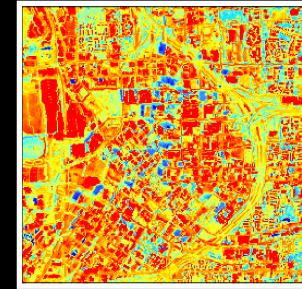# Extreme Heat and Health:
Warming Trends and Climate Action Planning in
Large U.S. Cities

Brian Stone
Associate Professor
Georgia Institute of Technology
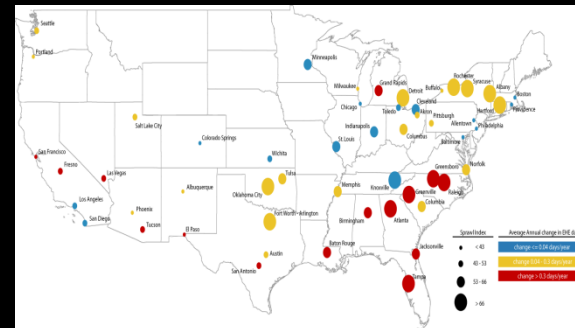stone@gatech.edu

February 13, 2012

Overview

1. How rapidly are cities warming?

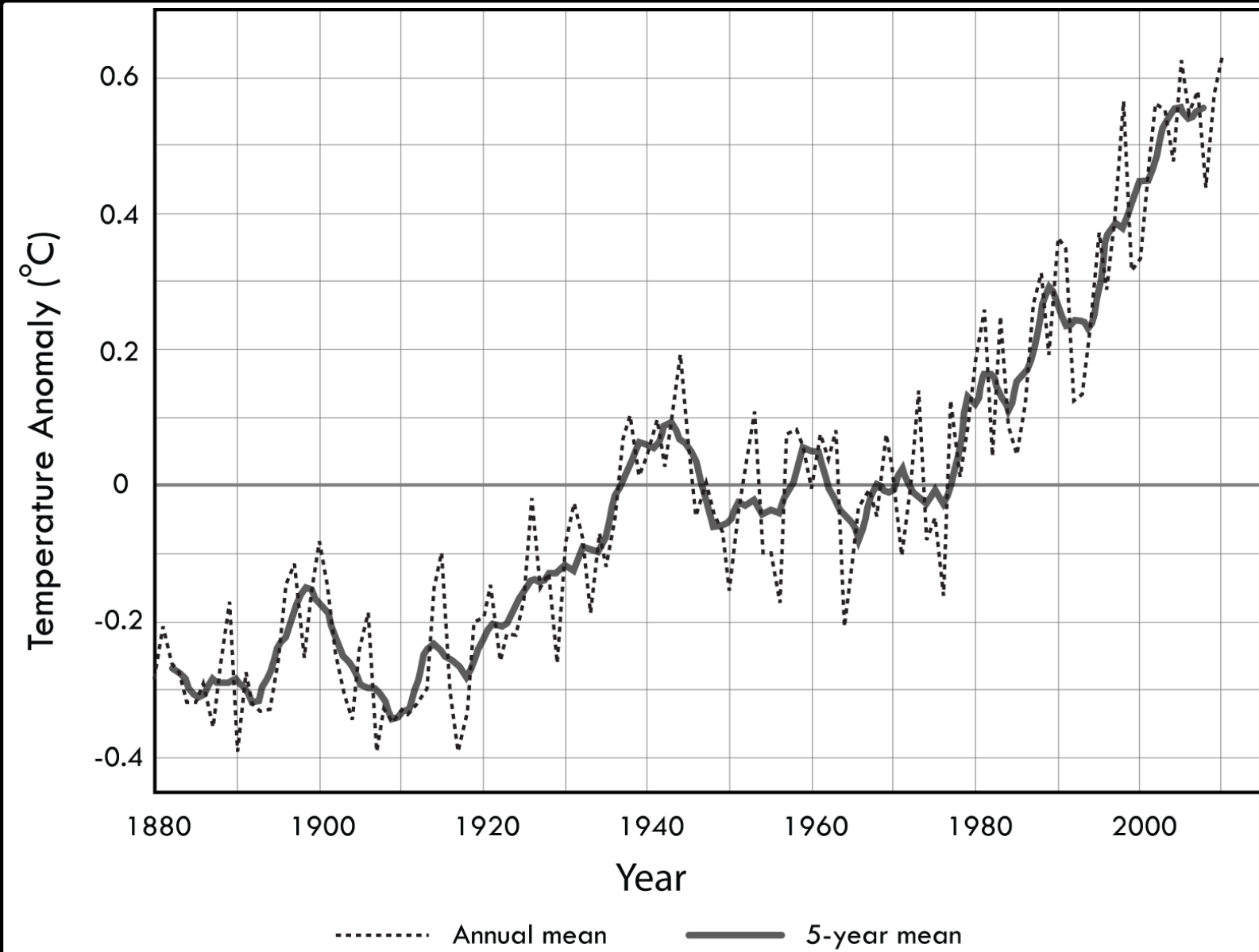2. Are some urban populations more vulnerable to extreme heat than others?

3. What are cities doing to prepare for extreme heat?

Global temperature anomaly

Goddard Institute for Space Studies, NASA

URBAN

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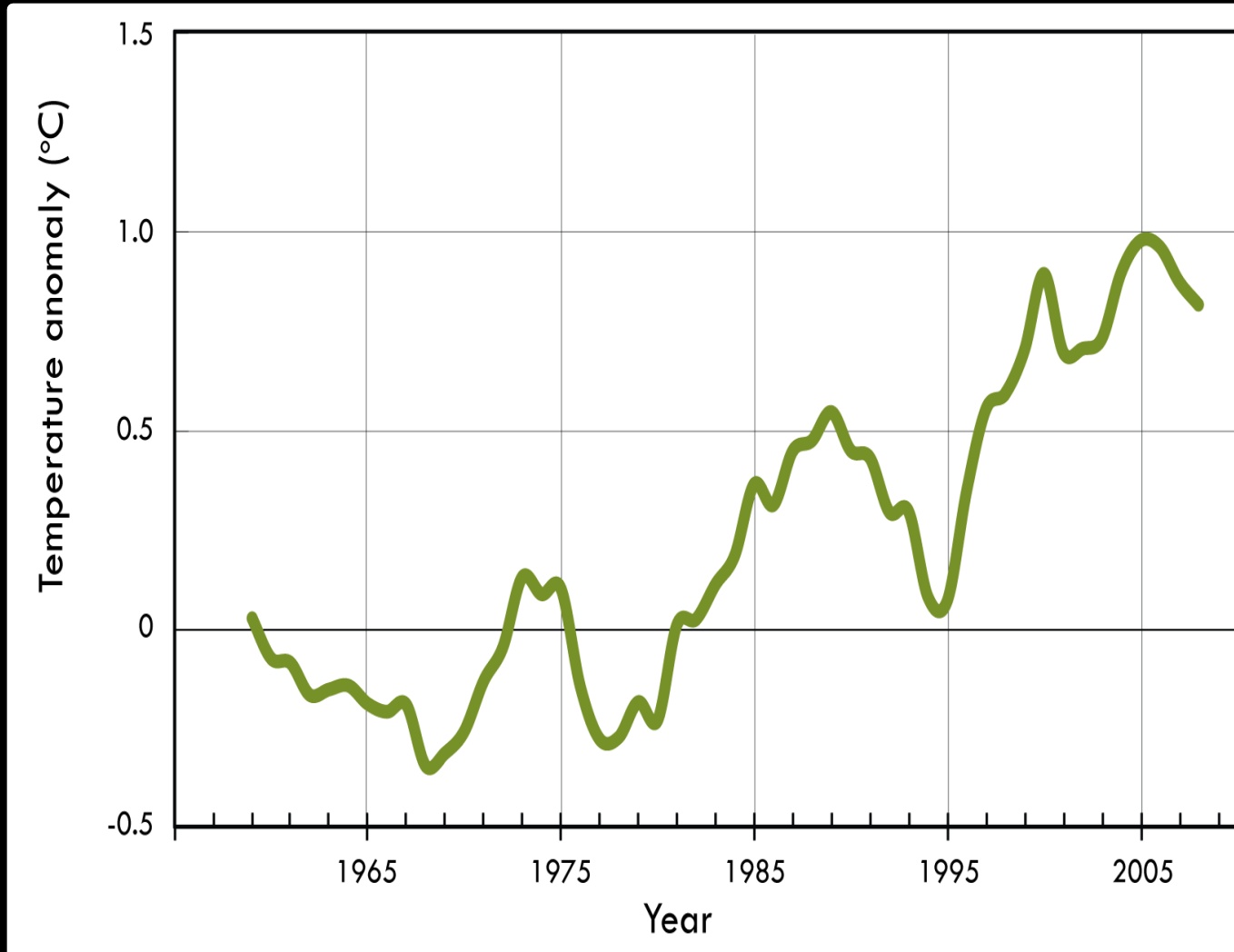
➡ Night light ranking of C (bright)

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

Rural areas have warmed by about 0.7 °C over 50 years.
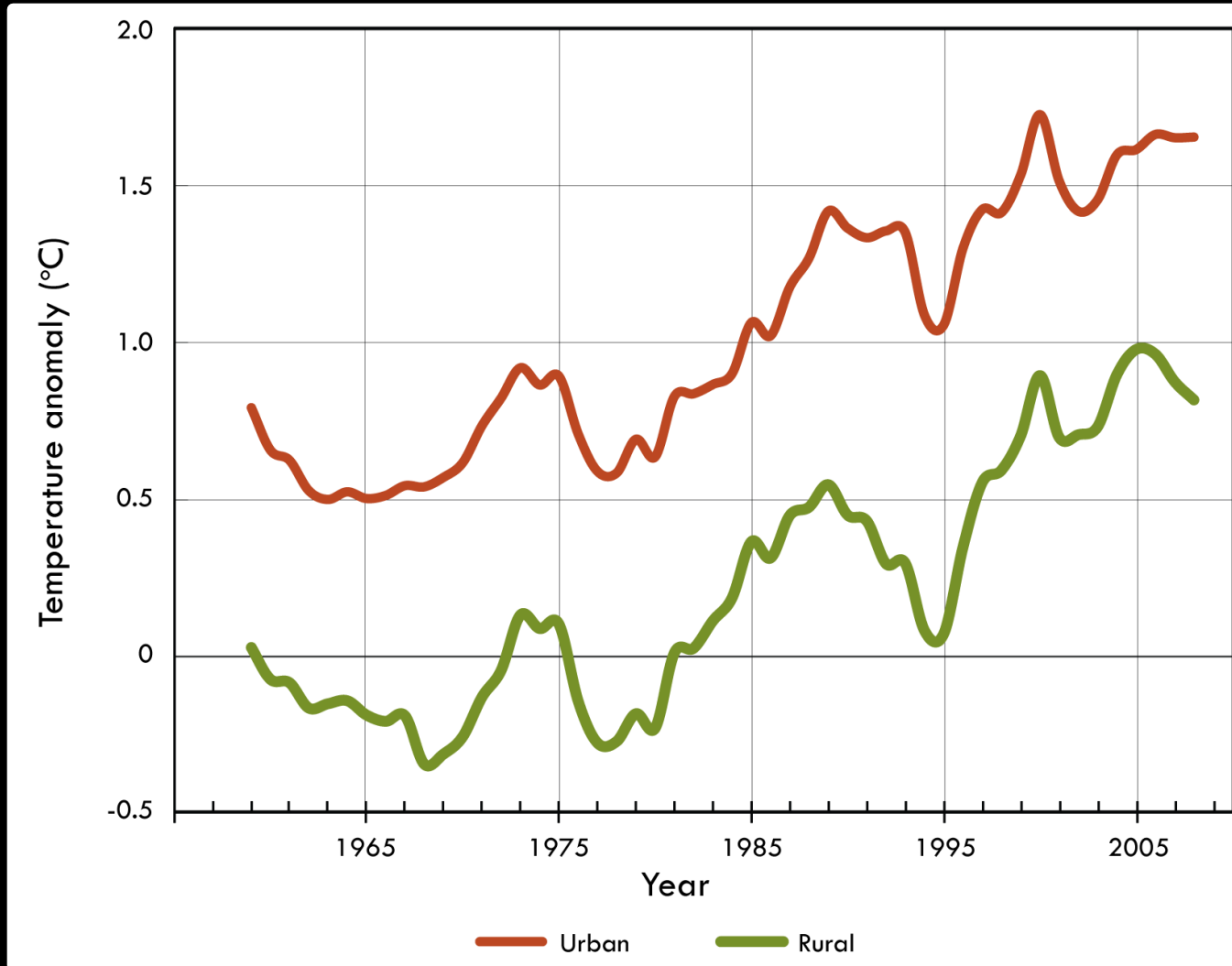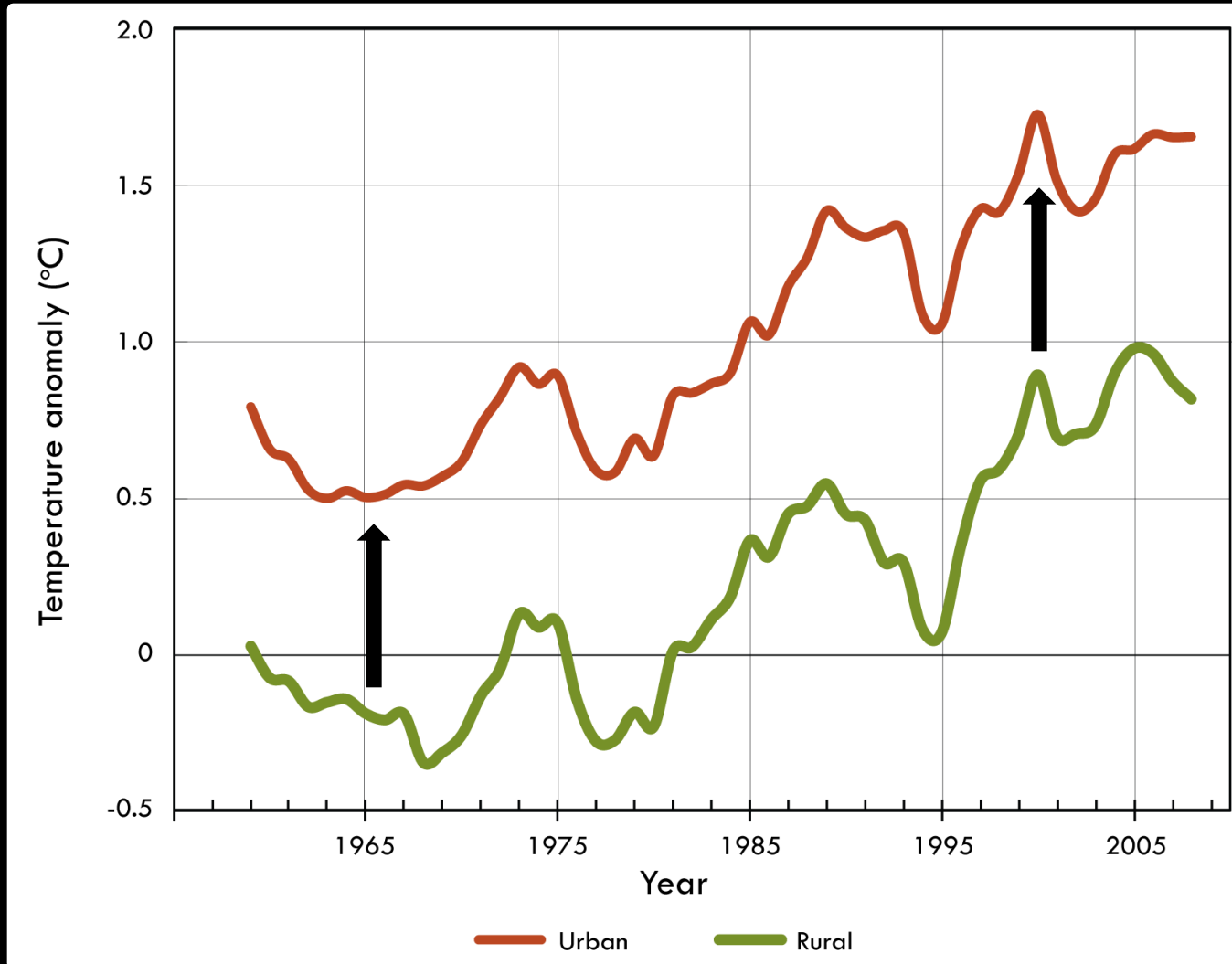
Urban areas, on average, are about 0.8 °C warmer than rural areas.

7
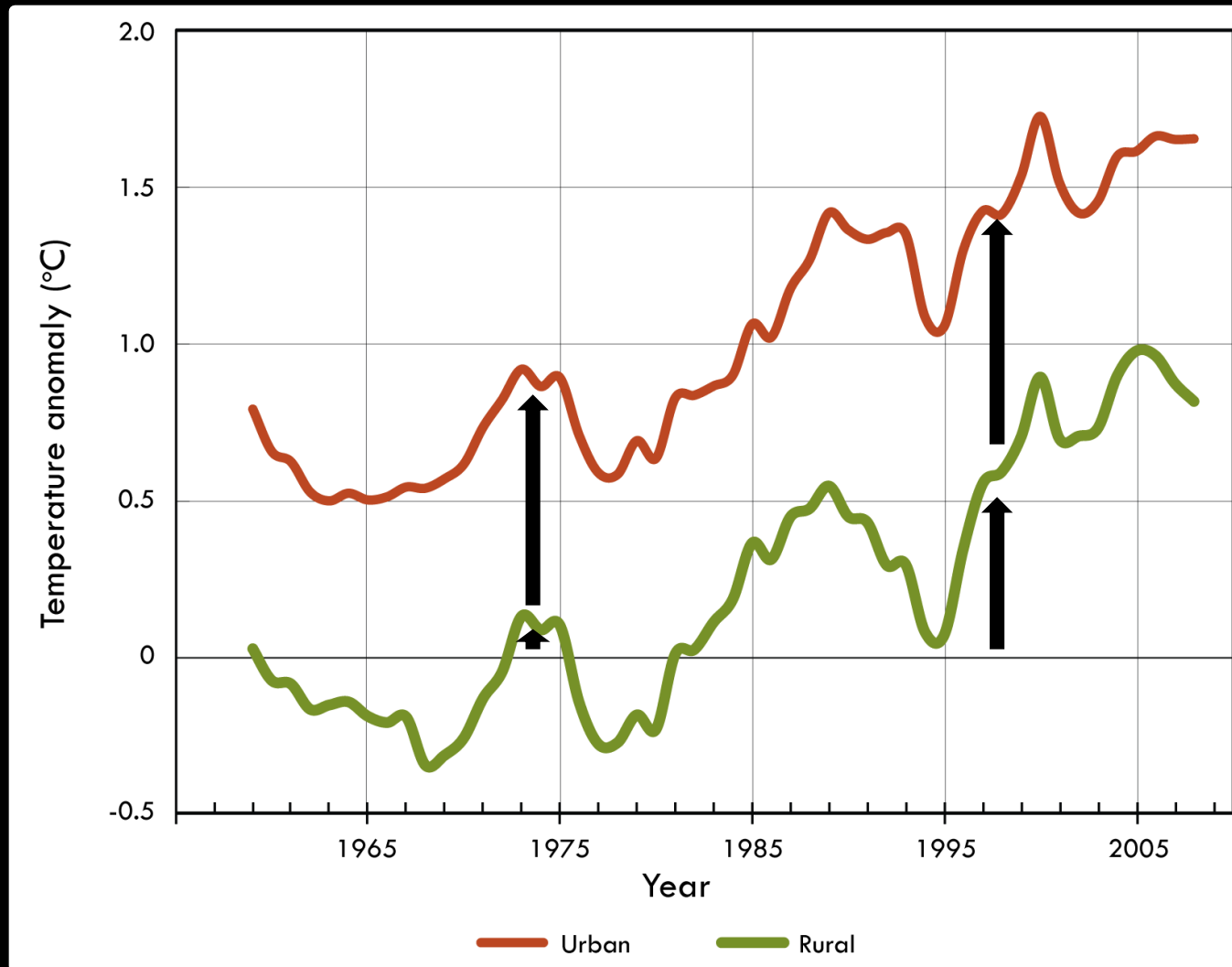
Most of the temperature anomaly in cities is attributable to UHI.
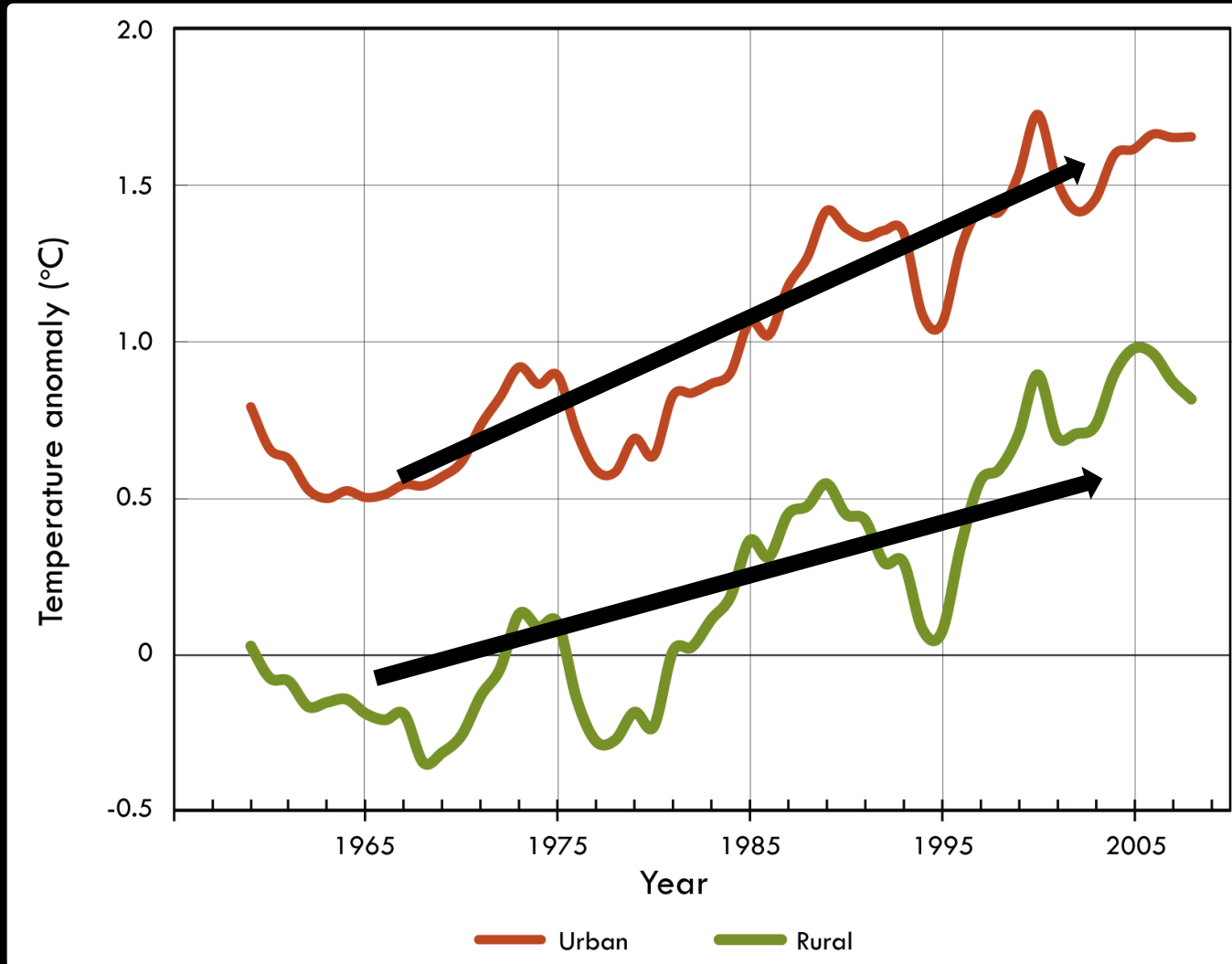
Urban areas are warming more rapidly over time than rural areas.
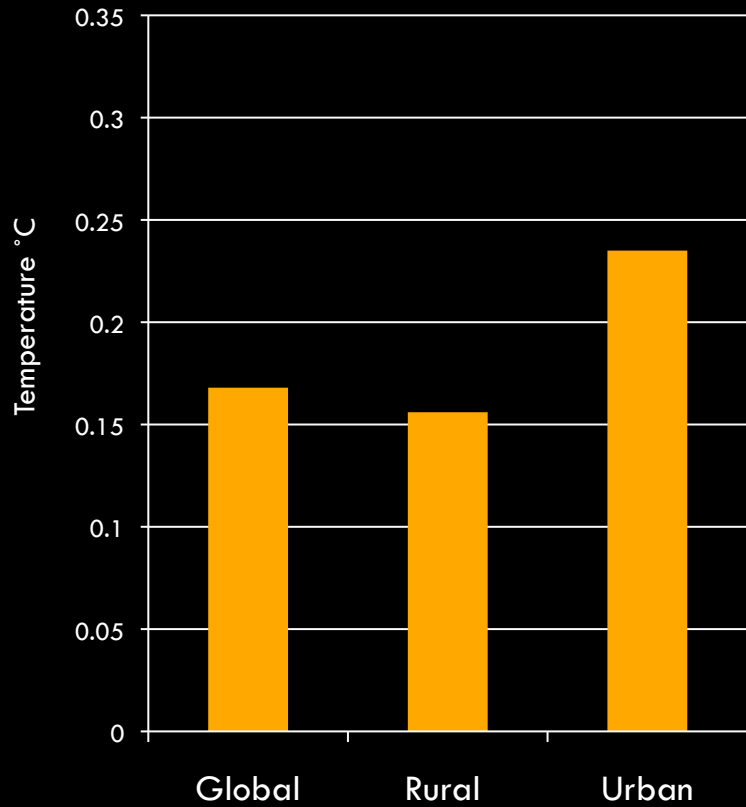
Amplification in all cities: 50%
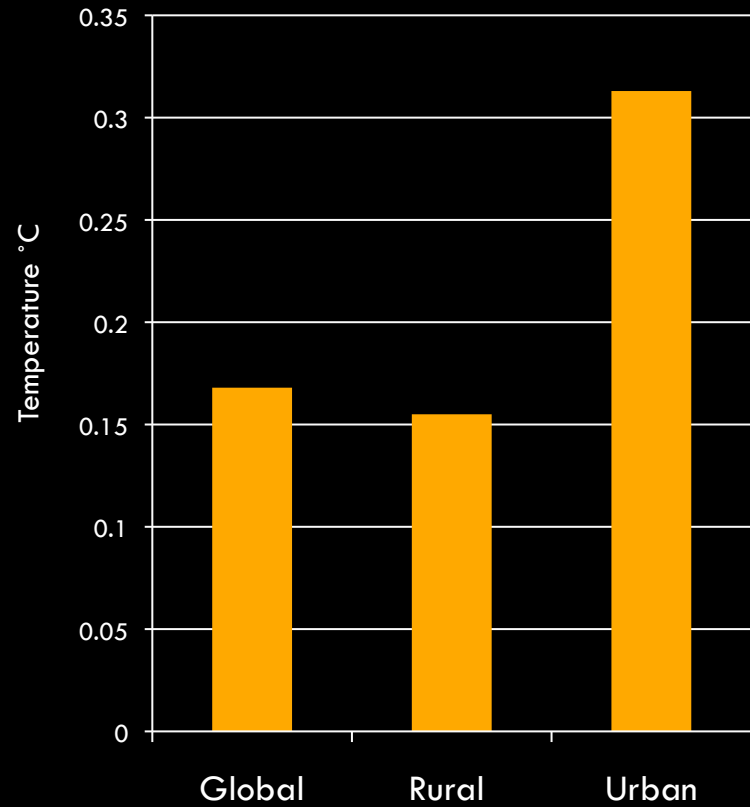
Amplification in cities with ↑ UHI: 100%

Urban Warming in Excess of Rural Trend (°F/century)
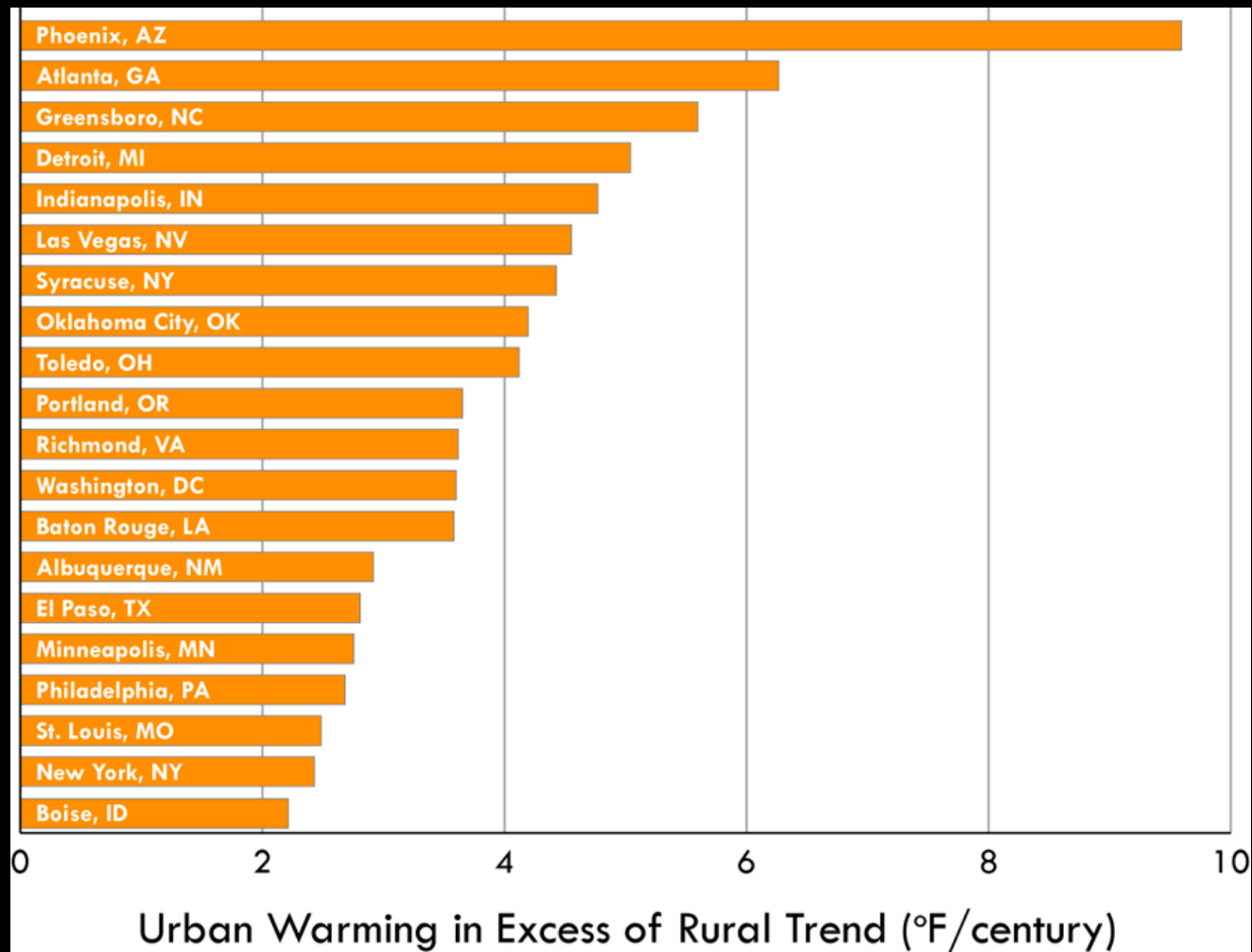
Is the frequency of extreme heat increasing?

❖ Heat stress index from Steadman (1984):

$$HSI\ (°C) = -1.3 + 0.92T + 2.2e$$

where: T is ambient air temperature (°C)

e is water vapor pressure (kPa)

❖ Gaffen & Ross (1998) define extreme heat-stress events as heat index values exceeding the 85th percentile of a long term average (1961-1990) for a location.

❖ The National Climate Data Center maintains a database of EHEs for 187 U.S. cities.

Mean annual frequency of
EHEs increased by 110%

Stone, Hess & Frumkin, 2010
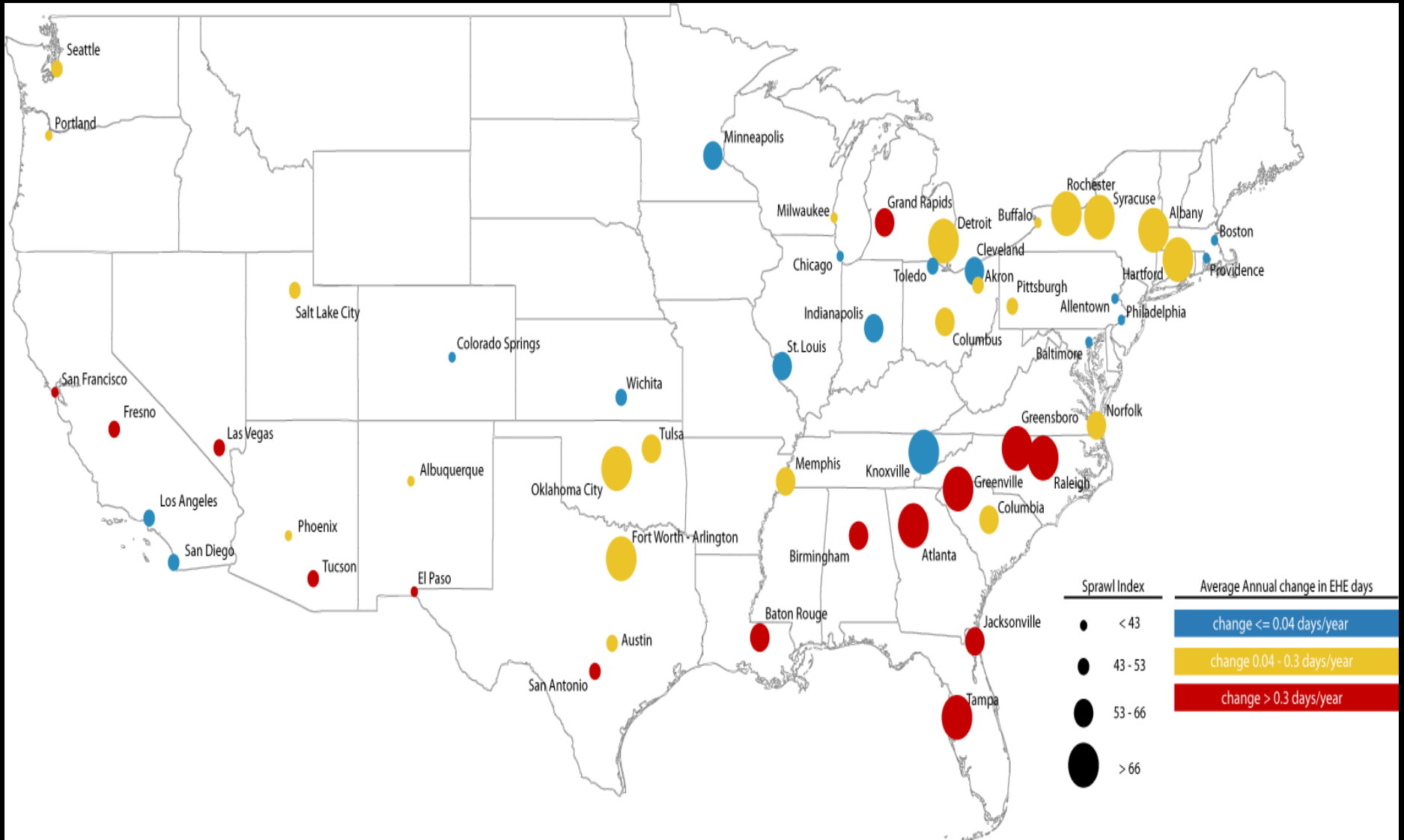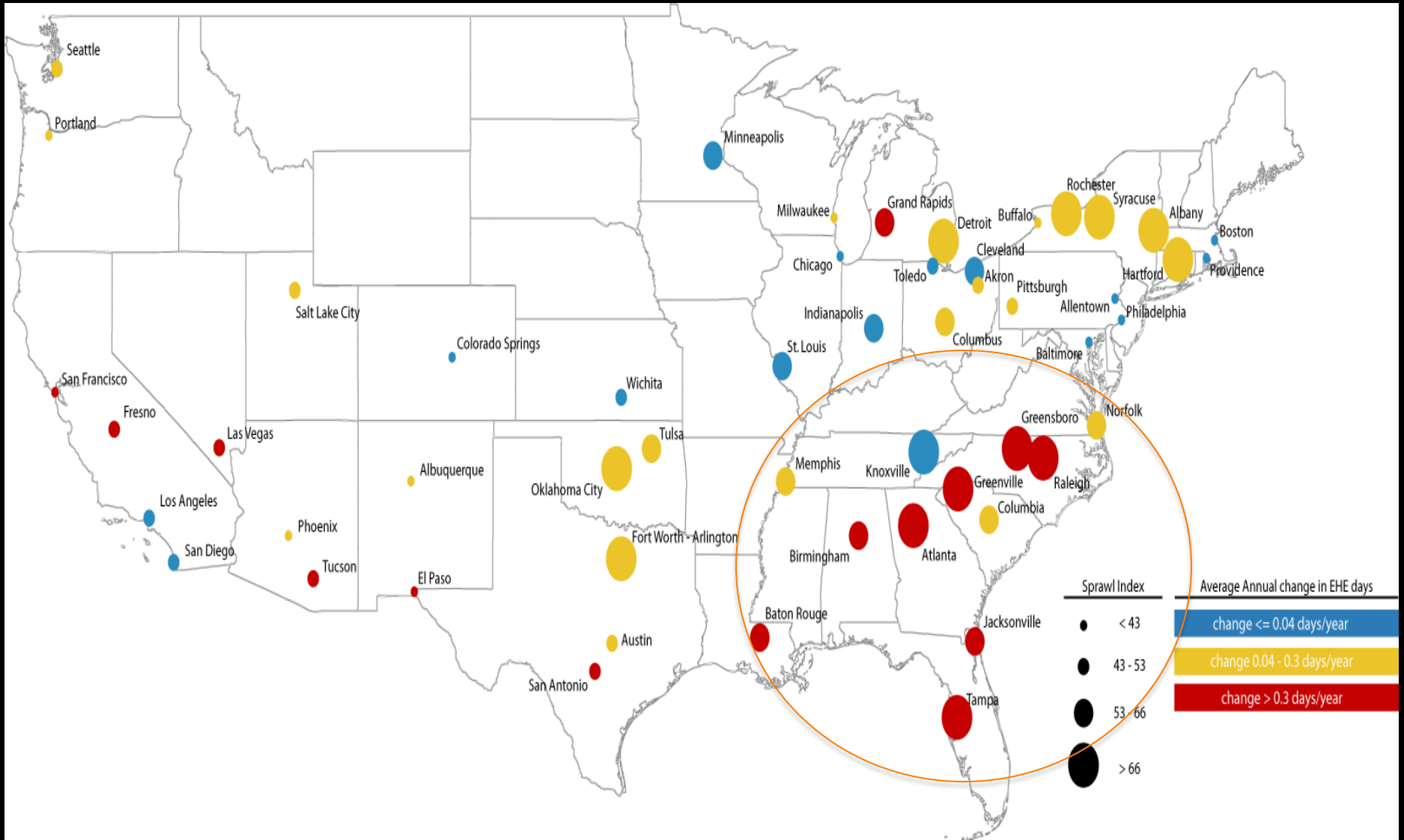
Mean annual change in EHEs (1956 – 2005)

Quartiles of sprawl index (2000)
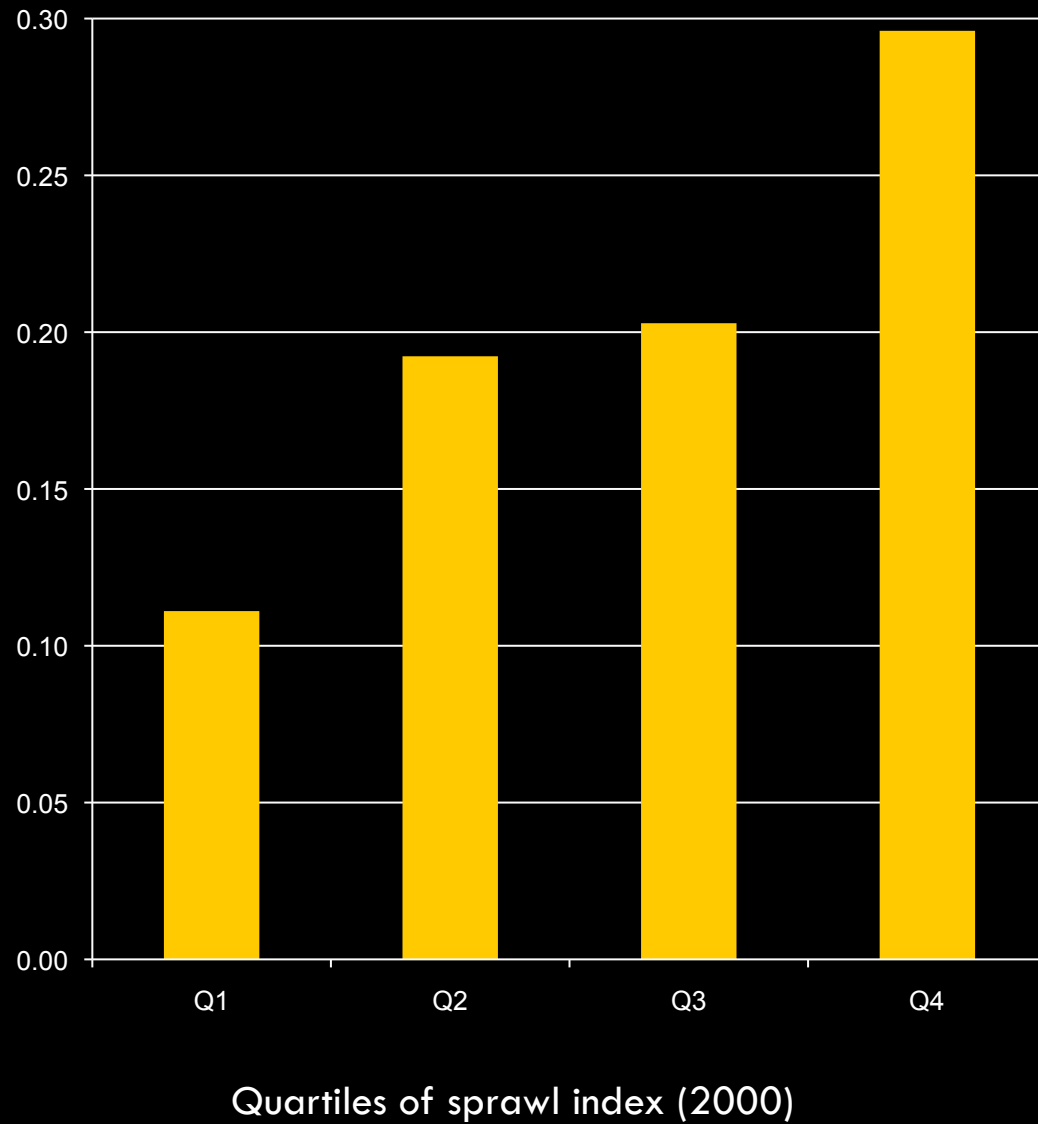
Change in tree canopy cover (Km²)
(1992 – 2001)
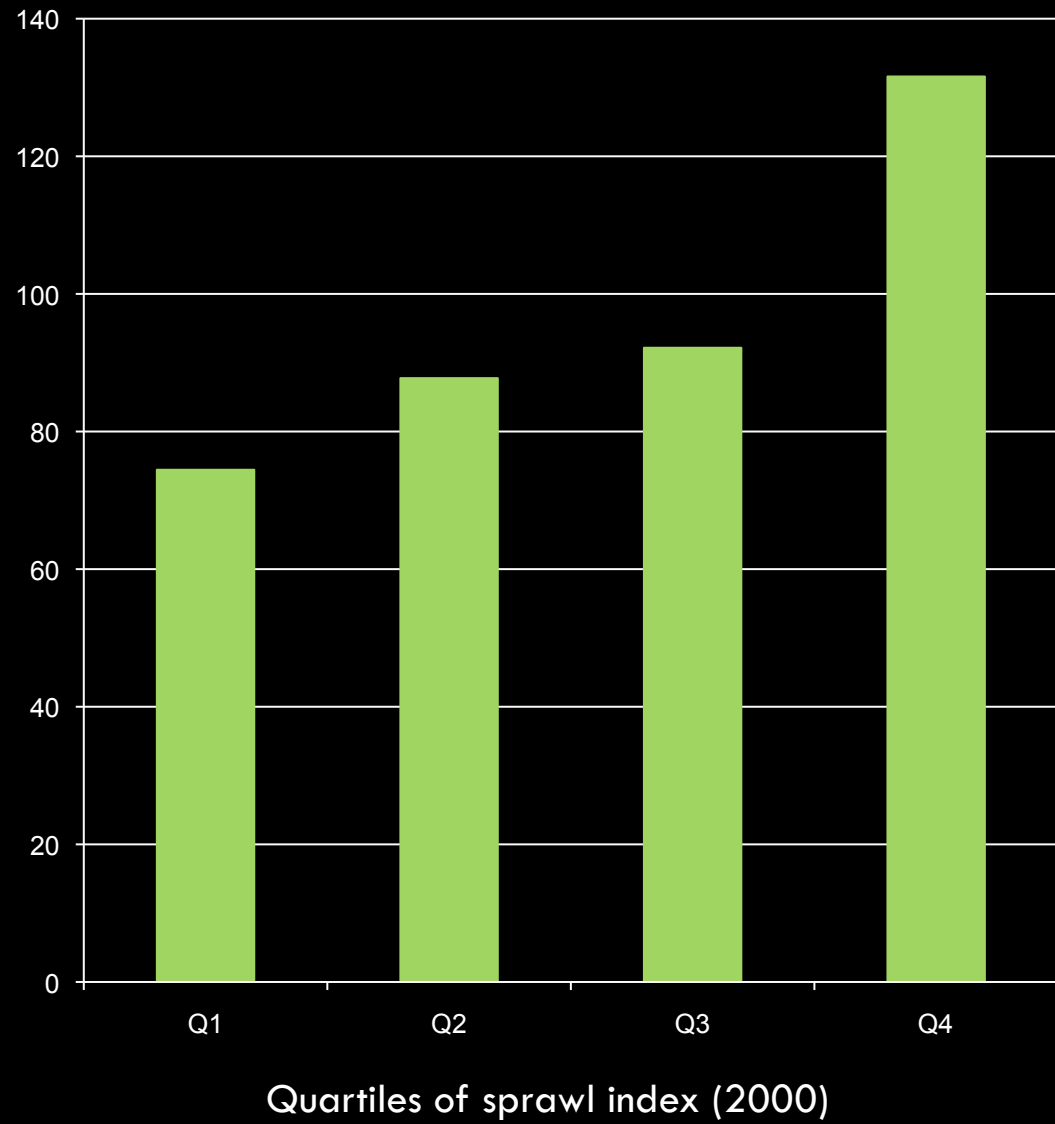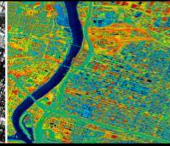
Quartiles of sprawl index (2000)

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

Heat Management in Climate Action Plans

Table Legend

Heat Island Mitigation Strategy ○

Greenhouse Effect Mitigation Strategy ●

MSA	Vegetation Enhancement	Albedo Enhancement	Energy Efficiency
Atlanta (2008)			○
Austin (2008)	○		○
Baltimore (2008-s)	○		○
Birmingham (1997-s)	○		○
Boston (2011)	●	○	○
Buffalo (2010-s)			○
Charlotte (2008-s)	○		○
Chicago (2008)	●	●	○
Cincinnati (2008)	●	●	○
Cleveland			
Columbus			
Dallas			
Denver (2007)	○		○
Detroit (2009-s)	○		○
Hartford (2005)	●		○
Houston (2008)			○
Indianapolis			
Jacksonville (2008-s)	○		○
Kansas City (2008)			○
Las Vegas (2008-s)			○
Los Angeles (2008)	●	●	○
Louisville (2009)	●	●	○
Memphis (1999-s)			○
Miami (2008)	●	●	○
Milwaukee (2008-s)	○		○
Minneapolis (2008-s)	○		○
Nashville (1999-s)			○
New Orleans (2008-s)	○		○
New York City (2008)	●		○
Oklahoma City			
Orlando (2008-s)	○		○
Philadelphia (2007)	●	○	○
Phoenix (2009)			○
Pittsburgh (2008)	●	○	○
Portland (2009)	●		○
Providence (2002-s)	○		○
Raleigh (2007)	○		○
Richmond (2008-s)	○		○
Riverside (2008-s)			○
Sacramento (2008-s)			○
Salt Lake City (2007-s)	○		○
San Antonio			
San Diego (2005)	●	●	○
San Francisco (2004)			○
San Jose (2008-s)			○
Seattle (2007)	○		○
St. Louis (2002)			○
Tampa (2008-s)	○		○
Virginia Beach (2008-s)	○		○
Washington DC			

Heat Management in Climate Action Plans

	U.S.
Primary Strategies:	24%
Secondary Strategies:	36%

Table Legend

Heat Island Mitigation Strategy	○
Greenhouse Effect Mitigation Strategy	●

MSA	Vegetation Enhancement	Albedo Enhancement	Energy Efficiency
Atlanta (2008)			○
Austin (2008)	○		○
Baltimore (2008-s)	○		○
Birmingham (1997-s)	○		○
Boston (2011)	●	○	○
Buffalo (2010-s)			○
Charlotte (2008-s)	○		○
Chicago (2008)	●	●	○
Cincinnati (2008)	●	●	○
Cleveland			
Columbus			
Dallas			
Denver (2007)	○		○
Detroit (2009-s)	○		○
Hartford (2005)	●		○
Houston (2008)			○
Indianapolis			
Jacksonville (2008-s)	○		○
Kansas City (2008)			○
Las Vegas (2008-s)			○
Los Angeles (2008)	●	●	○
Louisville (2009)	●	●	○
Memphis (1999-s)			○
Miami (2008)	●	●	○
Milwaukee (2008-s)	○		○
Minneapolis (2008-s)	○		○
Nashville (1999-s)			○
New Orleans (2008-s)	○		○
New York City (2008)	●		○
Oklahoma City			
Orlando (2008-s)	○		○
Philadelphia (2007)	●	○	○
Phoenix (2009)			○
Pittsburgh (2008)	●	○	○
Portland (2009)	●		○
Providence (2002-s)	○		○
Raleigh (2007)	○		○
Richmond (2008-s)	○		○
Riverside (2008-s)			○
Sacramento (2008-s)			○
Salt Lake City (2007-s)	○		○
San Antonio			
San Diego (2005)	●	●	○
San Francisco (2004)			○
San Jose (2008-s)			○
Seattle (2007)	○		○
St. Louis (2002)			○
Tampa (2008-s)	○		○
Virginia Beach (2008-s)	○		○
Washington DC			

Heat Management in Climate Action Plans

	U.S.	Southeast
Primary Strategies:	24%	15%
Secondary Strategies:	36%	70%

Table Legend

Heat Island Mitigation Strategy ○

Greenhouse Effect Mitigation Strategy ●

MSA	Vegetation Enhancement	Albedo Enhancement	Energy Efficiency
Atlanta (2008)			○
Austin (2008)	○		○
Baltimore (2008-s)	○		○
Birmingham (1997-s)	○		○
Boston (2011)	●	○	○
Buffalo (2010-s)			○
Charlotte (2008-s)	○		○
Chicago (2008)	●	●	○
Cincinnati (2008)	●	●	○
Cleveland			
Columbus			
Dallas			
Denver (2007)	○		○
Detroit (2009-s)	○		○
Hartford (2005)	●		○
Houston (2008)			○
Indianapolis			
Jacksonville (2008-s)	○		○
Kansas City (2008)			○
Las Vegas (2008-s)			○
Los Angeles (2008)	●	●	○
Louisville (2009)	●	●	○
Memphis (1999-s)			○
Miami (2008)	●	●	○
Milwaukee (2008-s)	○		○
Minneapolis (2008-s)	○		○
Nashville (1999-s)			○
New Orleans (2008-s)	○		○
New York City (2008)	●		○
Oklahoma City			
Orlando (2008-s)	○		○
Philadelphia (2007)	●	○	○
Phoenix (2009)			○
Pittsburgh (2008)	●	○	○
Portland (2009)	●		○
Providence (2002-s)	○		○
Raleigh (2007)	○		○
Richmond (2008-s)	○		○
Riverside (2008-s)			○
Sacramento (2008-s)			○
Salt Lake City (2007-s)	○		○
San Antonio			
San Diego (2005)	●	●	○
San Francisco (2004)			○
San Jose (2008-s)			○
Seattle (2007)	○		○
St. Louis (2002)			○
Tampa (2008-s)	○		○
Virginia Beach (2008-s)	○		○
Washington DC			

Management Strategy 1: Sunscreening

Management Strategy 2: Greenbelting

Management Strategy 3: Carbon cooling

❖ Climate change is not a phenomenon responsive greenhouse gases alone. At present, the urban heat island effect is the dominant driver of warming trends in large U.S. cities and a rising threat to public health.

❖ A survey of the climate change management activities of large cities suggests that relatively few resources are being directed at the principal driver of extreme heat at the urban scale.   This oversight is more pronounced in the southeast than in the country as a whole.

❖ Urban climate resilience requires urban environments to more closely mimic their regional ecological context. Adaptive mitigation in the form of sunscreening, greenbelting, and carbon cooling provides a direct mechanism for integrating regional and global climate management strategies.