Urban Warming: Measurement and Trends

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UHI Terminology: Defining the heat island

Howard reports mean temperature differences by month from thermometer readings in London and proximate rural areas in 1820.

Landsberg (1981) attributes first usage of the phrase to Manley in a 1958 paper and describes the phenomenon simply as “temperature differences between urban and rural areas”.

Oke (1987) states that “the air in the urban canopy is usually warmer than that in the surrounding countryside ... the difference between [the urban maximum temperature] and the background rural temperature defines the urban heat island intensity”.
Defining the heat island: Surface energy balance

- **Incoming and reflected solar**
- **Greenhouse effect**
- **Greenhouse + heat island effect**

**Atmosphere/GHG**

- Orange: Solar radiation
- Red: Sensible & longwave fluxes
- Blue: Latent heat flux
- Yellow: Waste heat

**Earth surface**

- Rural
- Urban

**urban climate lab**
Price (1979) observes “Particularly limiting [in weather station analyses] is the inability to describe quantitatively the areal extent and distribution of changes in air temperature … for investigation of urban heating, the peak temperature is less significant than a summation (area integral) of the excess power radiated as a result of the surface temperature elevation.”

Stone and Norman (2006) define urban heat island magnitude as “the excess flux of sensible heat energy”
Issues of terminology:
Local vs. global climate change

Climate change is:

“a change in the state of the climate that can be identified by changes that persist for an extended period, usually decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity.”

Intergovernmental Panel on Climate Change

“a change of climate which is attributable directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.”

United Nations Framework Convention on Climate Change
Mitigation entails “an intervention to reduce the sources and enhance the sinks of greenhouse gases”

Adaptation entails “adjustments in natural or human systems in response to expected or actual climatic stimuli or their effects, which moderates harm”
UHI measurement:
Fixed thermometers
UHI measurement:
Vehicle temperature traverses
UHI measurement:
Remote sensing

Price 1979
Measurement issues:
Data inhomogeneity
Measurement issues:  
Data inhomogeneity

Station history: Adjustments for changes in geographic location of station over time

Time of observation: Adjustments for changes in diurnal period over which data is recorded

Instrumentation: Adjustments for changes in measurement instruments (e.g., thermometers)

Missing data: Addition of interpolated data for gaps in measurement record

Urbanization: Adjustments for influence of urban heat island effect on urban temperature observations

Hansen et al. 2001
Measurement issues: Data inhomogeneity

Hansen et al. 2001
Measurement issues:
Data inhomogeneity

No division of the federal government is charged with measurement of unadjusted urban climate trends. At present, there is no federal source of data suitable for tracking climate trends in cities.

The regular development of new homogeneity algorithms for historical observations limits the utility of NOAA datasets for climate time series analysis.
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 300 km of urban station
  4. Observations adjusted for elevation and latitude
rural areas have warmed by about 1.5 °F over 50 years
urban areas are about $1.5^\circ F$ warmer than rural areas
most of the temperature anomaly in cities is attributable to heat island effect
Urban areas are warming more rapidly over time than rural areas.
global vs. urban rates of warming (°F/decade): 1961-2010

- **global**
- **rural (all cities)**: 50% amplification
- **urban (all cities)**
- **rural (cities with growing UHI)**: 100% amplification
- **urban (cities with growing UHI)**
urban warming rankings

- LOUISVILLE
- PHOENIX
- ATLANTA
- GREENSBORO
- DETROIT
- INDIANAPOLIS
- LAS VEGAS
- SYRACUSE
- OKLAHOMA CITY
- TOLEDO
- PORTLAND
- RICHMOND
- WASHINGTON DC
- BATON ROUGE
- ALBUQUERQUE
- EL PASO
- MINNEAPOLIS
- PHILADELPHIA
- ST LOUIS
- NEW YORK
- BOISE
- CHARLOTTE
- HARTFORD
- SEATTLE
- NEW ORLEANS

warming in excess of rural trend (°F/decade)
Observations

The urban heat island effect is the dominant driver of recent warming in large cities.

Until these patterns change, heat island mitigation is likely to yield more rapid results in slowing warming in cities than greenhouse gas reductions.

Urban design and land use planning are helpful tools for reducing greenhouse gas emissions. Urban design and land use planning are among the only tools for reducing the urban heat island effect.
Current challenges

There remains a need for greater uniformity of terminology employed in the field of urban climatology. In particular, conceptual inconsistencies in the study of local and global scale climate change may be increasingly problematic in climate change management.

Greater standardization of methods employed in UHI measurement would better facilitate cross study comparisons and lead to the development of consensus science on urban phenomena, such as present and projected ranges for UHI.

There is a critical need for a long term, time series climate dataset that can support analysis of urban scale climate trends across independent research groups.