Urban and Rural Temperature Trends in Proximity to Large U.S. Cities: 1957-2006

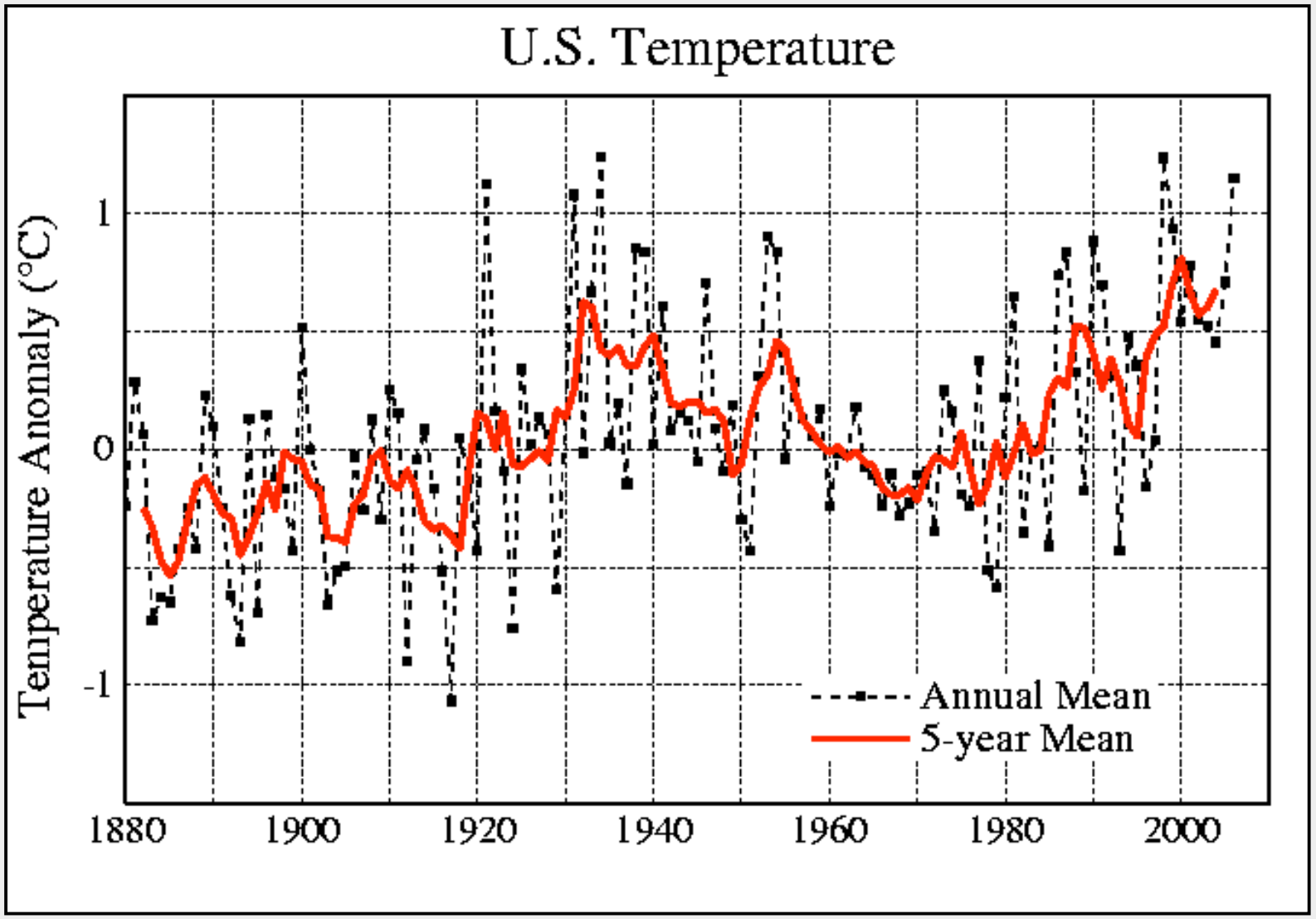
Presentation to the 2nd International Conference on Countermeasures to Urban Heat Islands

Brian Stone, Ph.D.
Associate Professor
City and Regional Planning Program
Georgia Institute of Technology
stone@gatech.edu

September 21, 2009

Overview

- Measuring climate change
- Study design
- Urban and rural temperature trends
- Implications for heat island management



Source: NASA Goddard Institute for Space Studies

Global Historical Climatology Network

Figure 1: GHCN-Monthly Coverage Map for Mean Temperature

Source: GISS, 2007.

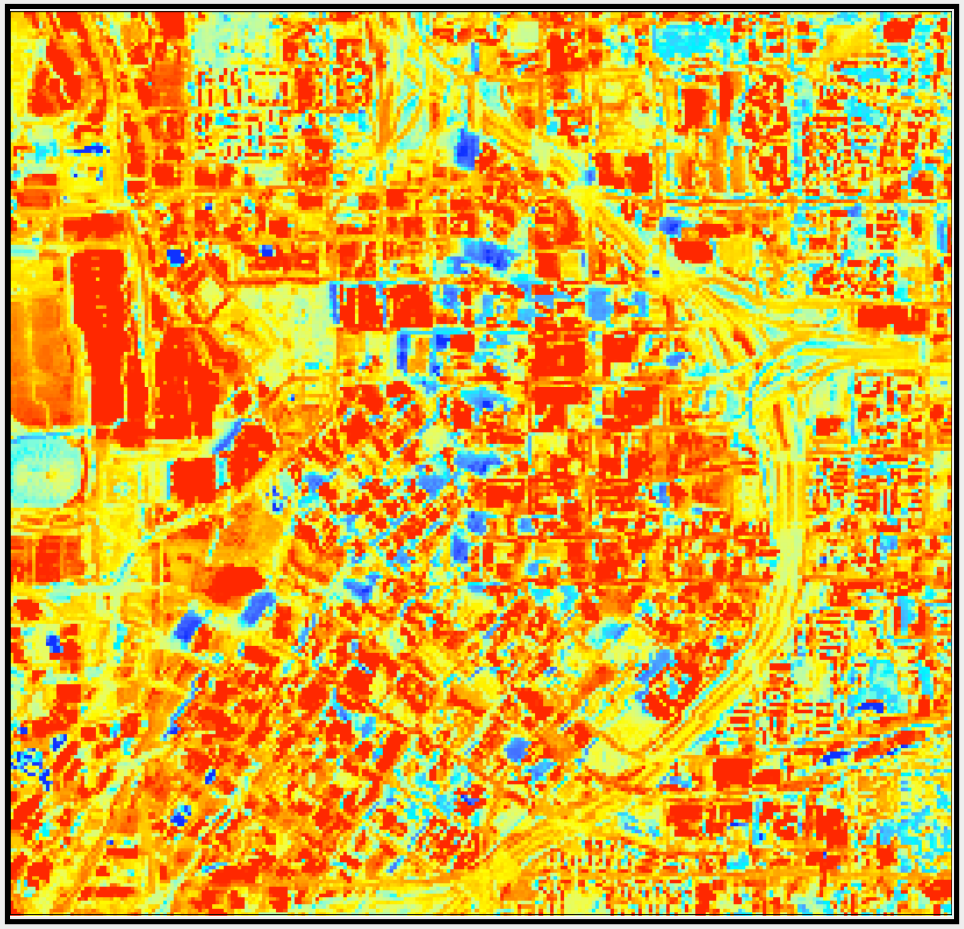
Sources of “Inhomogeneity” in Temperature Record

1. Change in location of instrument
2. Change in instrumentation
3. Change in time of observation
4. Contamination by urbanization

Research Question

The IPCC projects a range of increase in mean global temperatures of between 1.4 and 5.8 ^{O}C by 2100.

Are large U.S. cities warming more rapidly than the planet as a whole?



Intensity of surface heat in Atlanta's CBD, 1997

Station Selection

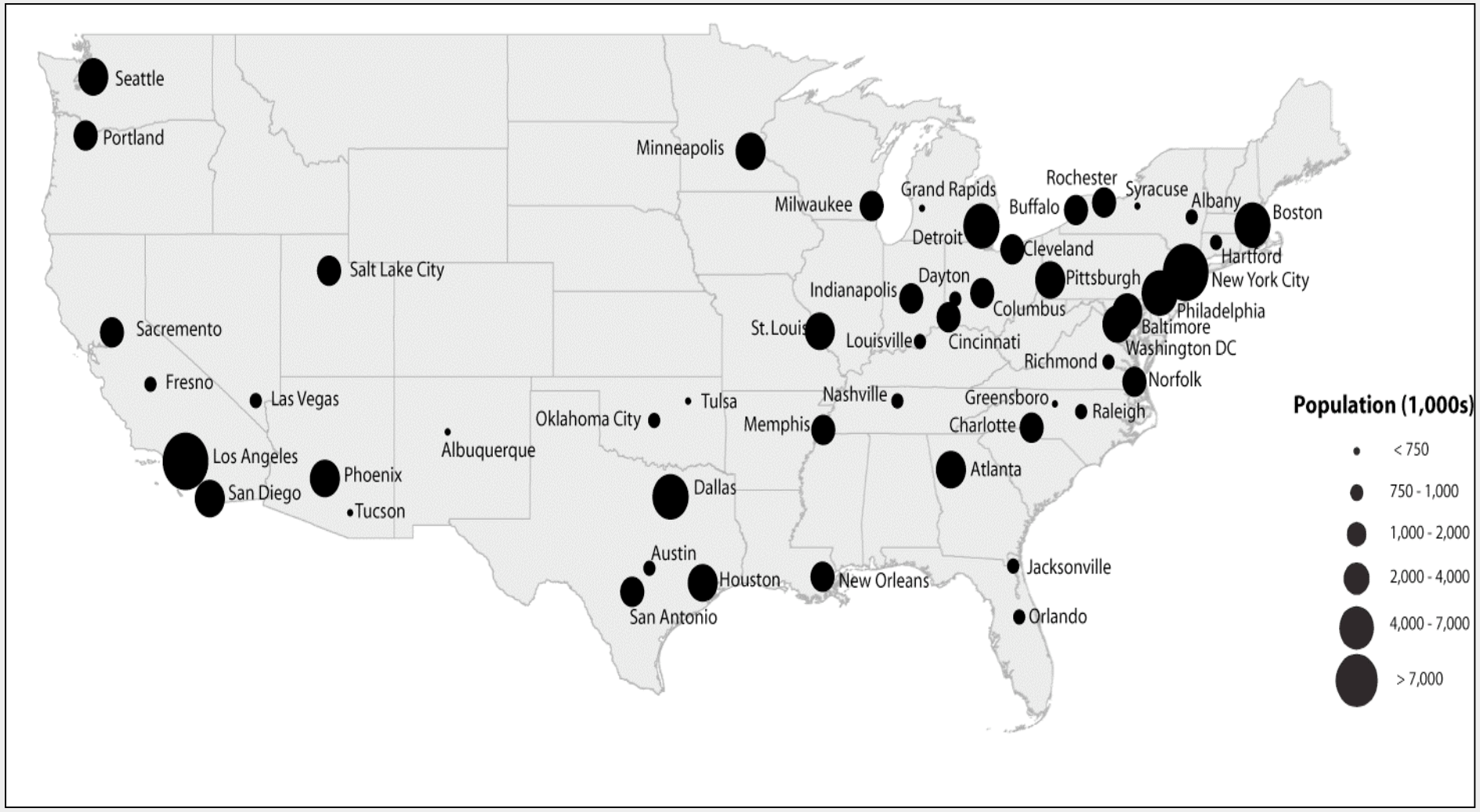
URBAN

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

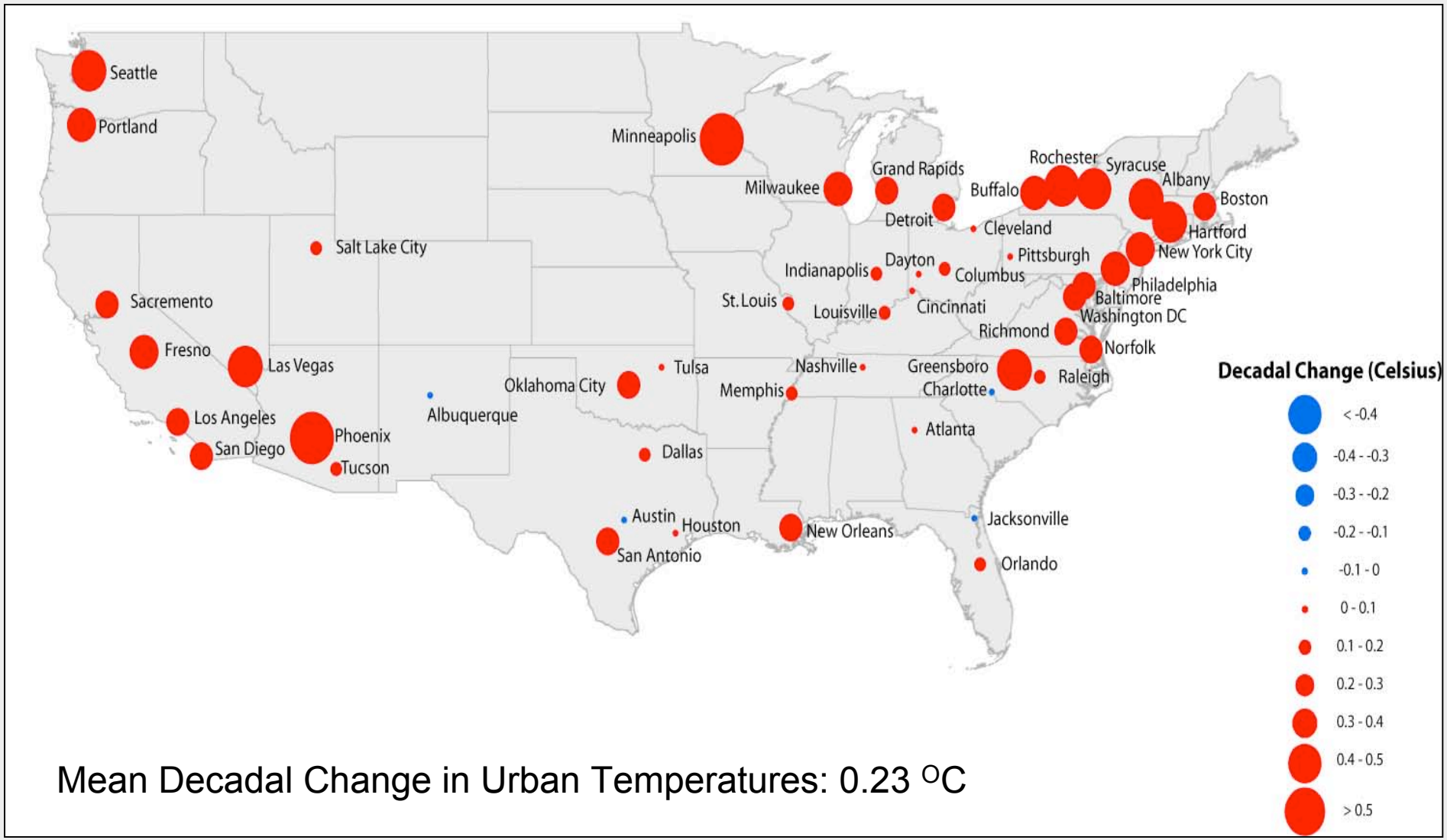
RURAL

- 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

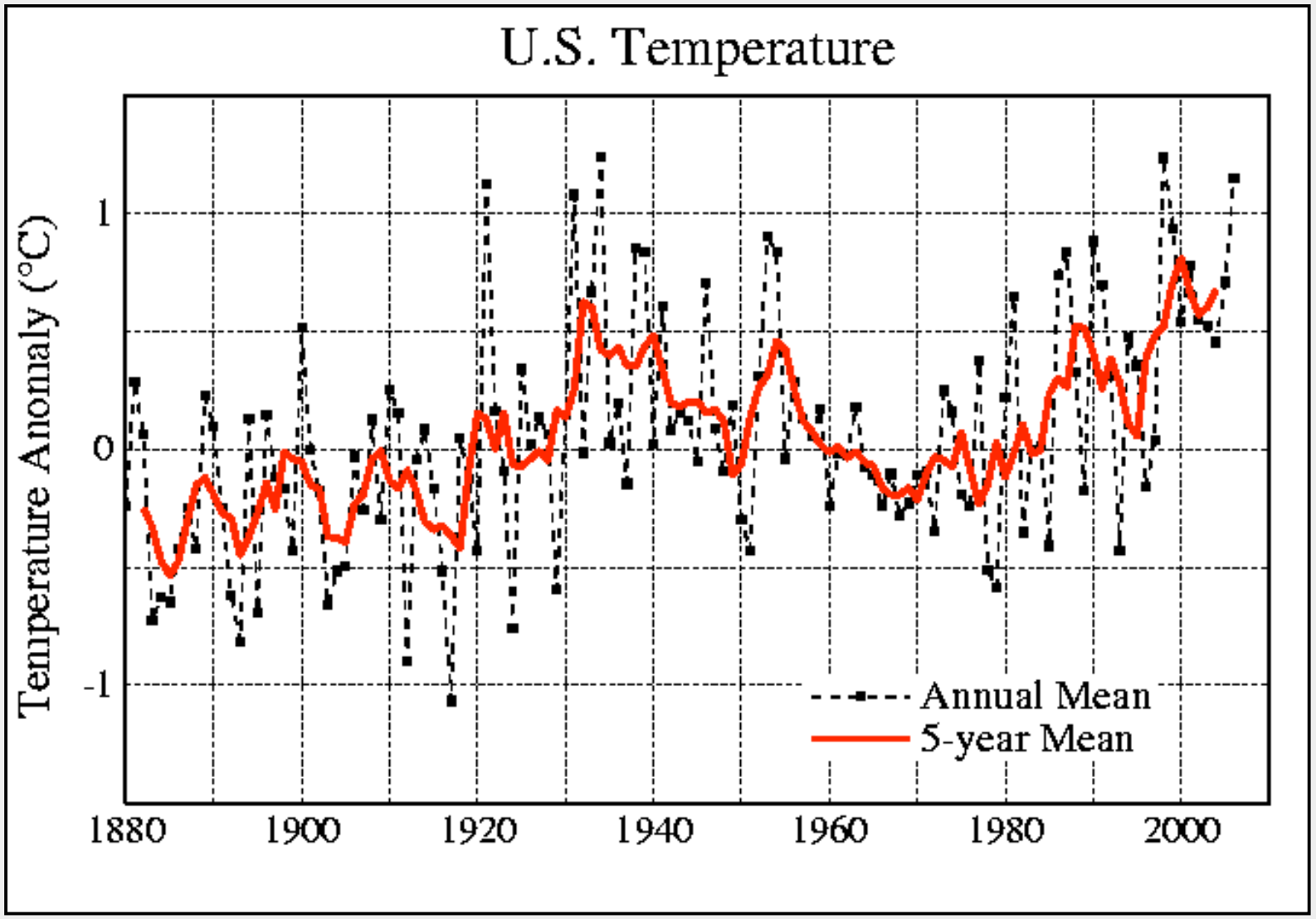
50 Cities Included in Study



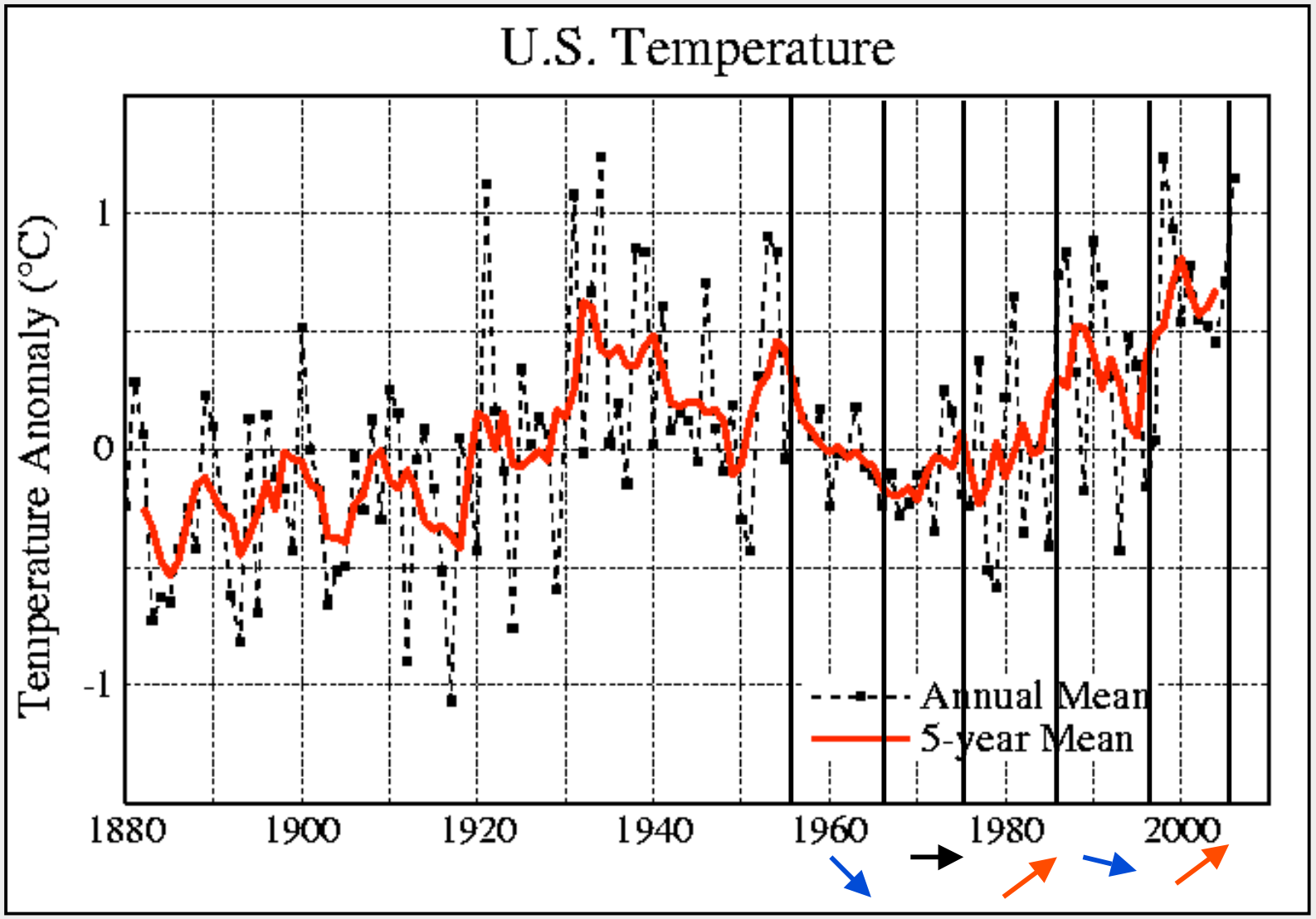
Urban Trends: 1957-2006



Mean Decadal Change in Urban Temperatures: 0.23 ^{O}C

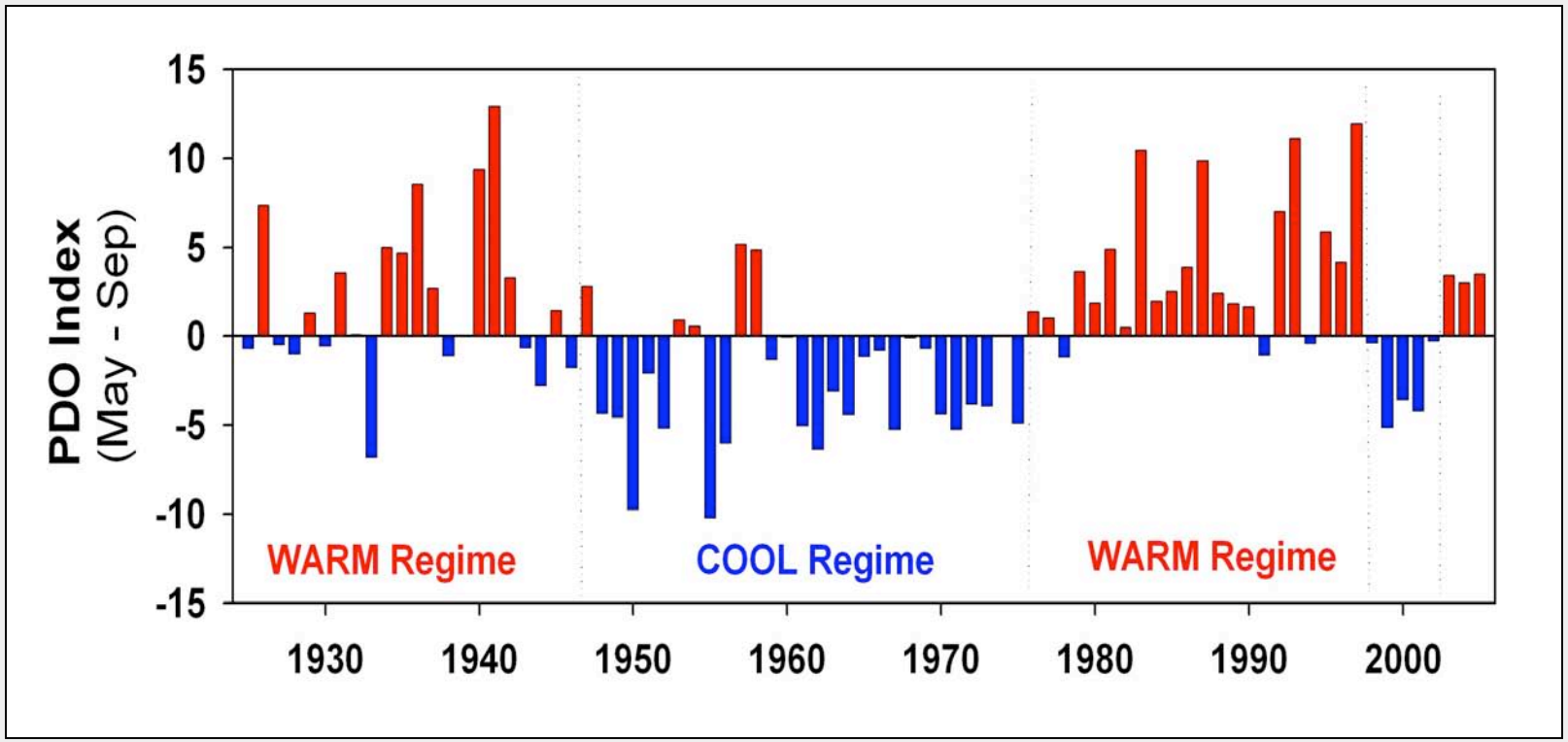


Source: NASA Goddard Institute for Space Studies

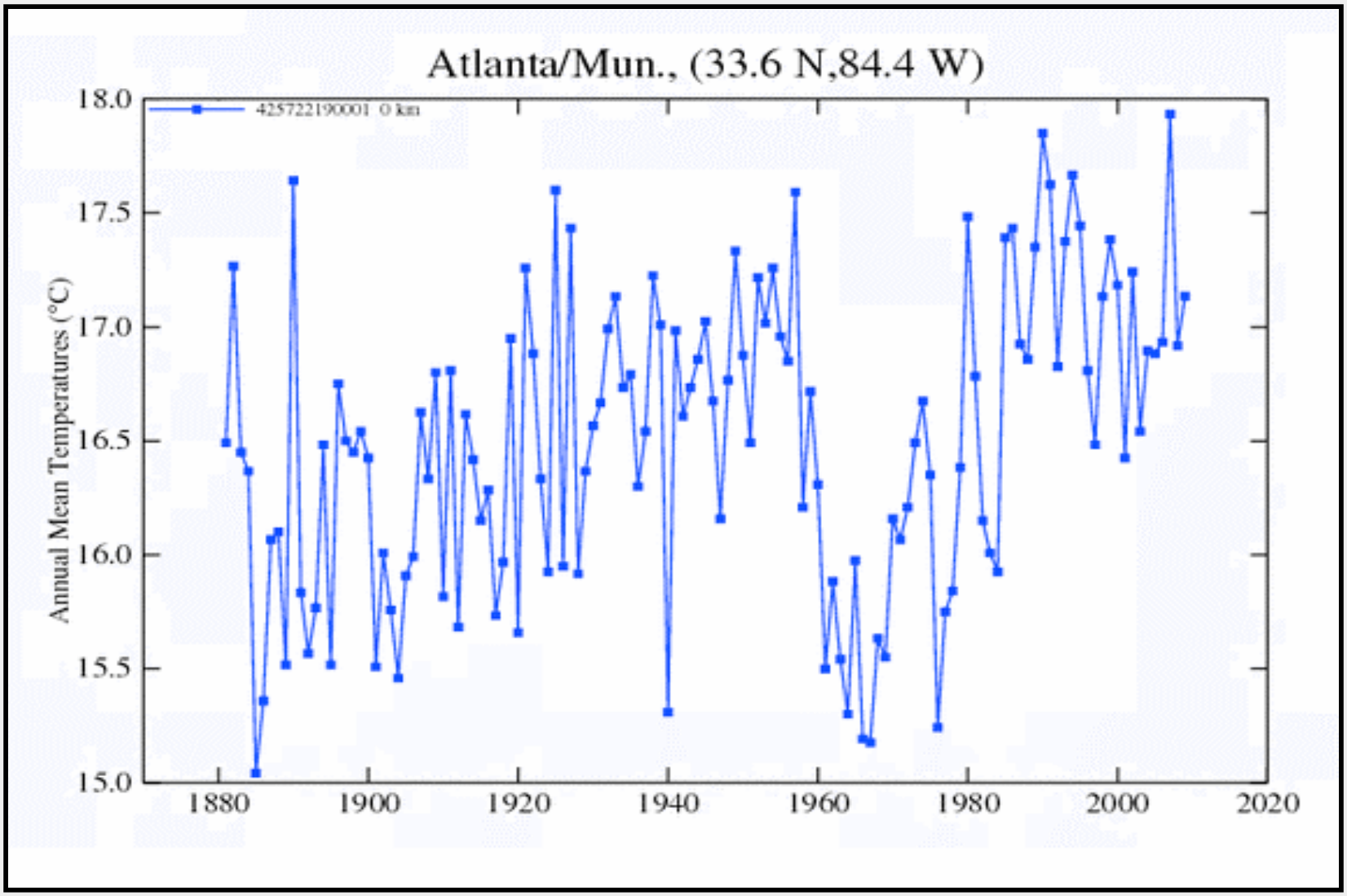


Source: NASA Goddard Institute for Space Studies

Pacific Decadal Oscillation (PDO)

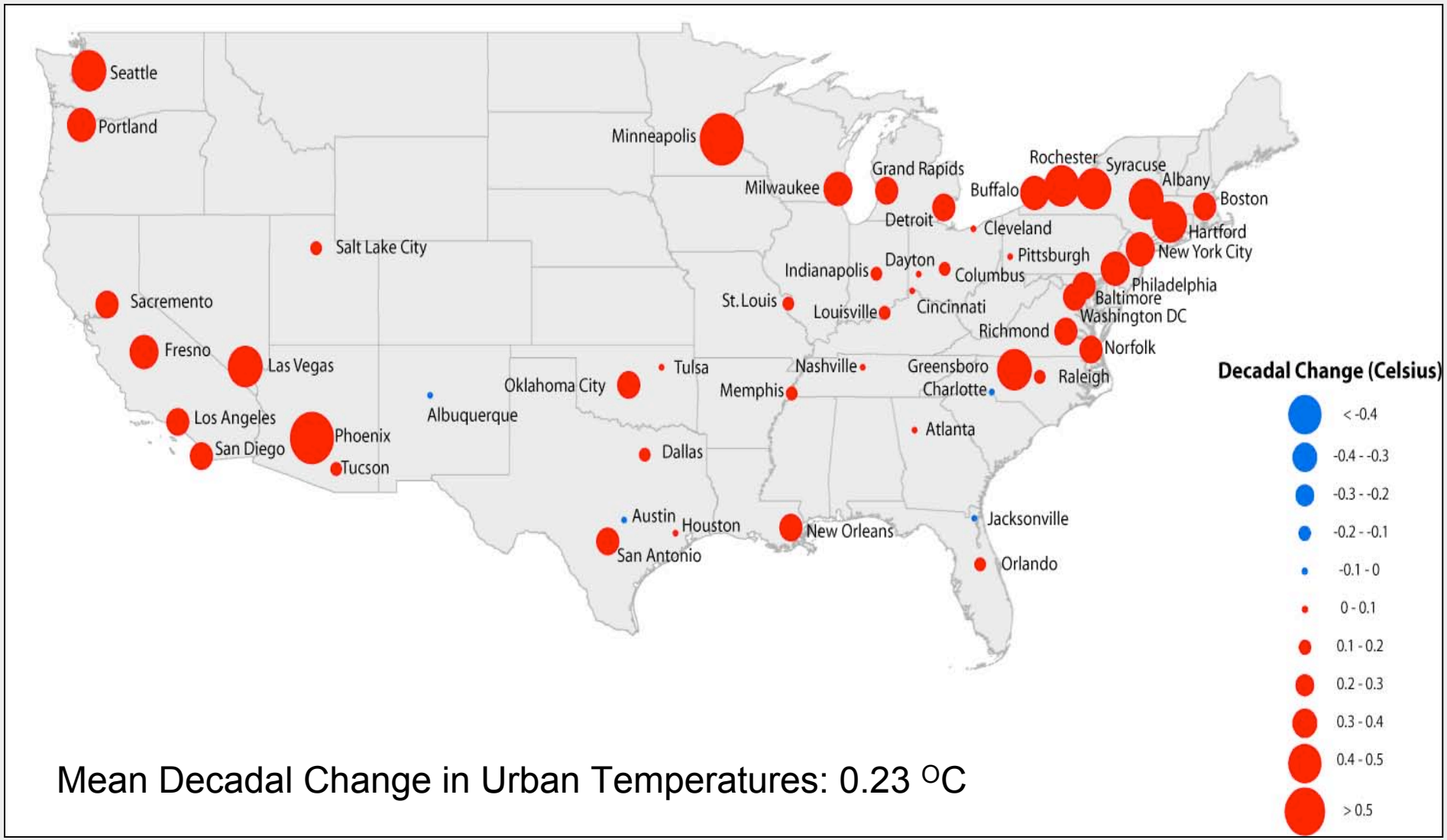


The Pacific Decadal Oscillation is a climate index reflective of patterns of variation in sea surface temperature of the North Pacific from 1900 to the present (Mantua et al. 1997). While derived from sea surface temperature data, the PDO index is well correlated with many records of climate and ecology, including sea level pressure, winter land–surface temperature and precipitation, and stream flow (NOAA Fisheries Service).



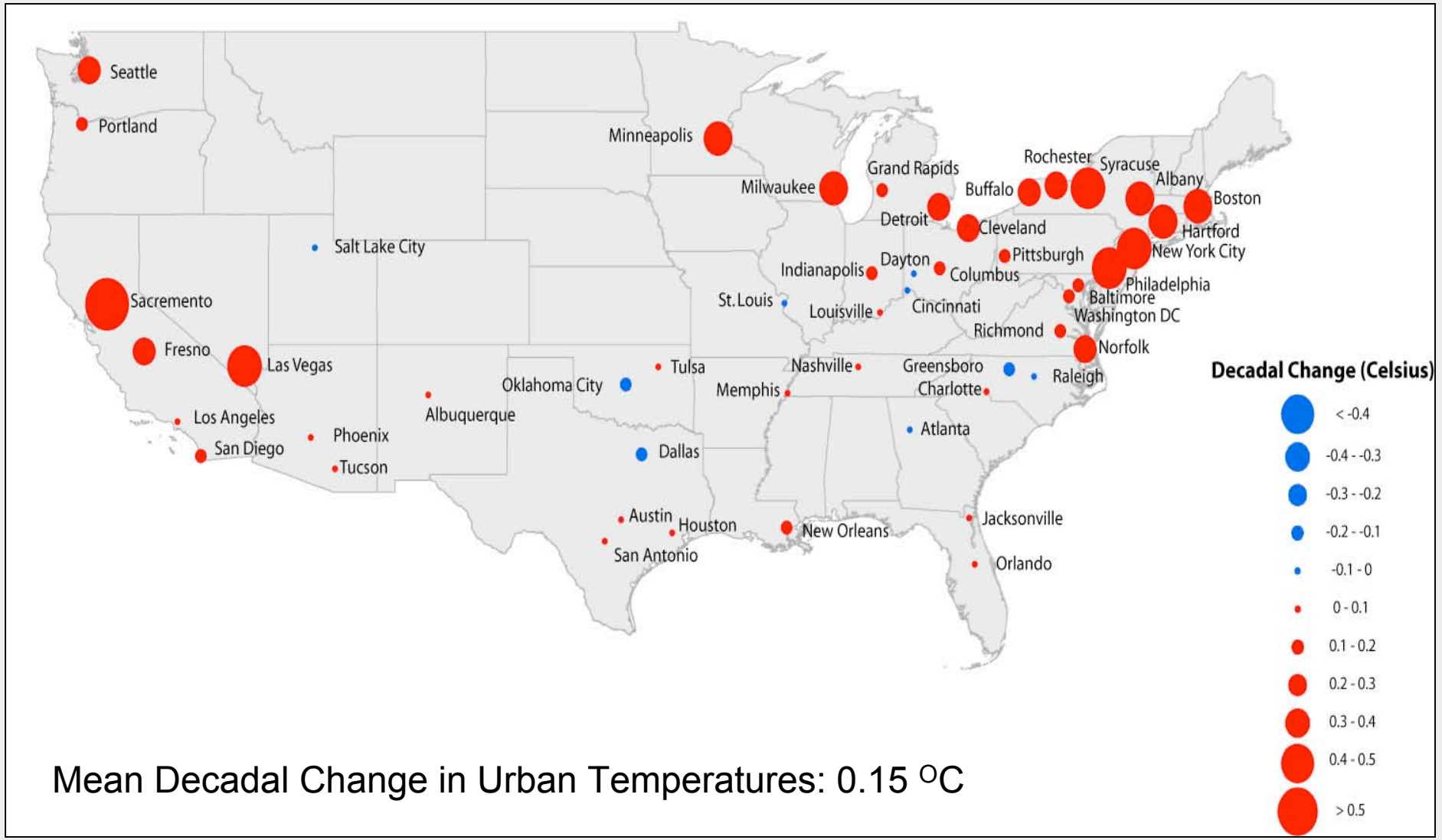
Source: NASA Goddard Institute for Space Studies, GHCN

Urban Trends: 1957-2006



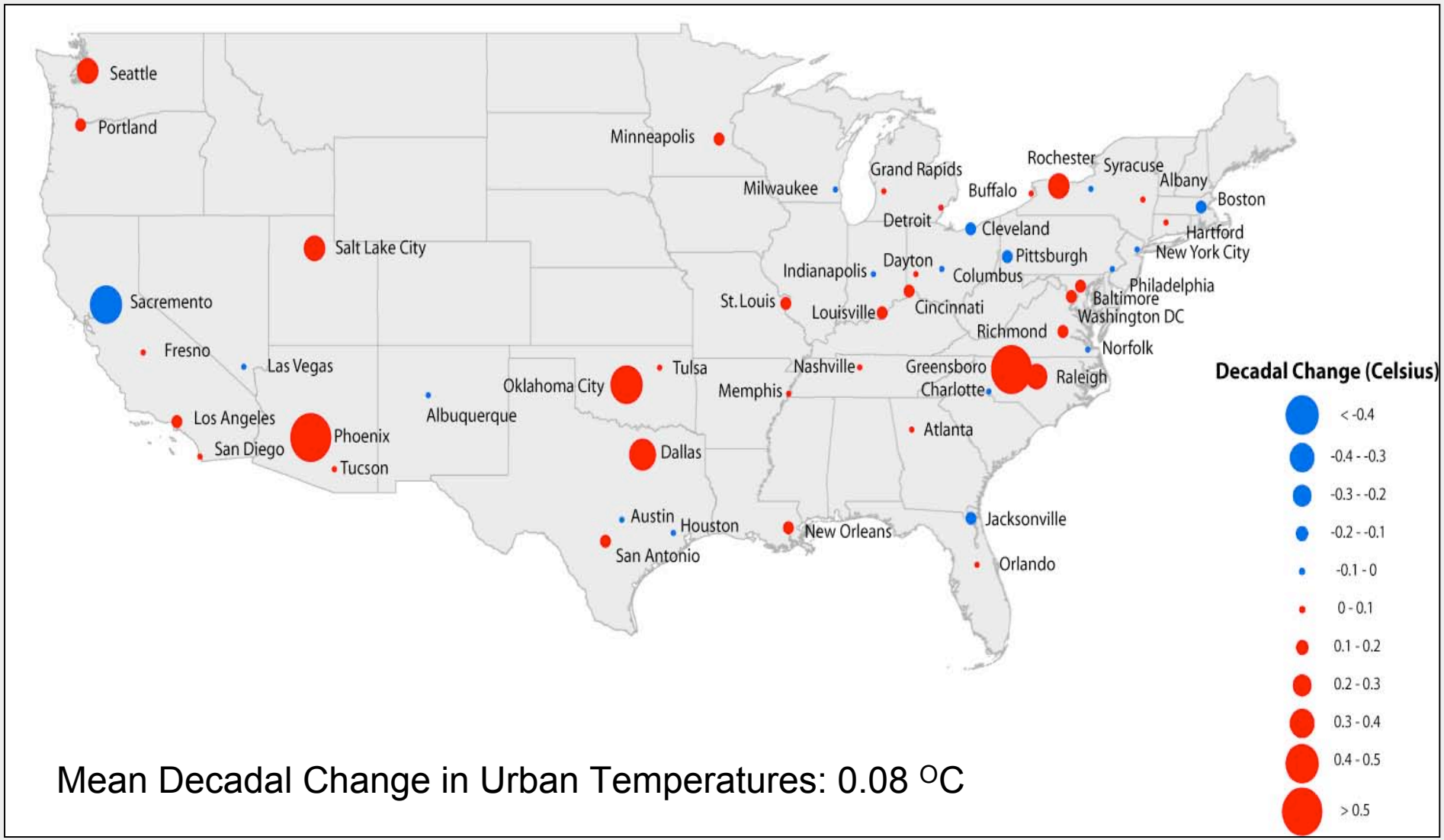
Mean Decadal Change in Urban Temperatures: 0.23 ^{O}C

Rural Trends: 1957-2006



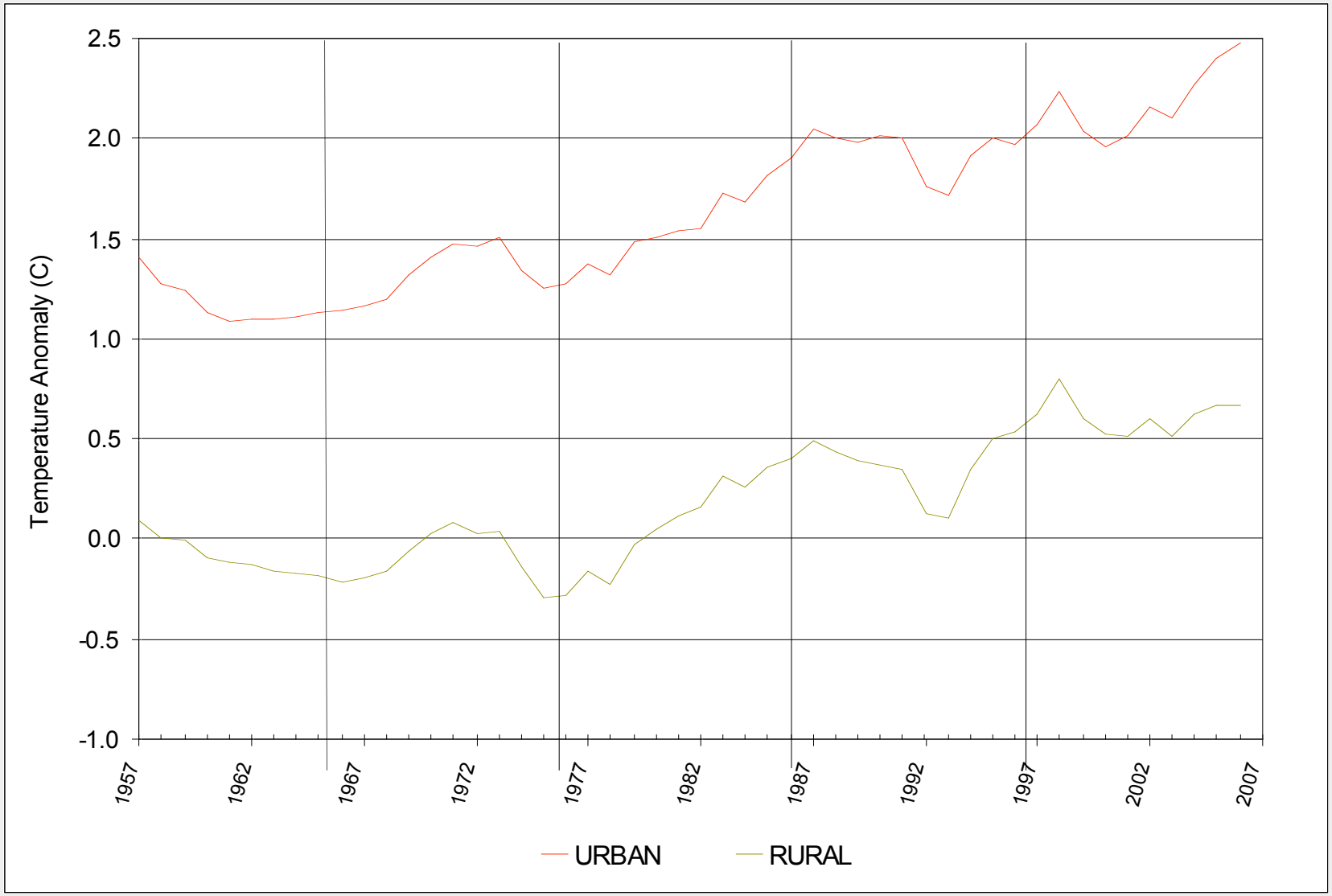
Mean Decadal Change in Urban Temperatures: 0.15 ^{O}C

UHI Trends: 1957-2006



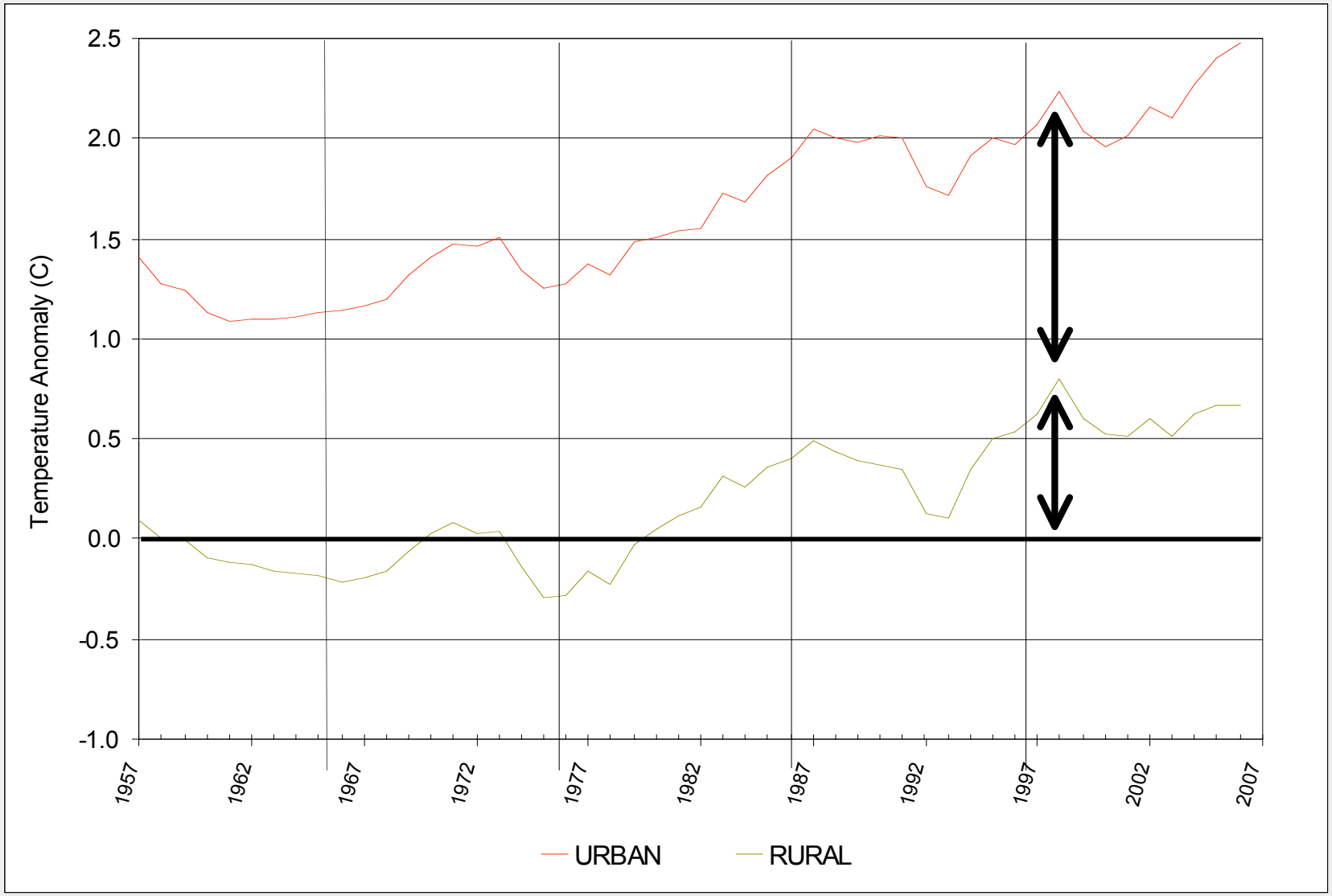
Mean Decadal Change in Urban Temperatures: 0.08 ^{O}C

Urban and Rural Temperature Anomalies: 1957-2006



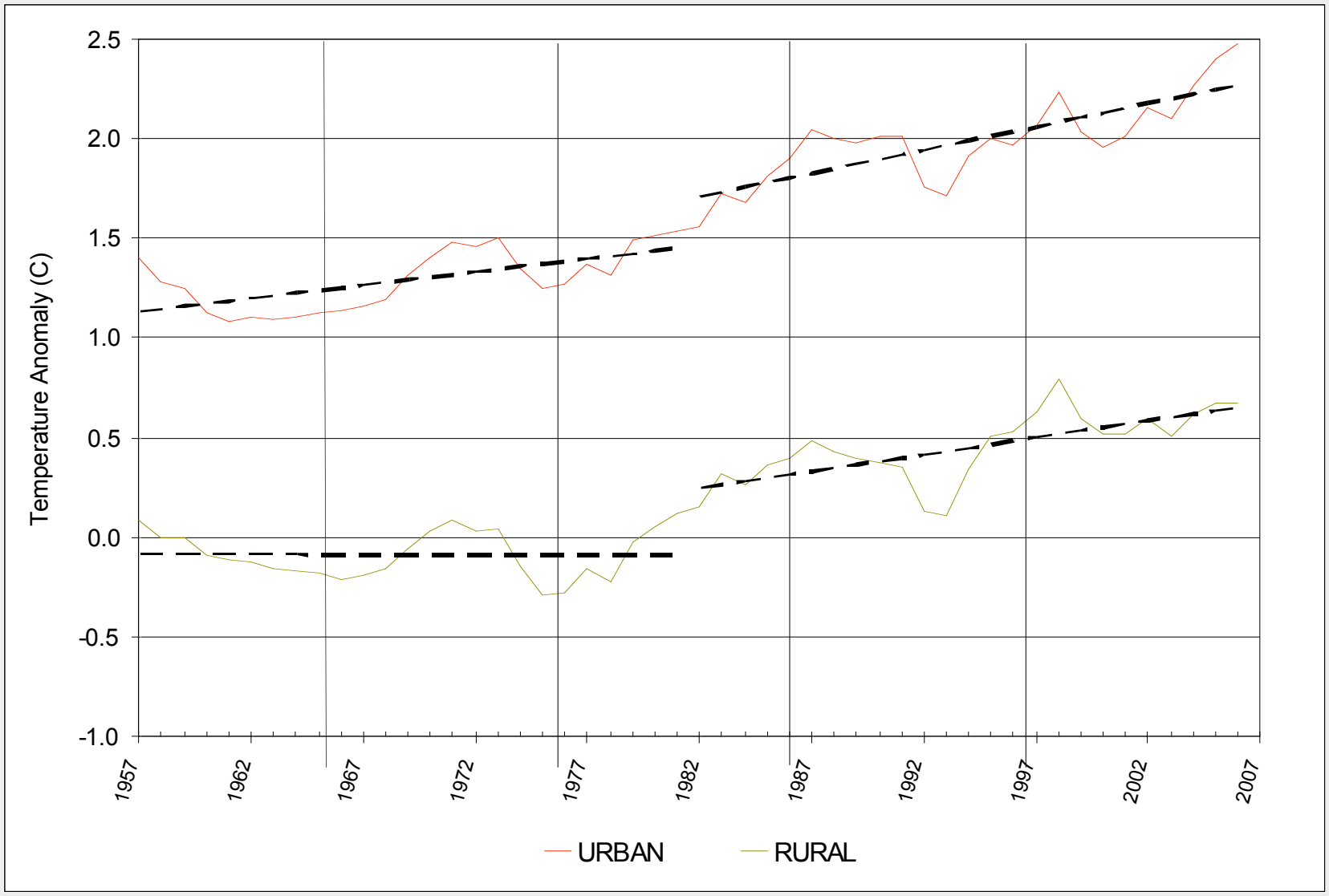
Temperature anomalies (^{O}C) relative to 1951-1980 mean.

Urban and Rural Temperature Anomalies: 1957-2006

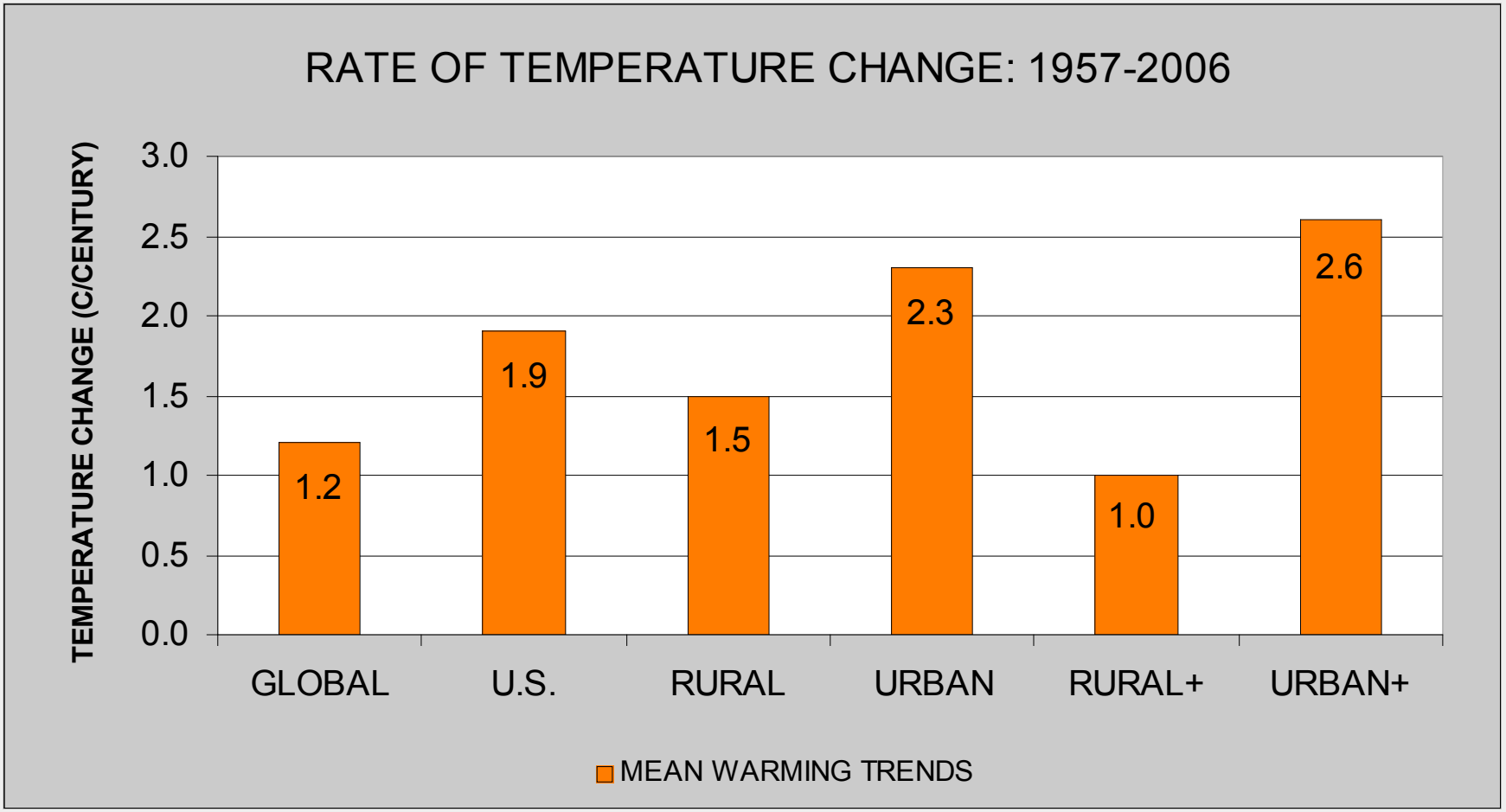


Temperature anomalies (^{O}C) relative to 1951-1980 mean.

Urban and Rural Temperature Anomalies: 1957-2006



Temperature anomalies (^{O}C) relative to 1951-1980 mean.



Source: NASA Goddard Institute of Space Studies

+ Cities in which UHI increased between 1957 and 2006

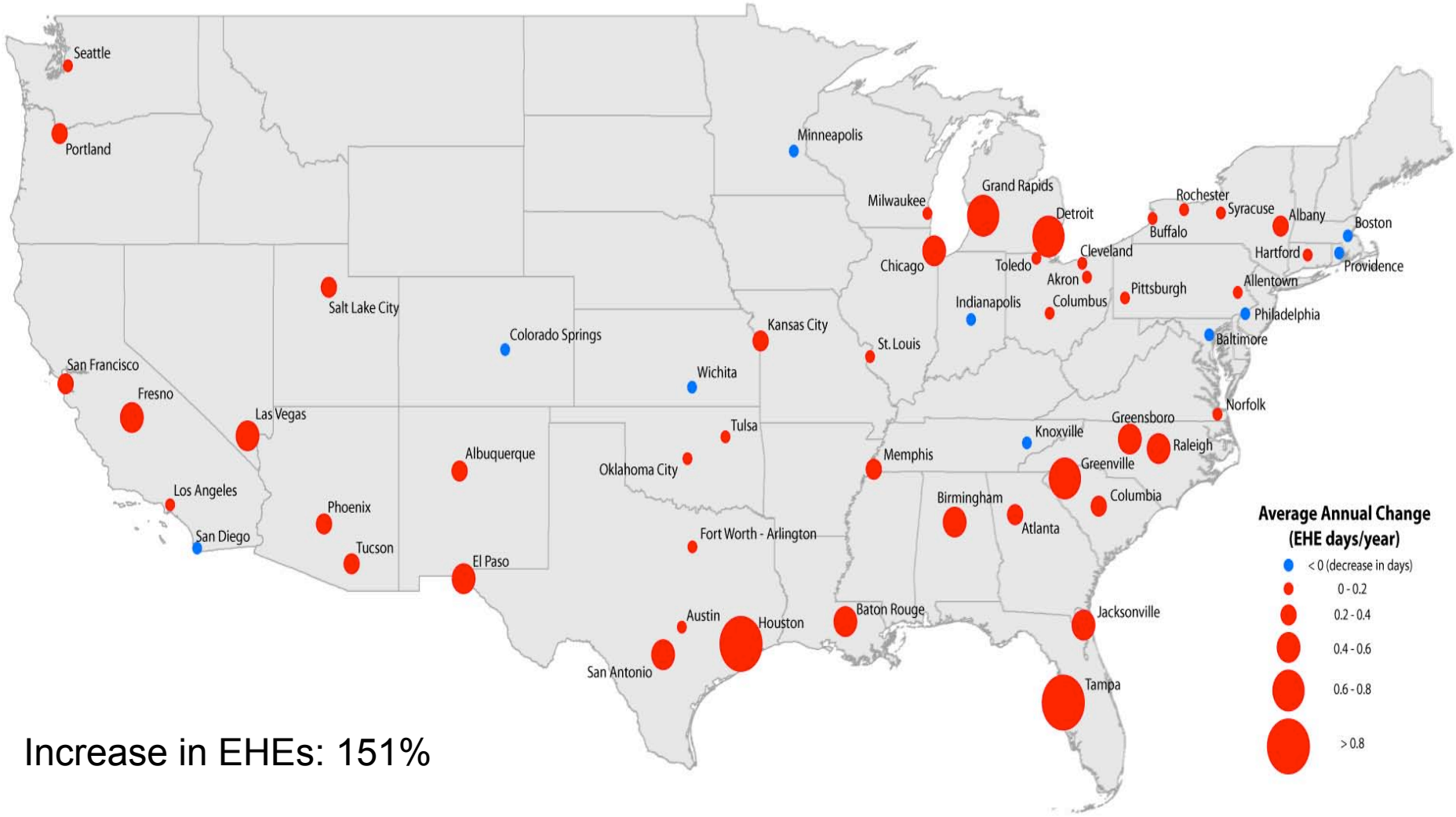
Study Findings

- On average, the decadal rate of warming in large U.S. cities was approximately 50% greater than that of proximate rural areas taken to represent "background" warming trends over the period of 1957-2006

- For cities in which the urban heat island effect intensified during this period (60%), the decadal rate of warming was approximately 160% greater than that of proximate rural areas

- As warming scenarios developed by the Intergovernmental Panel on Climate Change (IPCC) are based on background global rates of warming, these scenarios (1.4 to 5.8 ^{O}C by 2100) are likely to significantly underestimate the rate of warming in large cities over time

Change in Excessive Heat Events: 1956 - 2005

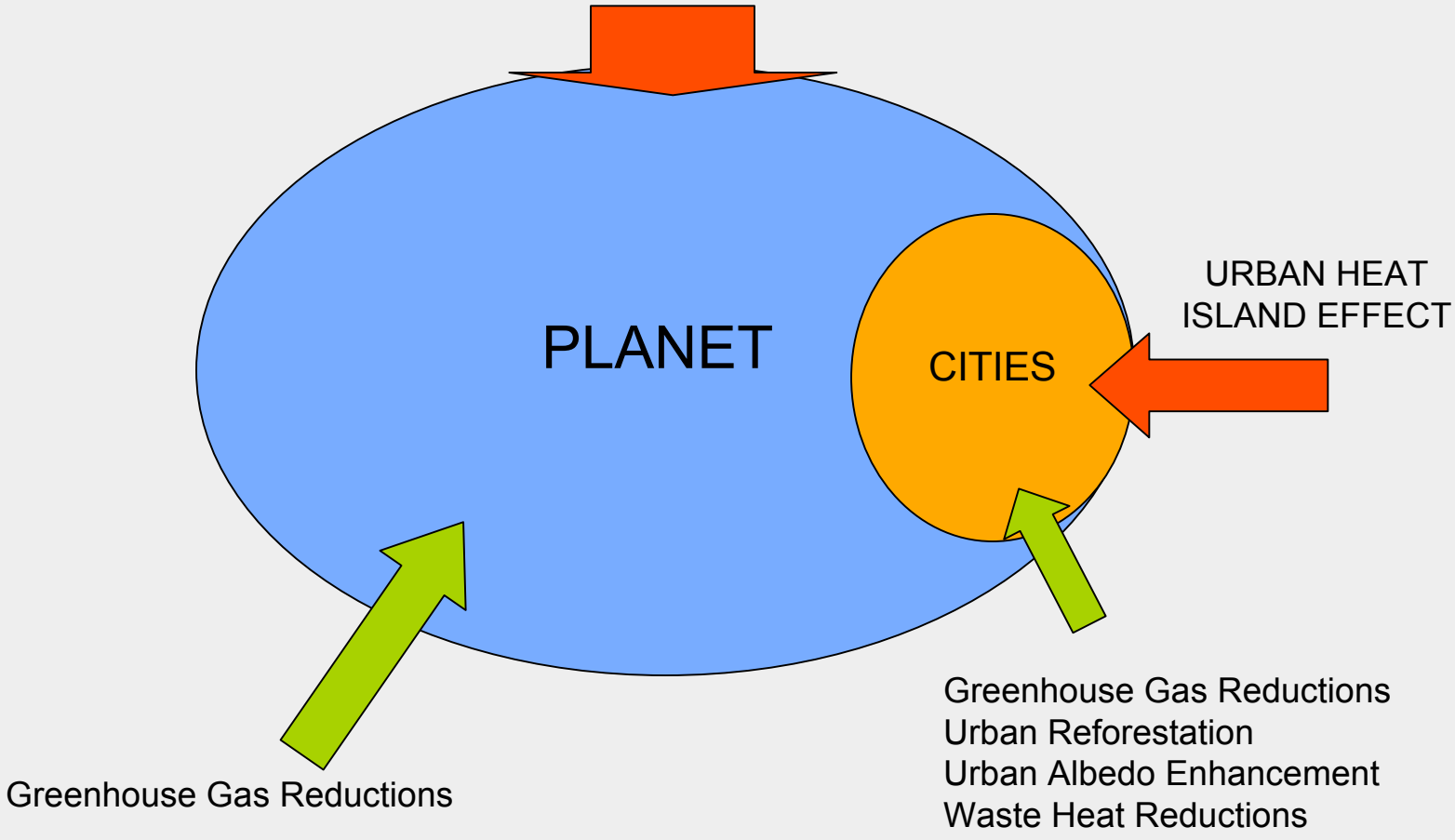


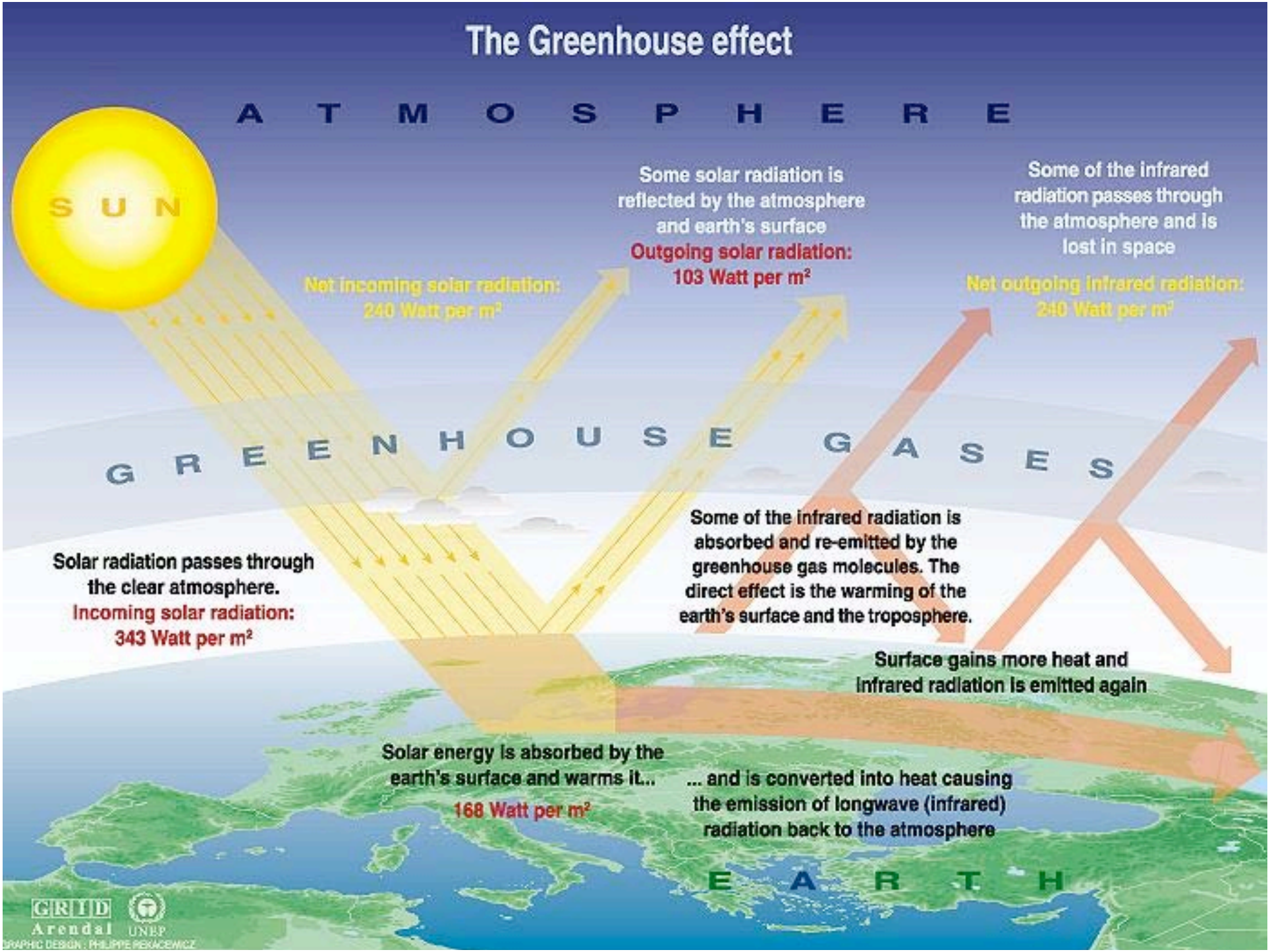
Increase in EHEs: 151%

Source: Stone, Hess, Frumkin, 2009

The Need for a Duality of Management Strategies in Cities

GREENHOUSE EFFECT




The Greenhouse effect
ATMOSPHERE
SUN
Some solar radiation is reflected by the atmosphere and earth's surface
Outgoing solar radiation: 103 Watt per m²
Some of the infrared radiation passes through the atmosphere and is lost in space
Net incoming solar radiation: 240 Watt per m²
Net outgoing infrared radiation: 240 Watt per m²
GREENHOUSE GASES
Some of the infrared radiation is absorbed and re-emitted by the greenhouse gas molecules. The direct effect is the warming of the earth's surface and the troposphere.
Solar radiation passes through the clear atmosphere.
Incoming solar radiation: 343 Watt per m²
Surface gains more heat and infrared radiation is emitted again
Solar energy is absorbed by the earth's surface and warms it..
168 Watt per m²
... and is converted into heat causing the emission of longwave (infrared) radiation back to the atmosphere
EARTH
GRID Arendal
UNEP
GRAPHIC DESIGN : PHILIPPE REKACEWICZ

In the continental U.S., approximately 50% of the rise in near surface air temperatures since the 1960s is attributable to land use change.

Impact of urbanization and land-use change on climate

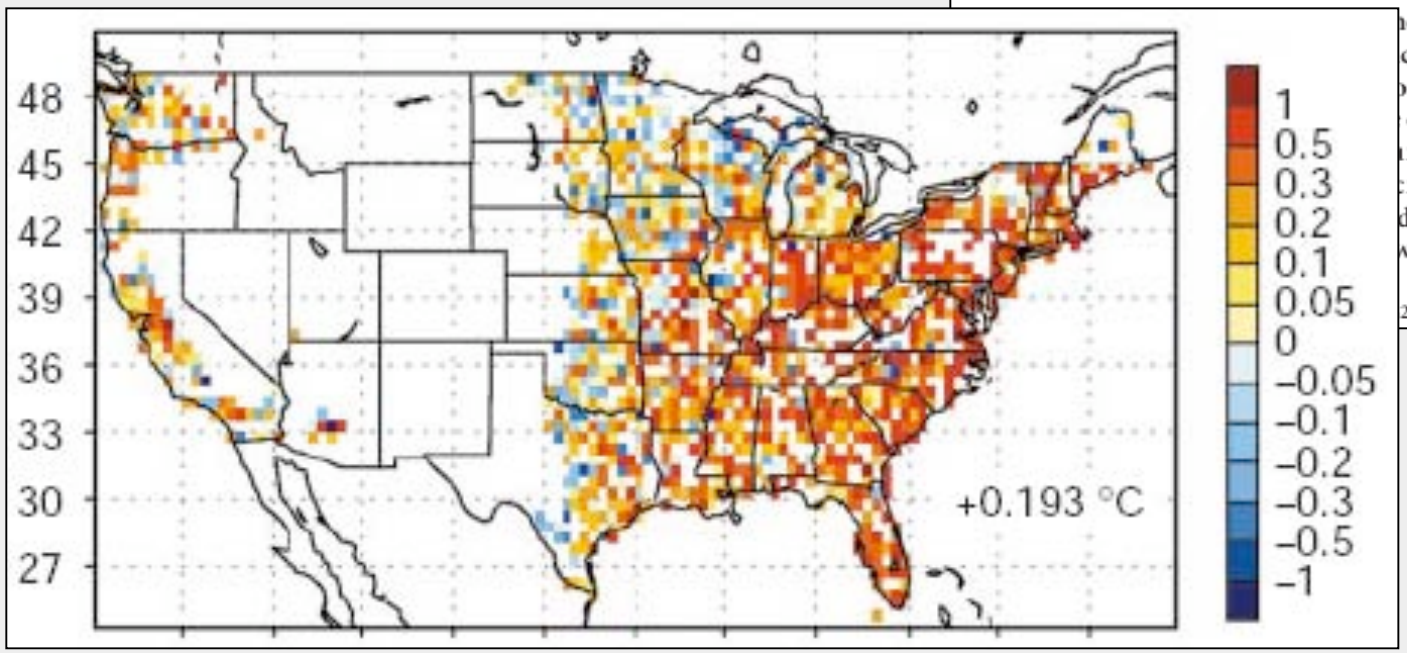
Eugenia Kalnay & Ming Cai

University of Maryland, College Park, Maryland 20770-2425, USA

The most important anthropogenic influences on climate are the emission of greenhouse gases[1] and changes in land use, such as urbanization and agriculture[2]. But it has been difficult to separate these two influences because both tend to increase the daily mean surface temperature[3,4]. The impact of urbanization has been estimated by comparing observations in cities with those in surrounding rural areas, but the results differ significantly depending on whether population data[5] or satellite measurements of night light[6–8] are used to classify urban and rural areas[7,8]. Here we use the difference between trends in observed

...ental United States and the ...ction of surface temperatures ...bal weather over the past 50 ... observations, to estimate the ...rface warming. Our results ...crease in diurnal temperature ...d-use changes. Moreover, our ...warming per century due to

...23 | 29 MAY 2003 | www.nature.com/nature



Source: Kalnay & Kai, 2003