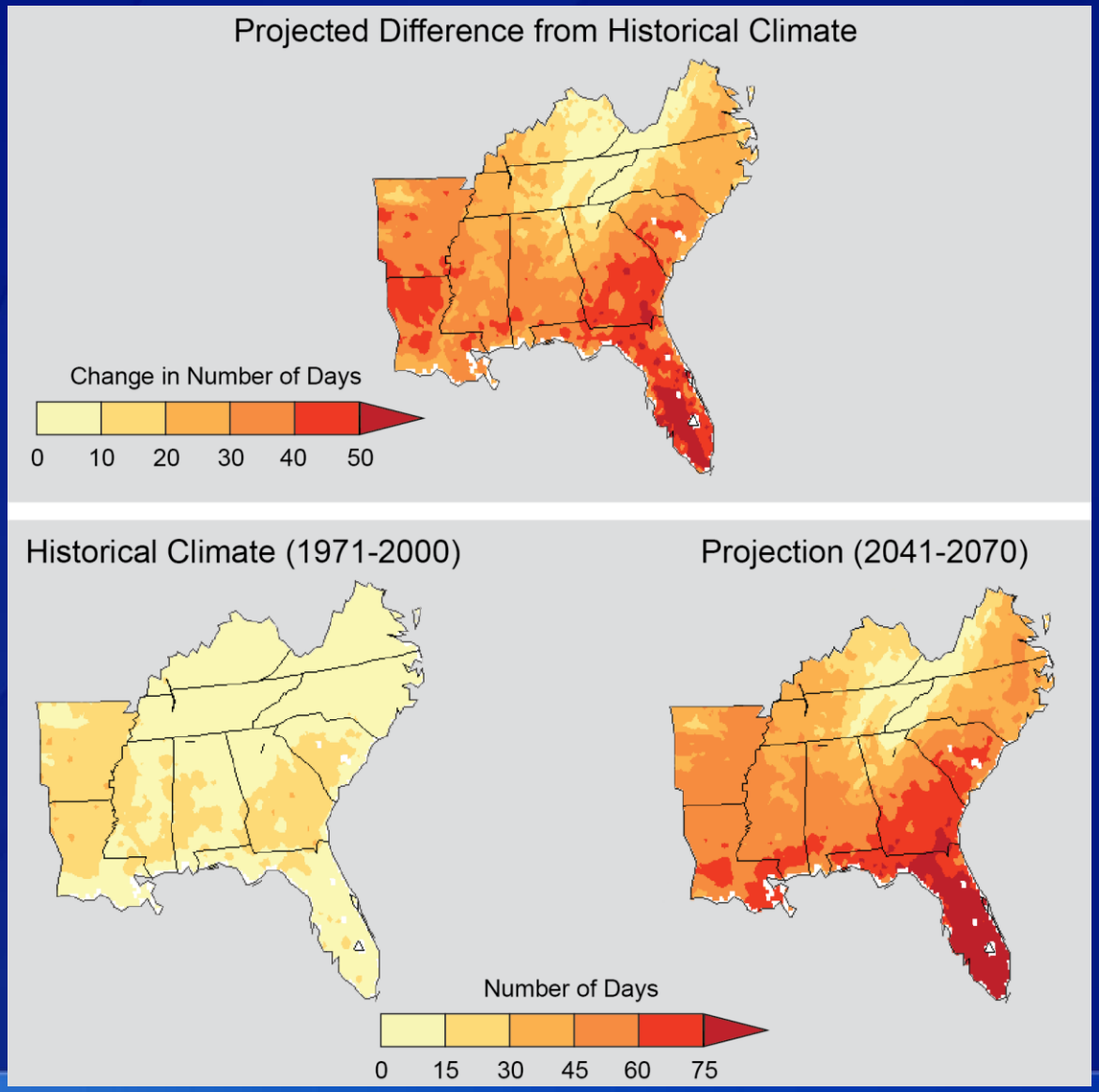
Source: NASA/GISS; Hansen, et al., "Perceptions of Climate Change," *Proc. Natl. Acad. Sci. USA* 10.1073, August 2012

Summer Temperatures Have Shifted 2001 – 2011



Source: NASA/GISS; Hansen, et al., "Perceptions of Climate Change," *Proc. Natl. Acad. Sci. USA* 10.1073, August 2012

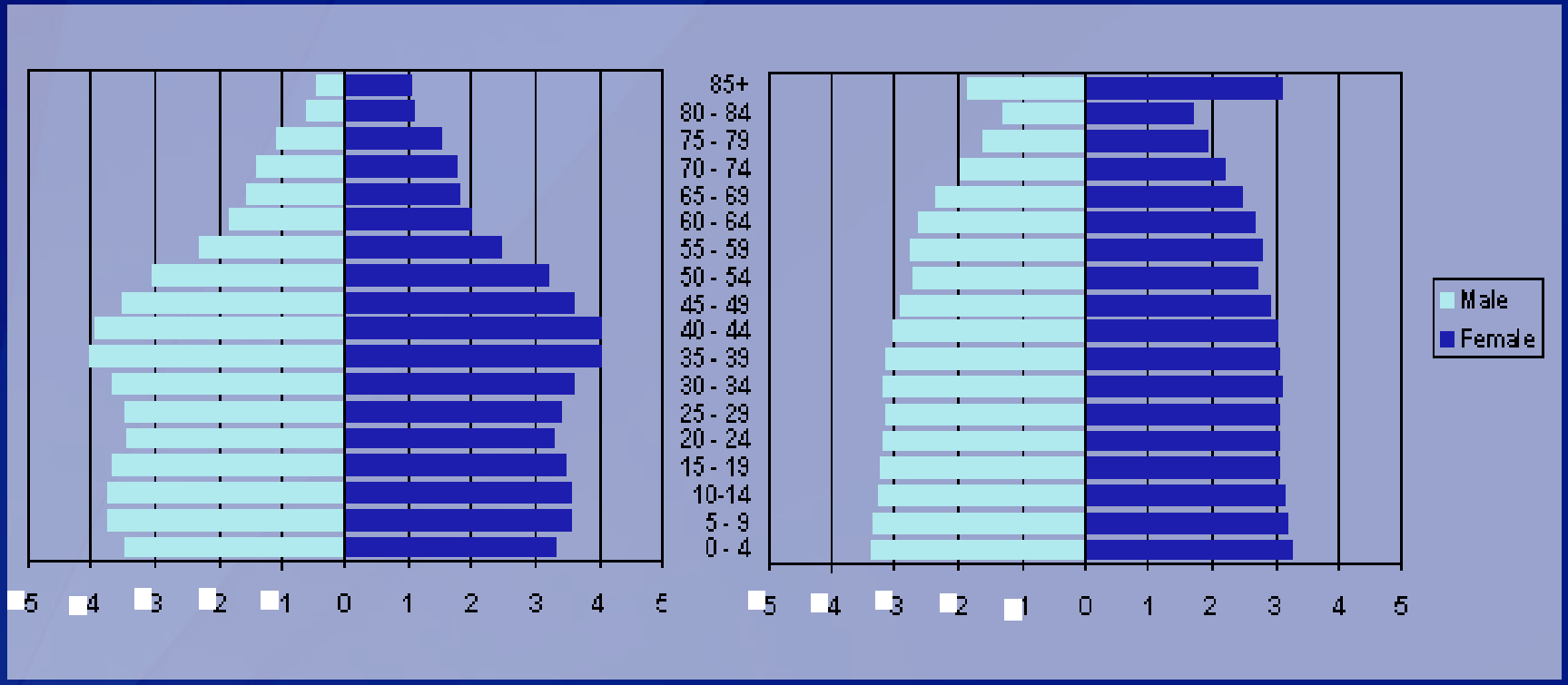
Projected Change in Number of Days Over 95° F



Demographic Shifts and Urban "Built" Environments

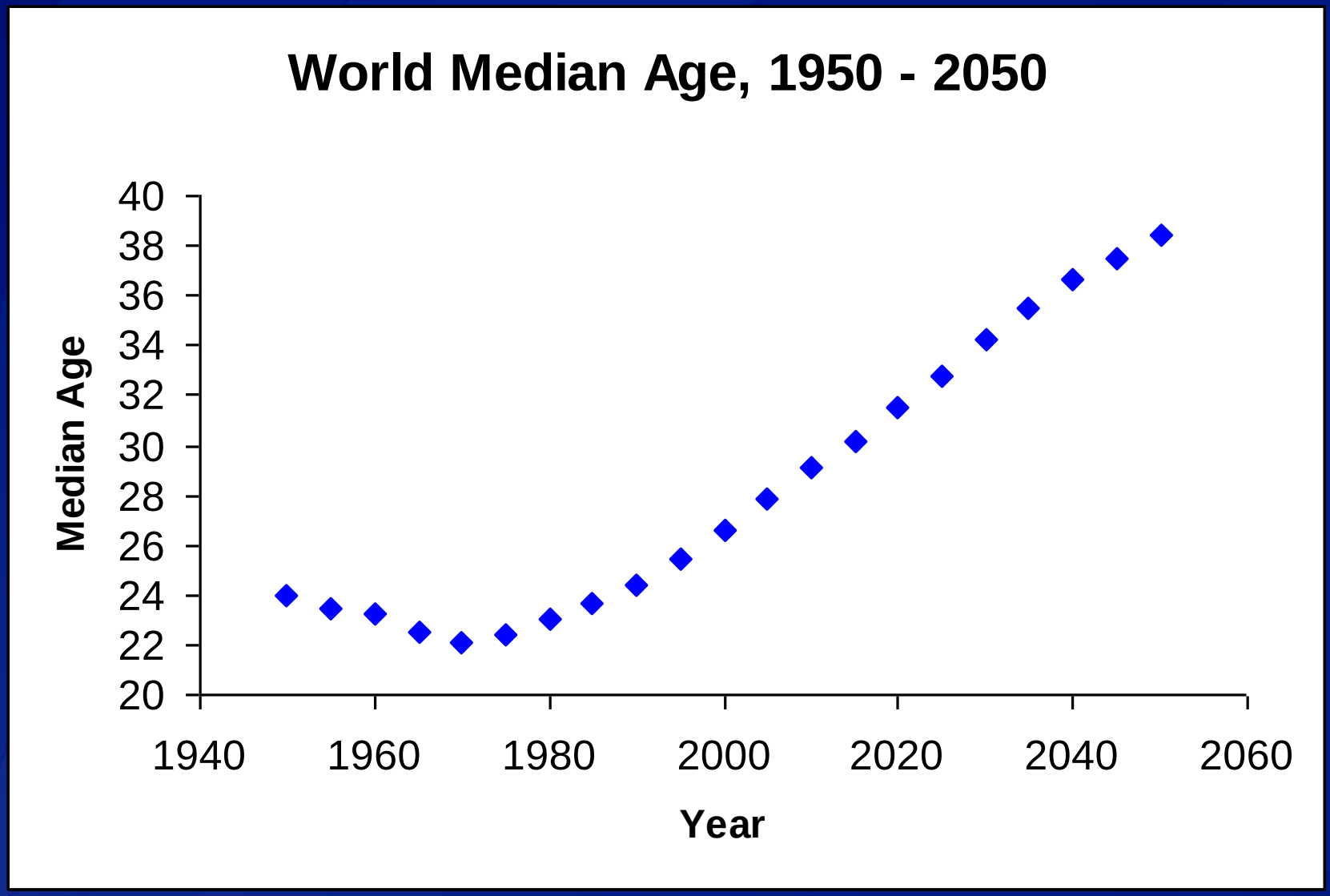
- Cities and climate are coevolving in a manner that will place more populations at risk.
- Increase in vulnerable populations:
  - Today, more than half of the world's population lives in cities, up from 30% in 1950.
  - By 2100 there will be 100 million more people > 65 years old (relative to 2000) (Ebi et al. 2006).
- Urban heat islands

Population Pyramids of the U.S. 2000 and 2050 (Interim Projections from 2000 Census)



2000 % of Total Population 2050

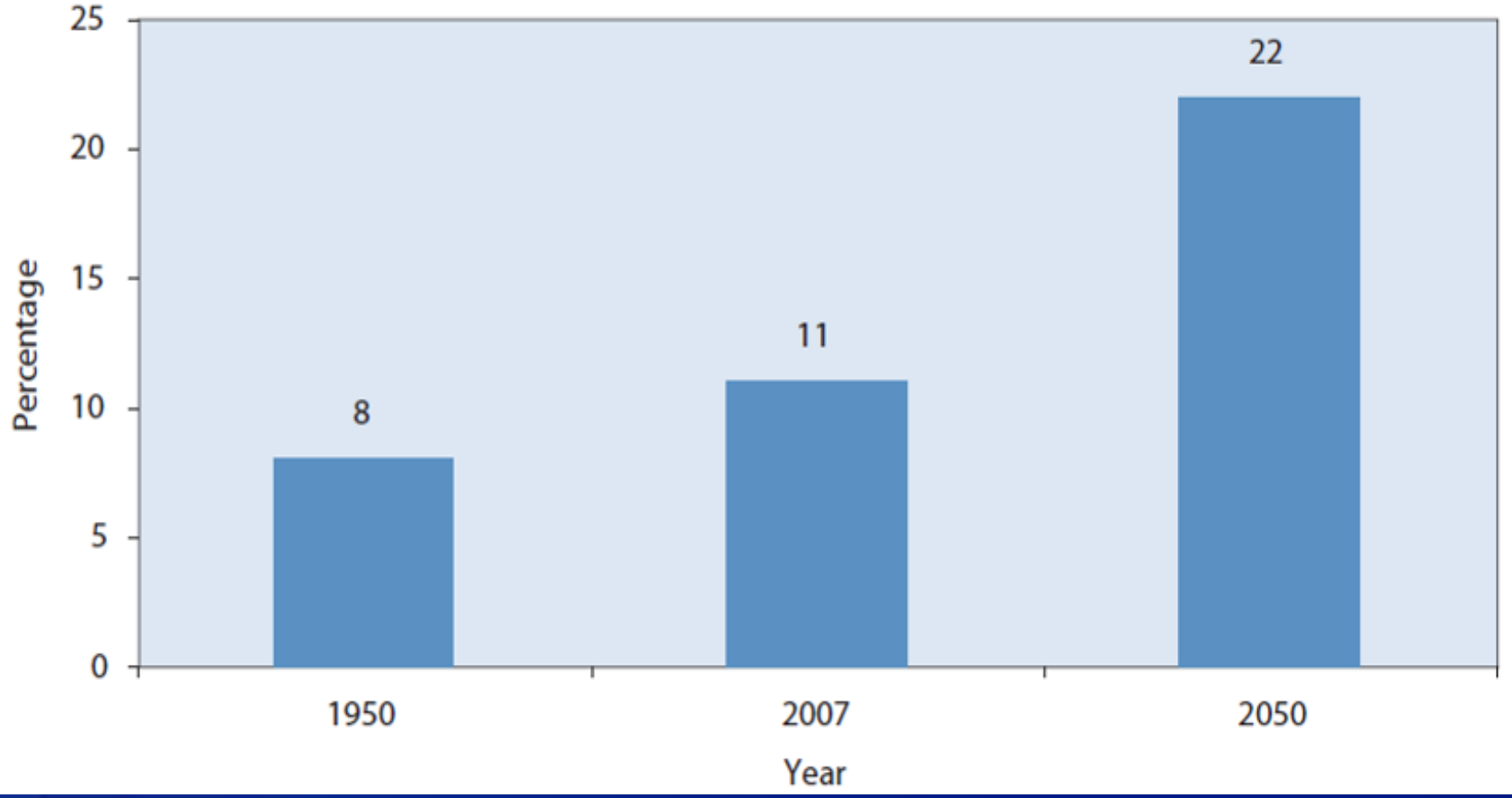
Data source: Census Population Projections
http://www.census.gov/ipc/www/usinterimproj/



Adapted from: United Nations World Urbanization Prospects, 2008

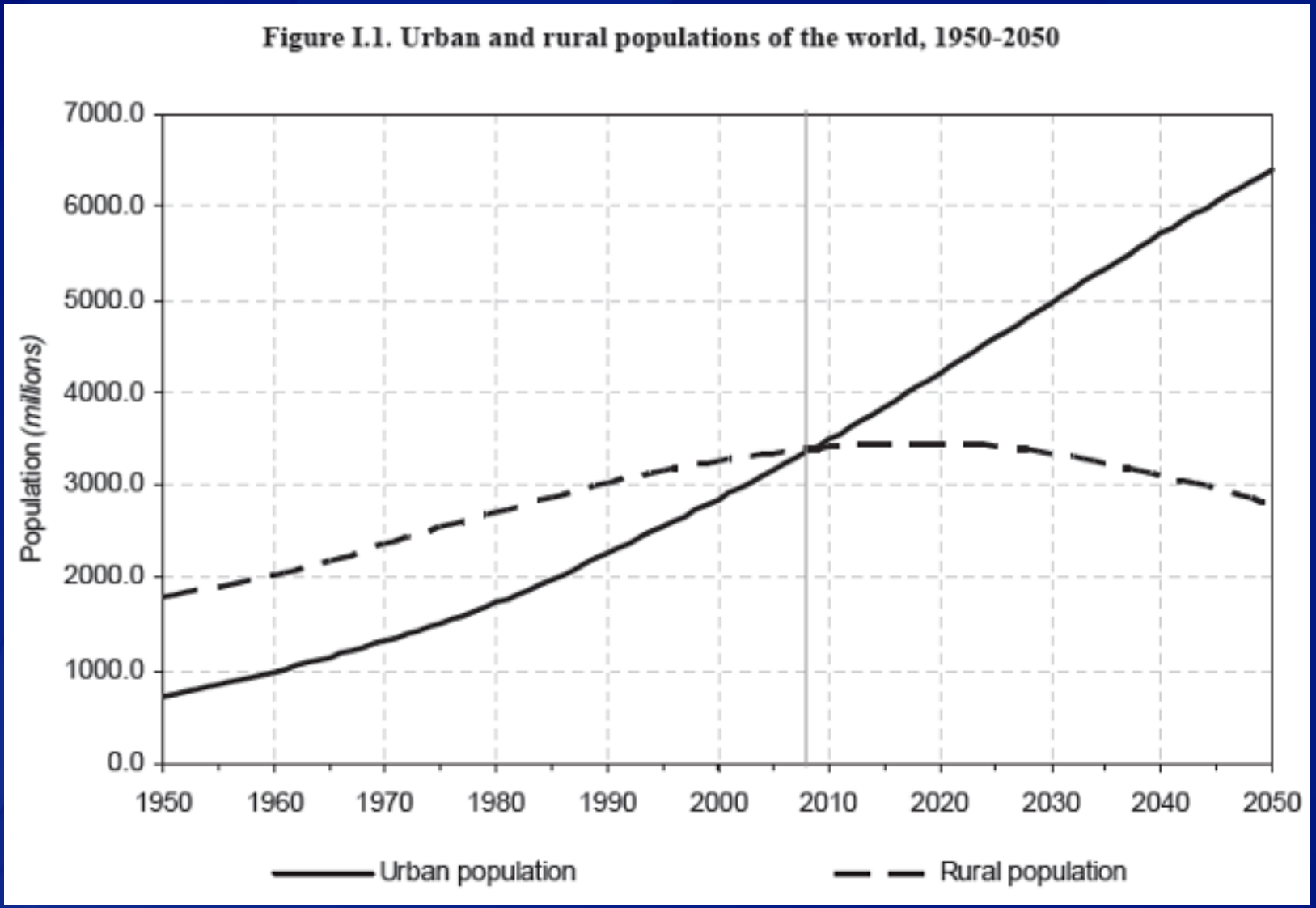
Figure I

Proportion of population 60 years or over: world, 1950-2050

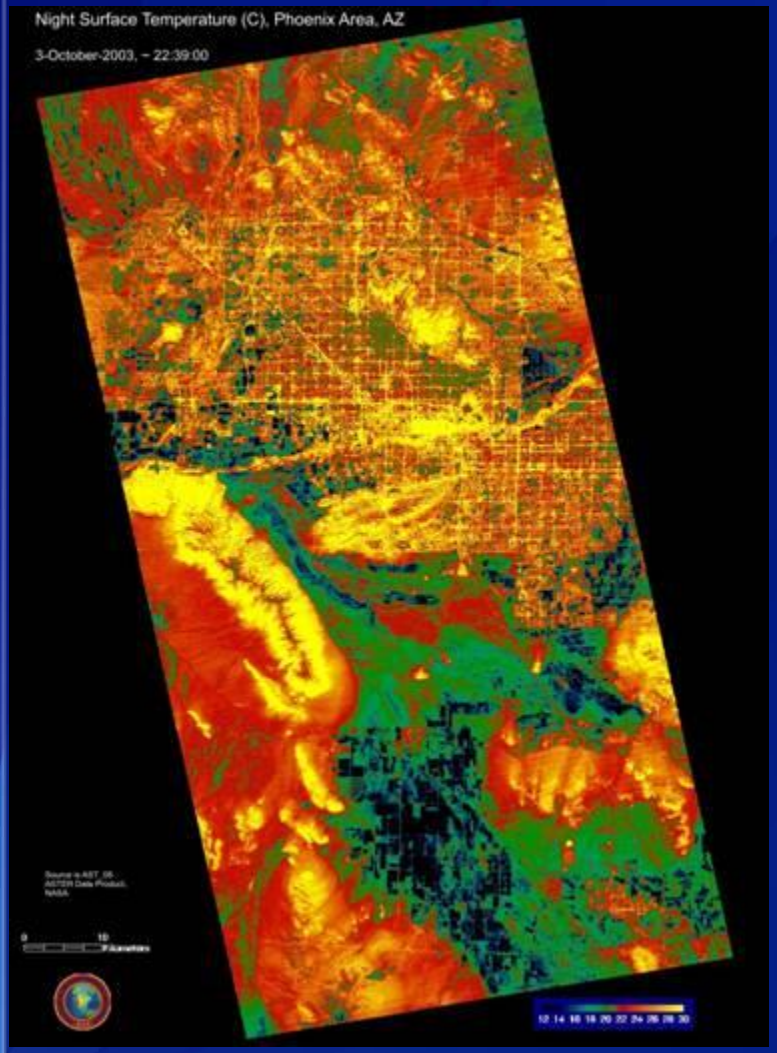


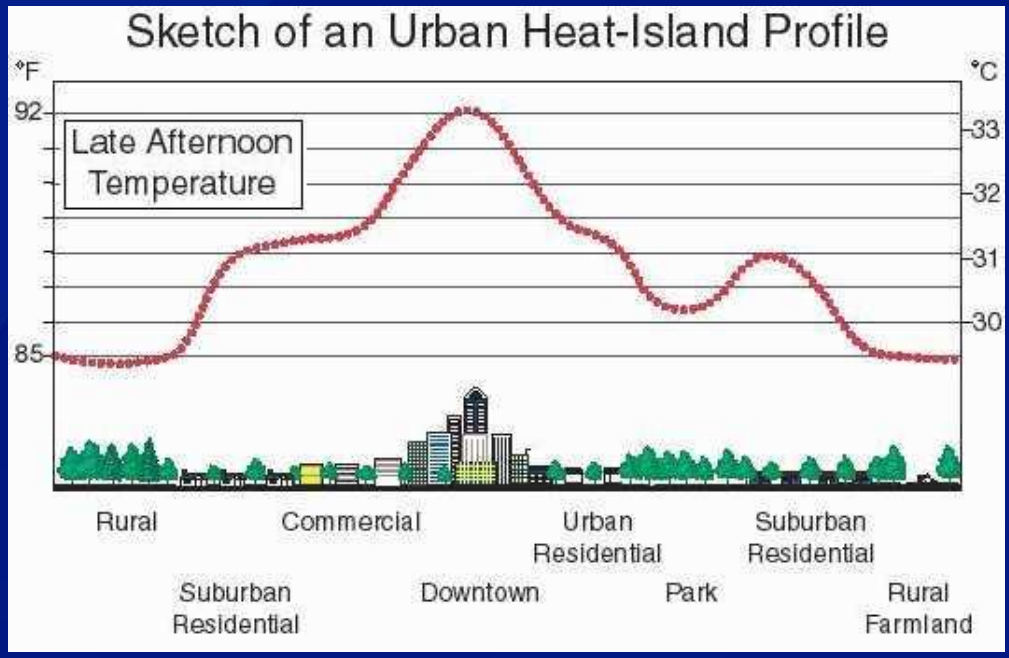
Source: United Nations *World Population Ageing, 2007*

In 2008, for the first time in history, the proportion of the population living in urban areas reached 50%.



Source: United Nations World Urbanization Prospects, 2008





Urban heat island can add 7°–12° F

Thermal Satellite Image of Phoenix, AZ Night Surface Temperature

How Rapidly Are Large Cities Warming?

URBAN

- Airport as “first-order” meteorological station for each urban center
- Night light ranking of C (bright)

RURAL

- Three stations selected for each city based on:
  1. Night light ranking of A (dark) or B (dim)
  2. Population < 4,000 per square kilometer
  3. Located within 50 to 250 km of urban station

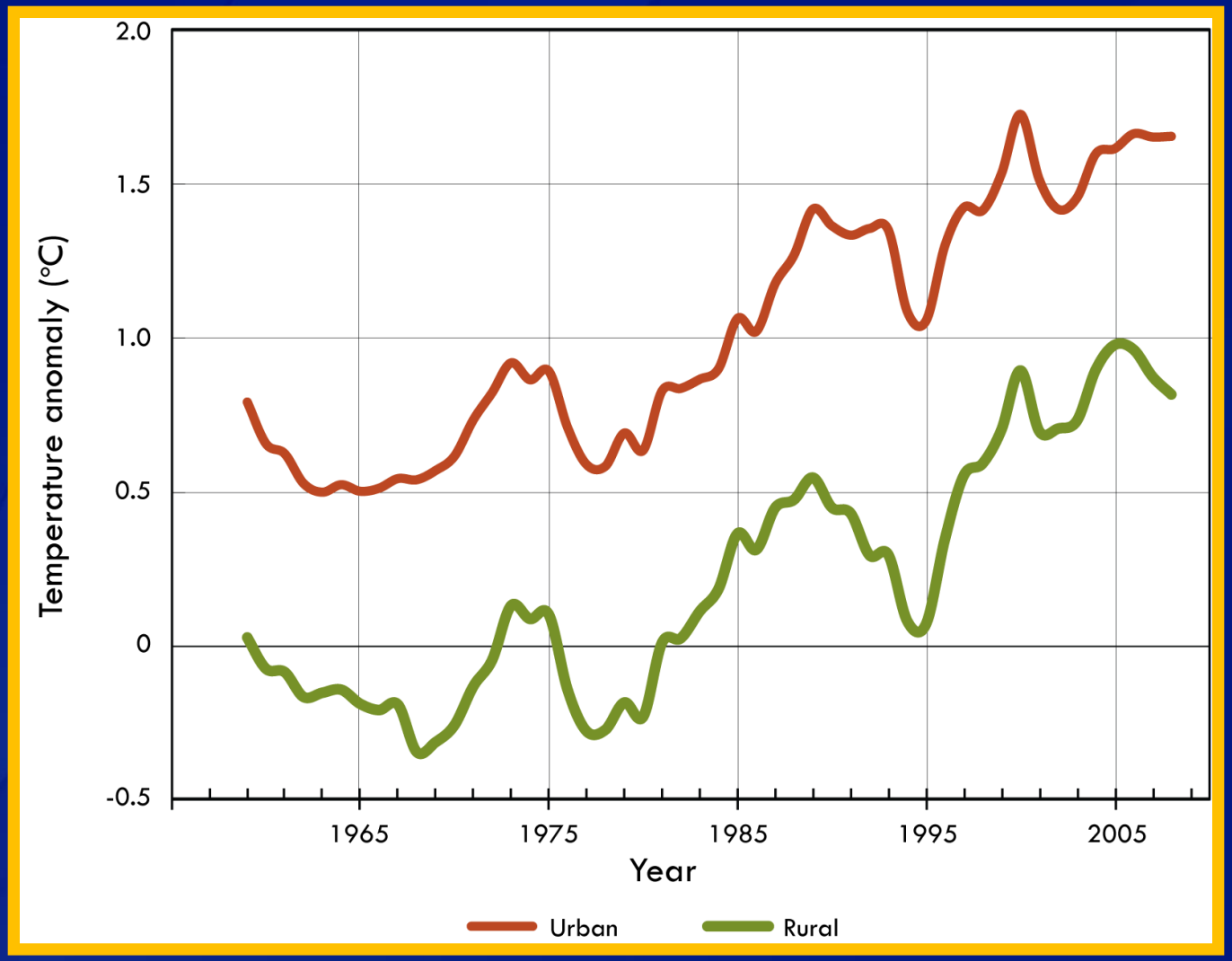
Stone B, Hess JJ, Frumkin H. 2010. Urban form and extreme heat events: are sprawling cities more vulnerable to climate change than compact cities? Environ Health Perspect. 2010 Oct;118(10):1425-8.

Warming trends outside of 50 most populous U.S. cities

Rural areas have warmed by about 0.7 ^{O}C over 50 years.

Stone B, Hess JJ, Frumkin H. 2010. Urban form and extreme heat events: are sprawling cities more vulnerable to climate change than compact cities? Environ Health Perspect. 2010 Oct;118(10):1425-8.

The Urban Heat Island Effect (UHI)



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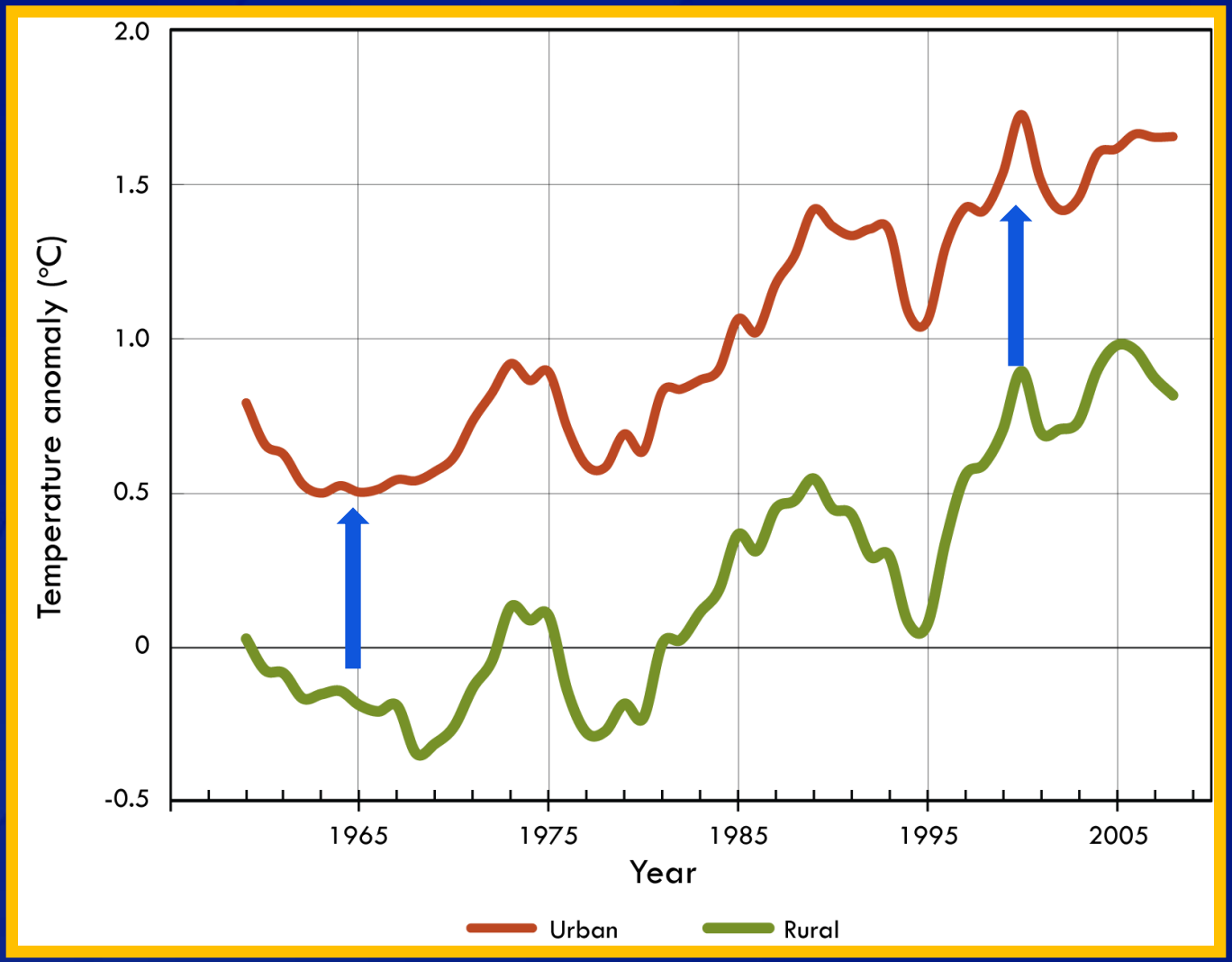
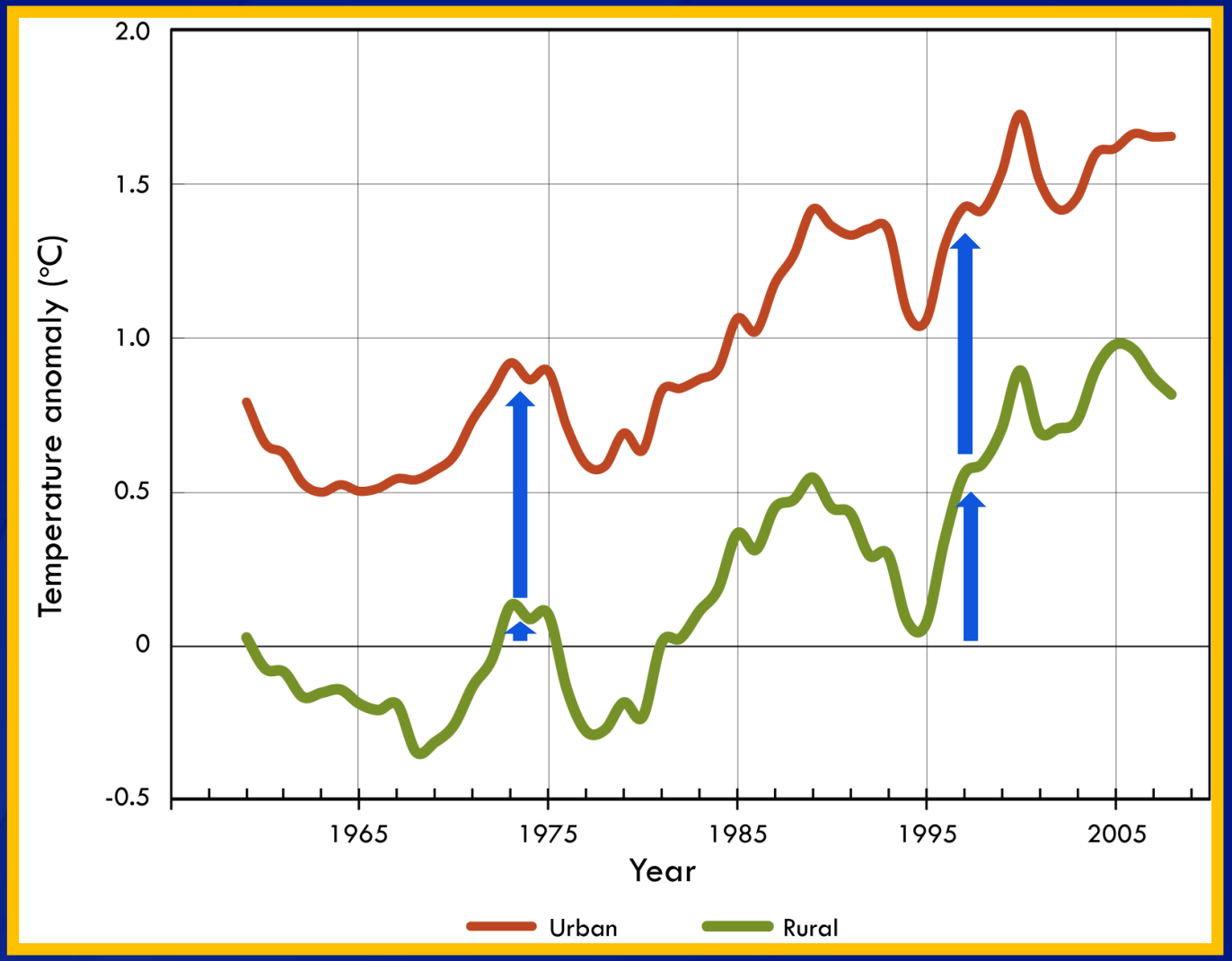
The Urban Heat Island Effect



Urban areas, on average, are about 0.8 °C warmer than rural areas.

Stone B, Hess JJ, Frumkin H. 2010. Urban form and extreme heat events: are sprawling cities more vulnerable to climate change than compact cities? Environ Health Perspect. 2010 Oct;118(10):1425-8.

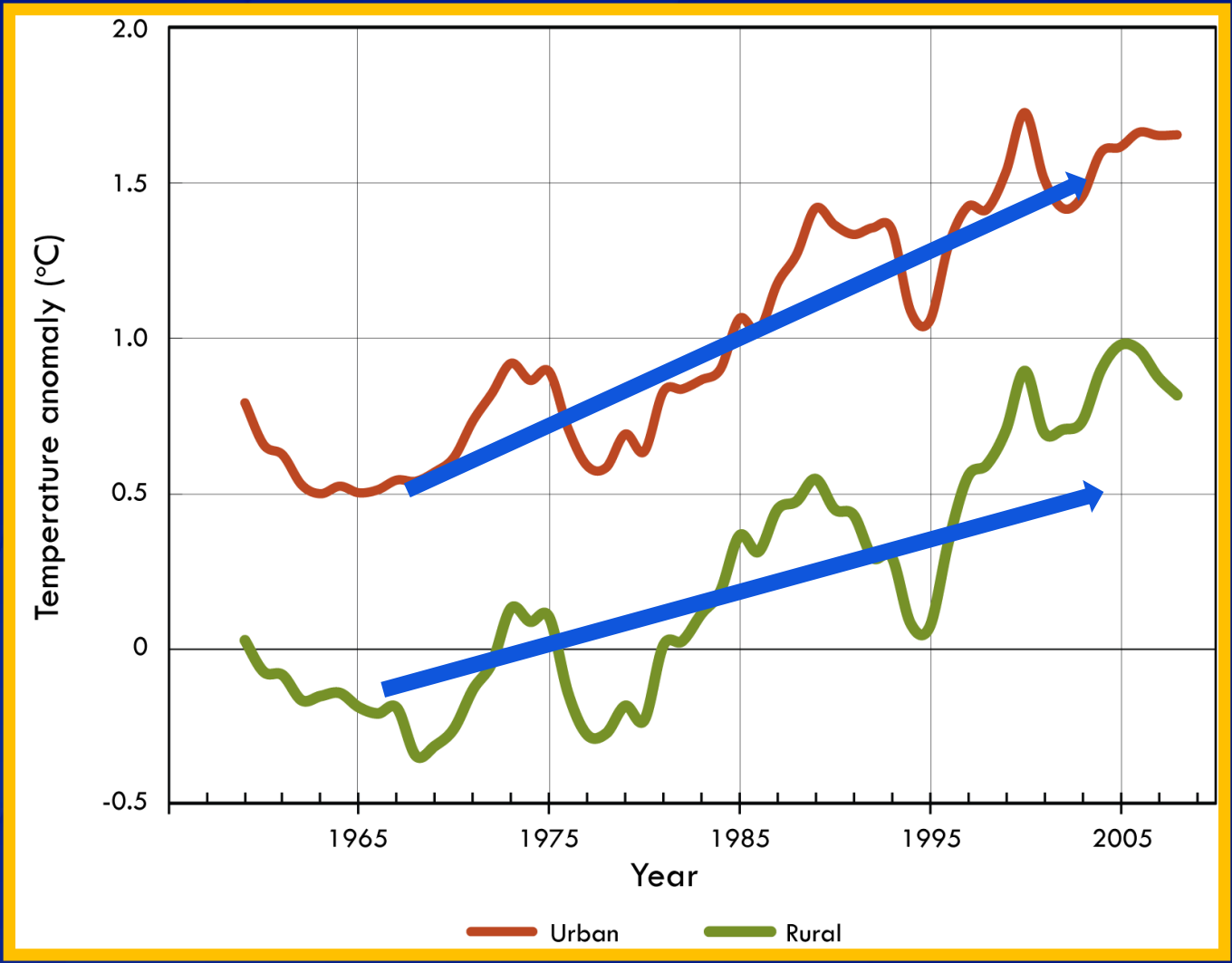
UHI effect > Greenhouse Effect



Most of the temperature anomaly in cities is attributable to UHI.

Stone B, Hess JJ, Frumkin H. 2010. Urban form and extreme heat events: are sprawling cities more vulnerable to climate change than compact cities? Environ Health Perspect. 2010 Oct;118(10):1425-8.

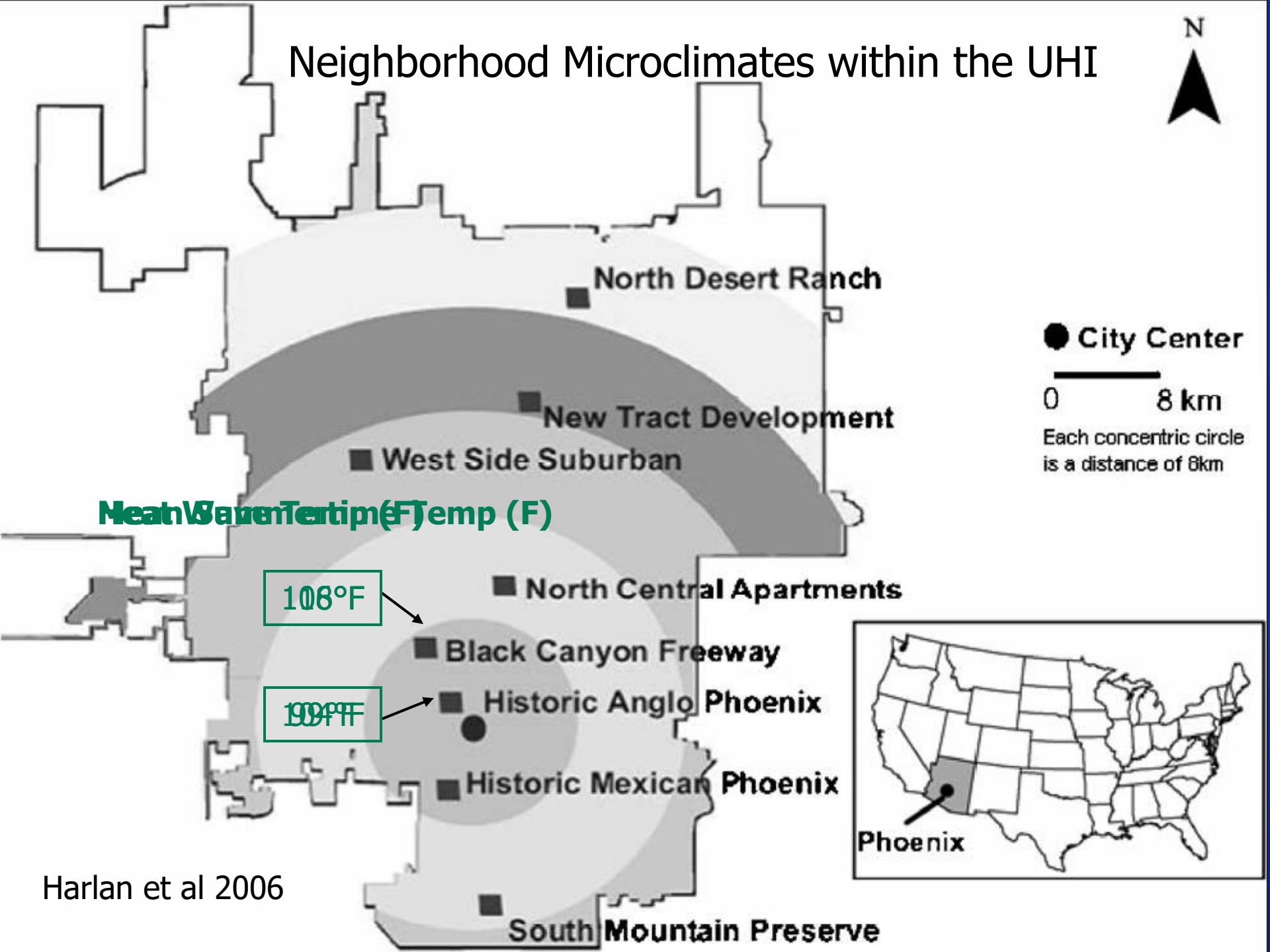
UHI Change > Greenhouse Effect Change



Urban areas are warming more rapidly over time than rural areas.

Stone B, Hess JJ, Frumkin H. 2010. Urban form and extreme heat events: are sprawling cities more vulnerable to climate change than compact cities? Environ Health Perspect. 2010 Oct;118(10):1425-8.

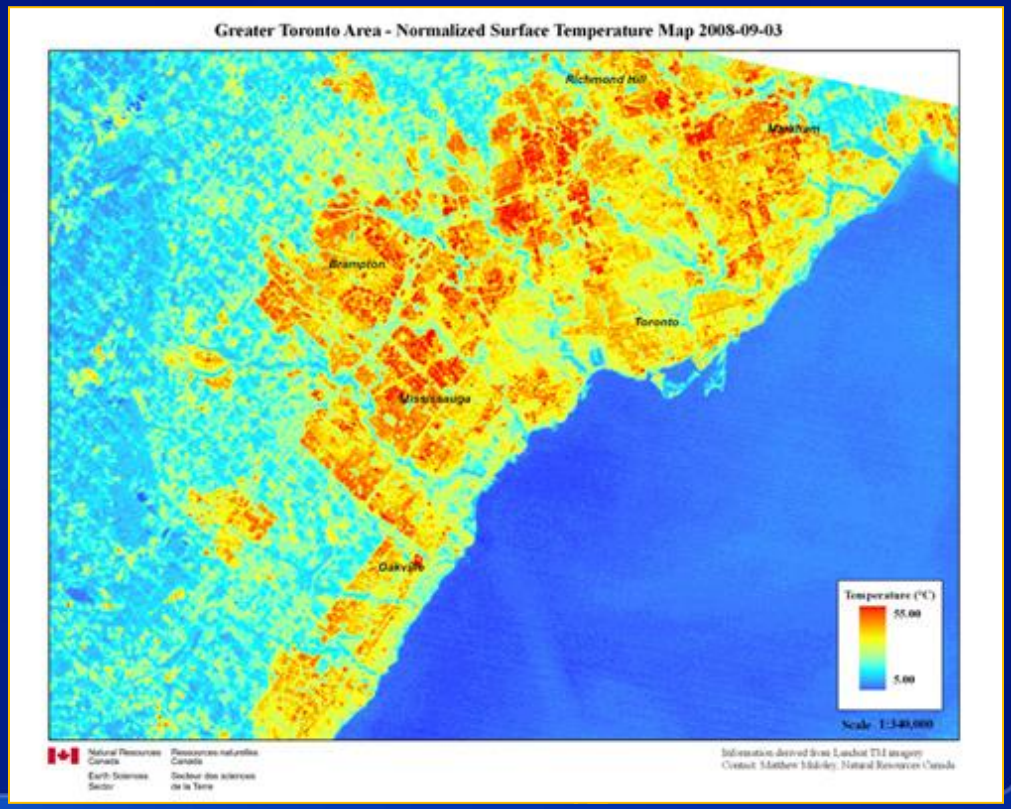
Neighborhood Microclimates within the UHI



Harlan et al 2006

Extreme heat, minorities

- Minorities more likely to live in heat islands
  - Black, African American (52%)
  - Asians (32%)
  - Hispanic (21%)



Jesdale et al. (2013)

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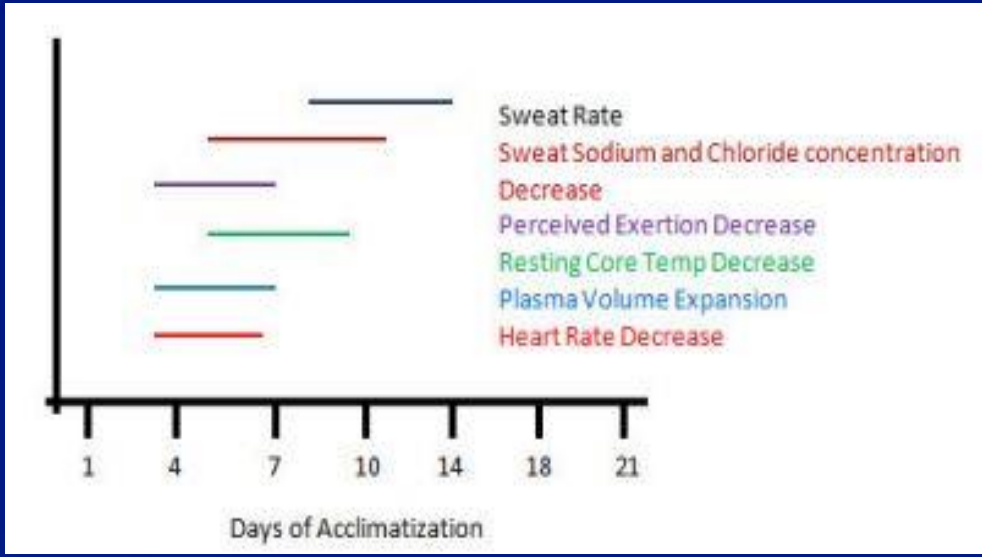
Adaptation to Heat

- Short-Term (acclimatization)
- Seasonal to multi-year: Heat response plans
- Decadal and longer: UHI reduction and mitigating climate change

Short-Term Adaptation: Acclimatization to Heat

Positive adaptations that occur include reductions in:

- Heart rate
- Body temperature responses
- Skin temperature responses
- Perceived exertion
- Decreased salt losses in urine



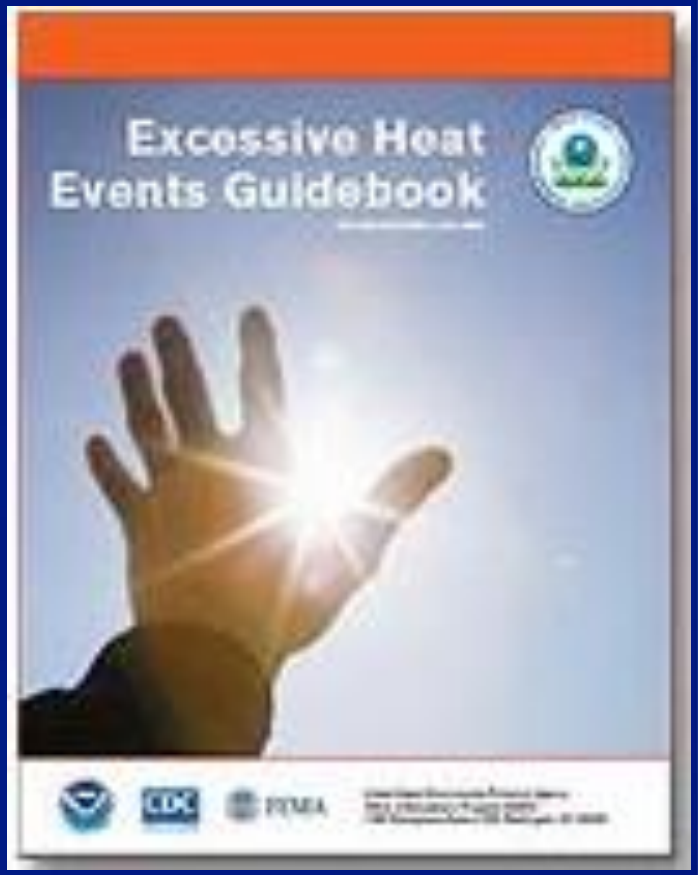
http://www.irunfar.com/2010/04/heat-acclimation-for-runners.html

As well as increases in:

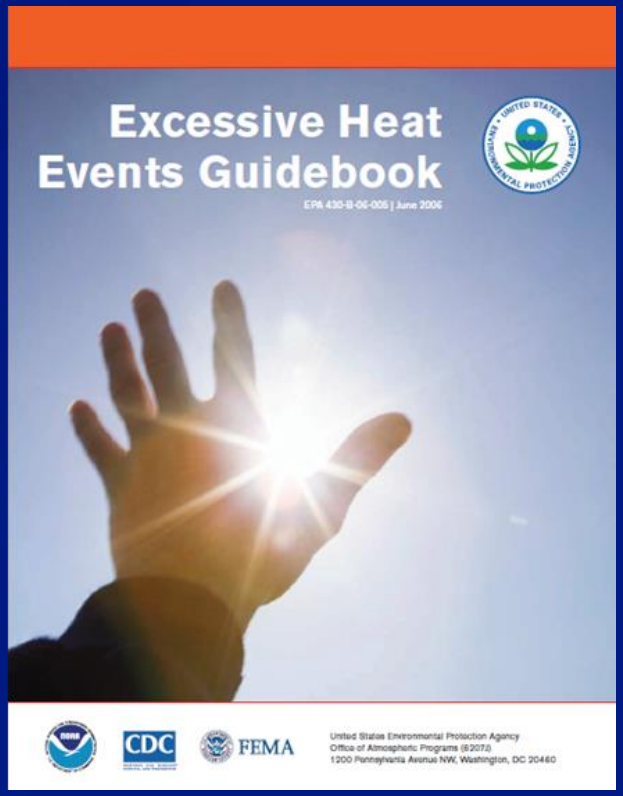
- Sweat rate
- Sweat onset (sweating starts earlier)
- Heart function/blood distribution
- Overall ability to perform in the heat

Seasonal Adaptation: Development of Heat Response Plans

- City-specific heat response plans are essential
- The EPA guidebook:
  - EPA, NOAA, CDC, FEMA collaboration
  - Options for defining EHE conditions
  - How to assess local vulnerability
  - EHE notification and response actions that work



CDC Guidance for preventing heat-related illness



CDC-APHA Fact Sheet

EXTREME
HEAT
CAN IMPACT OUR HEALTH IN MANY WAYS

Climate change poses many risks to human health. Some health impacts of climate change are already being felt in the United States.

We need to safeguard our communities by protecting people's health, wellbeing, and quality of life from climate change impacts. Many communities are already taking steps to address these public health issues and reduce the risk of harm.

BACKGROUND

When we burn fossil fuels, such as coal and gas, we release carbon dioxide (CO_2). CO_2 builds up in the atmosphere and causes Earth's temperature to rise, much like a blanket traps in heat. This extra trapped heat disrupts many of the interconnected systems in our environment.

Climate change also affects human health by increasing the frequency and intensity of extreme heat events. Increases in the overall temperature of the atmosphere and oceans associated with climate change cause changes in wind, moisture, and heat circulation patterns. These changes contribute to shifts in extreme weather events, including extreme heat events.

THE CLIMATE-HEALTH CONNECTION

Extreme heat events can be dangerous to health – even fatal. These events result in increased hospital admissions for heat-related illness, as well as cardiovascular and respiratory disorders.

- Extreme heat events can trigger a variety of heat stress conditions, such as heat stroke. Heat stroke is the most serious heat-related disorder. It occurs when the body becomes unable to control its temperature. Body temperature rises rapidly, the sweating mechanism fails, and the body cannot cool down. This condition can cause death or permanent disability if emergency treatment is not given. Small children, the elderly, and certain other groups including people with chronic diseases, low-income populations, and outdoor workers have higher risk for heat-related illness.
- Higher temperatures and respiratory problems are also linked. One reason is because higher temperatures contribute to the build-up of harmful air pollutants.
- Many cities across the United States, including St. Louis, Philadelphia, Chicago, and Cincinnati, have seen large increases in death rates during heat waves.

https://www.cdc.gov/climateandhealth/pubs/extreme-heat-final_508.pdf

New CDC Guidance (forthcoming) Cooling Center Technical Guidance Document

- **Widely used extreme heat intervention**
- **Can be housed in a variety of places:**
  - Libraries
  - Public pools
  - Movie theatres
  - Etc.

National Center for Environmental Health

Signs for free water at a cooling center in Maricopa County, Arizona. Photo credit: Travis L Williams Family Service Center.

Effectiveness Summary and Barriers

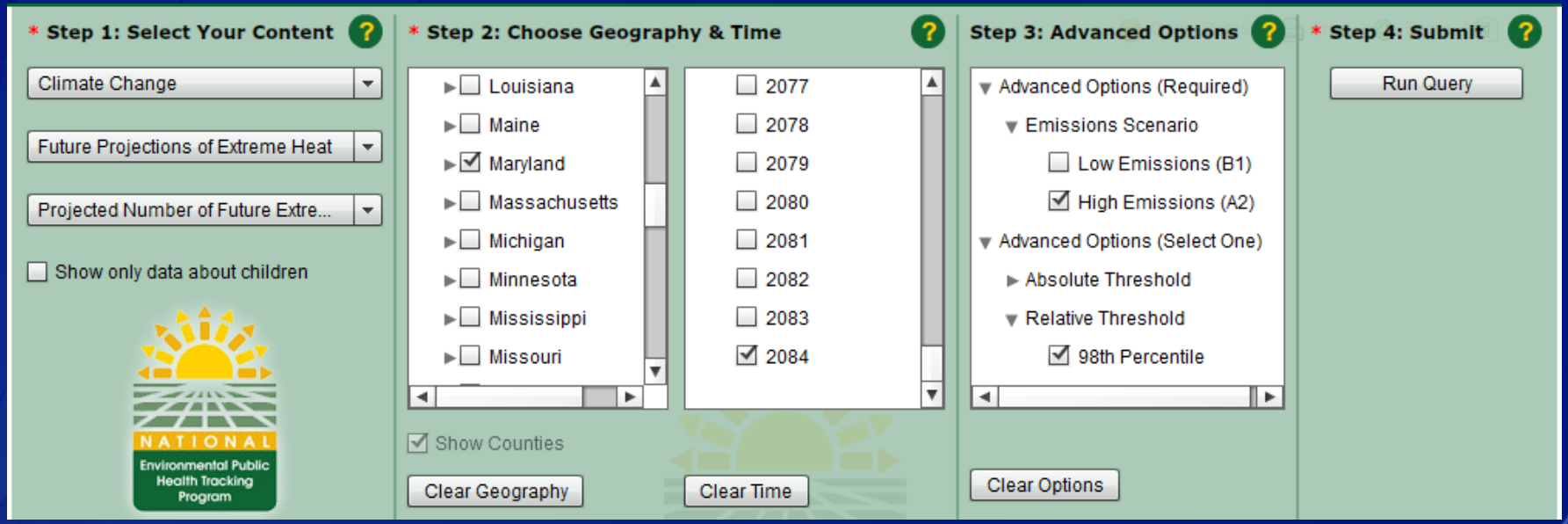
- **Common themes from the literature that showed effective use were:**
  - Communication strategies
  - Community outreach
  - Large group of diverse stakeholders

- **Barriers to implementation were:**
  - Limited access to transportation
  - High cost of A/C
  - Fear of leaving home/inability to leave home
  - Stigma of cooling centers

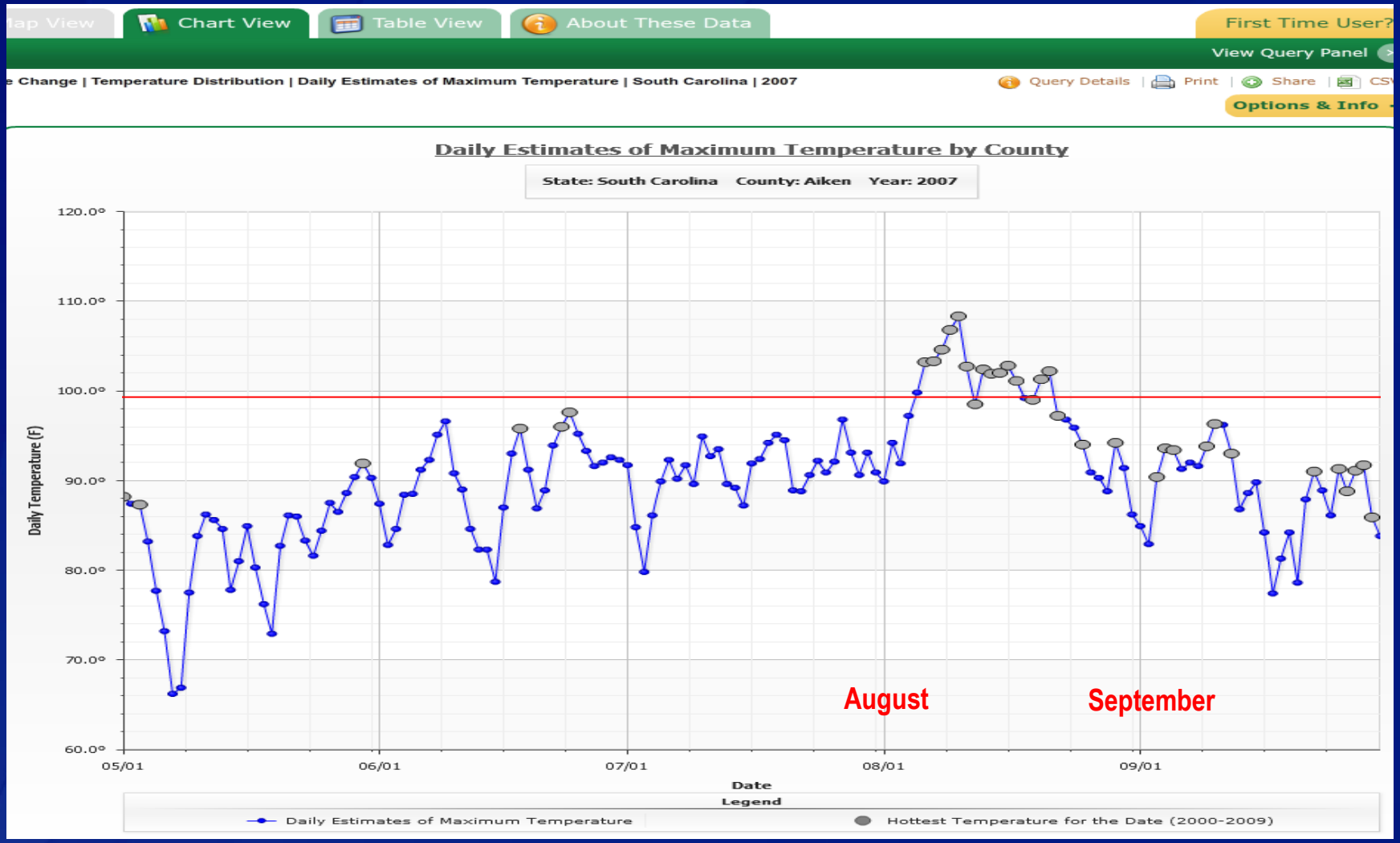
CDC's National Environmental Public Health Tracking Network

Includes data on climate change and heat:

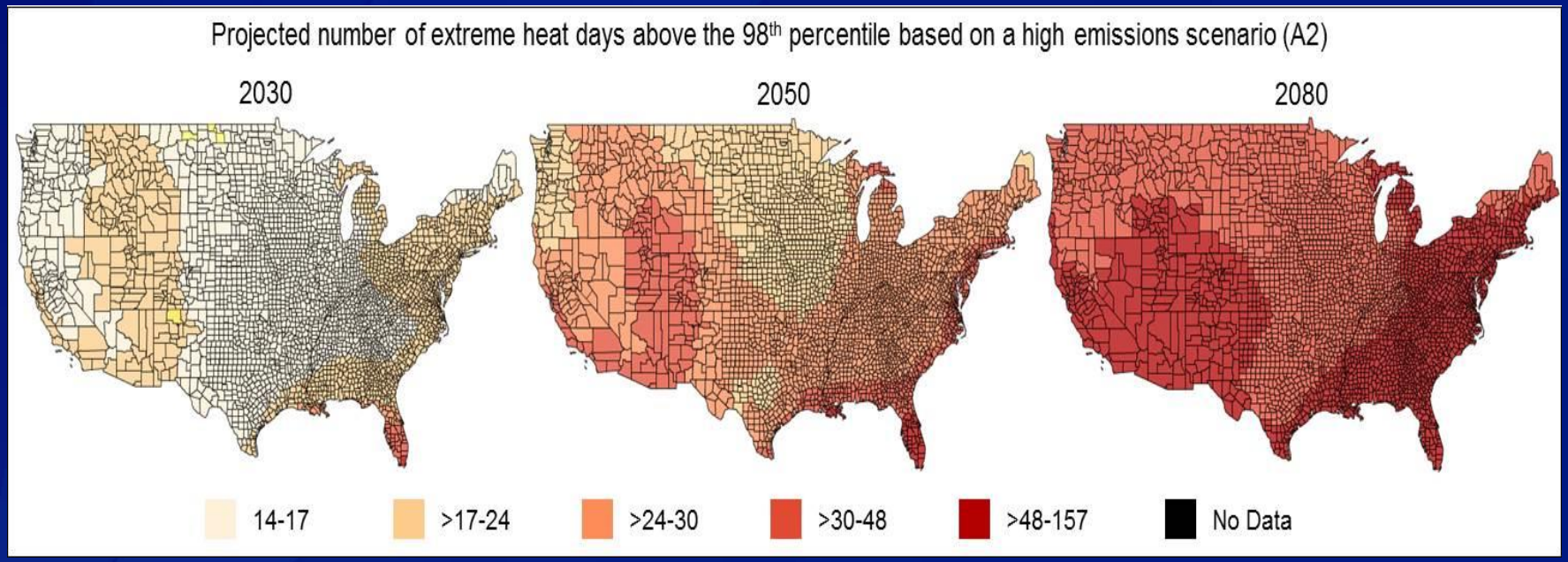
- Historic temperature distribution and extreme heat days
- Projected extreme heat days
- Heat vulnerability
- Heat ER visits, hospitalizations and deaths



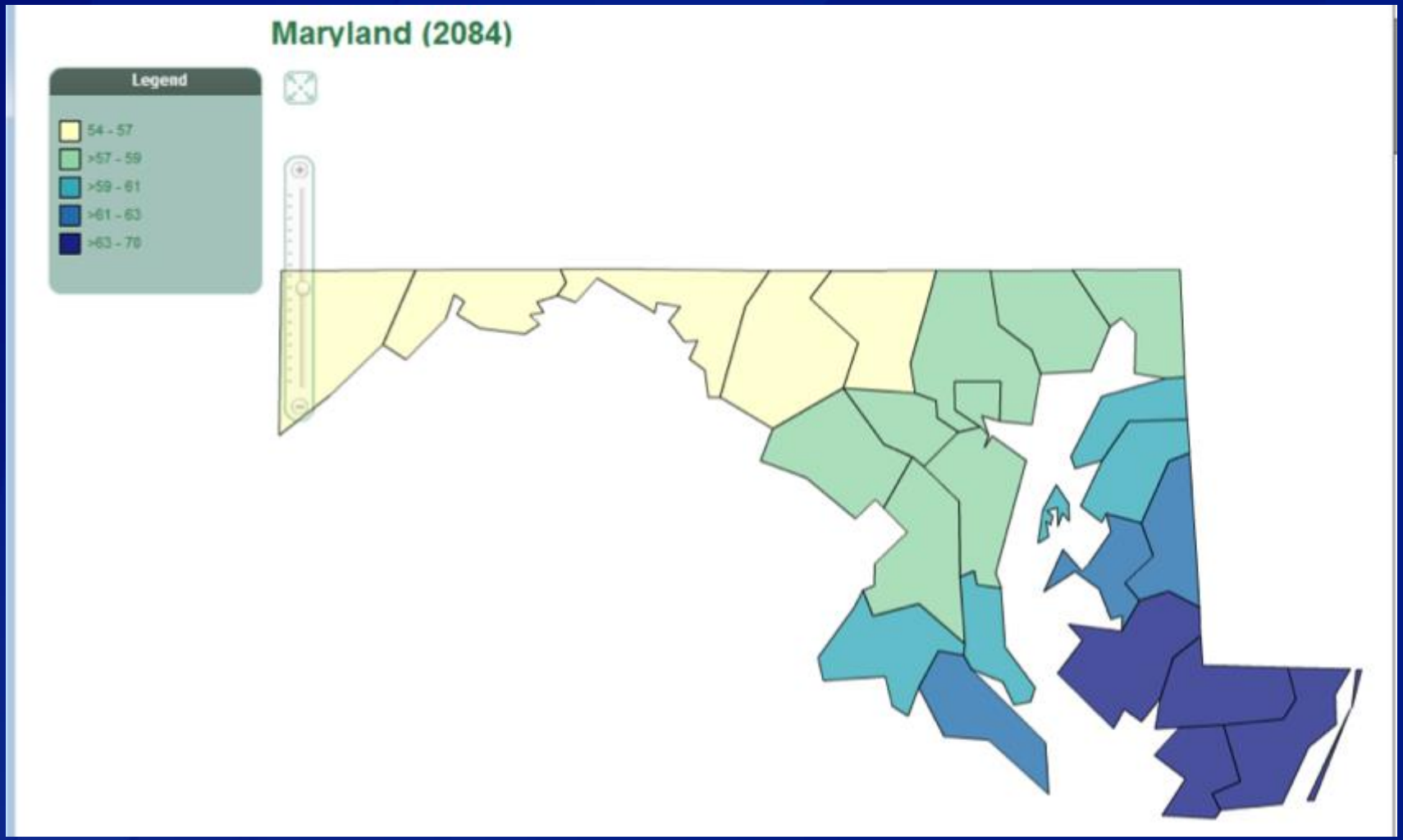
Historic temperature data (EPHTN)



Future modeled temperature data (EPHTN)



Source: NOAA, National Climate Assessment 2014



Projected number of extreme heat days (>98 percentile) in 2084 in Maryland. A2 (high emissions) scenario.

Mitigation: What actions are cities taking?

Management Strategy	Common Components	Category
Albedo Enhancement	Installation of highly reflective roofing or paving materials	Albedo Enhancement
Building Energy Efficiency	Minimum insulation values in building codes; efficient light fixtures and appliances	Energy Efficiency
Green Roofs	Installation of vegetative roofing materials	Vegetation Enhancement
Regional Forest Management	Requirements for the protection of regional forest cover in proximity to urbanized areas	Vegetation Enhancement
Renewable Energy Programs	Requirements for wind, solar, geothermal, or other renewable energy sources	Energy Efficiency
Urban Tree Management	Municipal tree planting programs; requirements for tree protection ordinances	Vegetation Enhancement
Vehicle Energy Efficiency	Minimum fuel efficiency standards for municipal fleets; acquisition of alternatively fueled vehicles	Energy Efficiency
Vehicle Travel Demand Management	Ride sharing programs; transit investments; provision of pedestrian and cycling facilities	Energy Efficiency

Stone B, Hess JJ, Frumkin H. 2010. Urban form and extreme heat events: are sprawling cities more vulnerable to climate change than compact cities? Environ Health Perspect. 2010 Oct;118(10):1425-8.

Management Strategy 1: Sunscreening

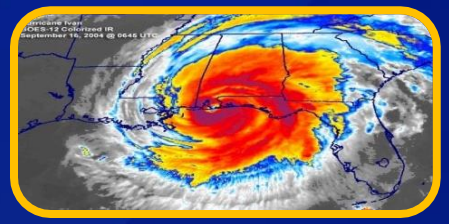
http://inhabitat.com/vertical-gardens-by-patrick-blanc/

Management Strategy 2: Greenbelting

Management Strategy 3: Carbon cooling







George Luber, PhD

770-488-3429

GLuber@cdc.gov

For more information please contact Centers for Disease Control and Prevention

1600 Clifton Road NE, Atlanta, GA 30333

Telephone: 1-800-CDC-INFO (232-4636)/TTY: 1-888-232-6348

E-mail: cdcinfo@cdc.gov Web: http://www.cdc.gov

National Center for Environmental Health

Division of Environmental Hazards and Health Effects