Rx for Hot Cities: More Trees and Solar Reflectance

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Director and Co-Founder | Los Angeles Urban Cooling Collaborative
PhD Student | UCLA Institute of the Environment & Sustainability
An initial question led us to explore trees through the lens of heat impacts, public health, and equity...
What should our region’s urban tree cover target be?
The urban context
The human context
Disparities in tree cover and heat vulnerability

Watts: 10% Tree Cover

Bel-Air: 35% Tree Cover
How did these disparities emerge?

A “Best”
B “Still Desirable”
C “Definitely Declining”
D “Hazardous”
How do historically redlined neighborhoods relate to current patterns of intra-urban heat?

Redlining impact on TREE COVER

Redlining impact on TEMPERATURE

Differences in redlined vs. non-redlined neighborhoods:

Average: 2.6°C (4.7°F)

Up to 7°C (12.6°F)

Project funding
We tested combinations or “prescriptions” of:

- Tree Canopy
- Solar Reflectance (albedo) of roofs & pavements

Low, Moderate, High
Study findings, in a nutshell

- Temperature reductions often exceeded 1.0°C (1.8°F), and went up to 2.0°C (3.6°F) --- a life or death difference
- 25%+ reductions in heat-related deaths are possible, saving dozens of lives during the worst heat waves
- Oppressive air masses could be shifted to more benign ones
- Heat impacts of climate change could be delayed ~25-65 years
Thinking about heat-health outcomes

David Eisenman, MD MSHS
Professor of Medicine and Public Health
David Geffen School of Medicine at UCLA
Director, UCLA Center for Public Health and Disasters
Fielding UCLA School of Public Health
Health effects of heat

• Dehydration, redirecting blood away from vital organs to the skin, elevated heart rate... inflammatory response, cellular metabolic breakdown.

• Exacerbation of chronic diseases especially kidney, heart, lung diseases.

• Heat Illness
  • Ten categories according to the WHO International Classification of Diseases: heat stroke, exertional heat stroke, heat syncope, heat cramps, heat exhaustion (3), heat fatigue, heat edema, other.

• Case Study: Elderly woman is brought to the clinic with nausea, lethargy and a temperature of 104.2 degrees. She may have sepsis, stroke, meningitis, or heat stroke.
# Social Vulnerability Factors for Heat Effects

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>VULNERABILITY FACTORS</th>
<th>SOURCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGE</td>
<td>65 years and older</td>
<td>Knowlton et al. 2009; Naughton et al. 2002; Basu and Ostro 2008; Whitman et al. 1997; Poumadere et al. 2005; Reid et al. 2009</td>
</tr>
<tr>
<td></td>
<td>Children and adolescents</td>
<td>Knowlton et al. 2009;</td>
</tr>
<tr>
<td></td>
<td>Infants (1 year of age or less)</td>
<td>Basu and Ostro 2008</td>
</tr>
<tr>
<td>HEALTH CONDITION</td>
<td>Certain medications</td>
<td>McGeehin and Mirabelli 2001</td>
</tr>
<tr>
<td></td>
<td>Cardiovascular disease</td>
<td>Poumadere et al. 2005</td>
</tr>
<tr>
<td></td>
<td>Diabetes</td>
<td>Reid et al. 2009; Schwartz 2005</td>
</tr>
<tr>
<td></td>
<td>Psychiatric illness, major tranquilizers</td>
<td>Naughton et al. 2002; Poumadere et al. 2005’ Kilbourne et al. 1982</td>
</tr>
<tr>
<td></td>
<td>Lack of health insurance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>People with medical problems who were confined to bed or who were unable to care for themselves</td>
<td>Semenza et al. 1996</td>
</tr>
<tr>
<td></td>
<td>Obesity</td>
<td>Luber and McGeehin 2008</td>
</tr>
<tr>
<td></td>
<td>Alcoholism</td>
<td>Kilbourne et al. 1982</td>
</tr>
</tbody>
</table>
## Social Vulnerability Factors for Heat Effects

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<thead>
<tr>
<th>CATEGORY</th>
<th>VULNERABILITY FACTORS</th>
<th>SOURCE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RESIDENCE</strong></td>
<td>Living on higher floors of multistory buildings</td>
<td>Kilboune et al. 1992; Semenza et al. 1996, Poumadere et al. 2005</td>
</tr>
<tr>
<td></td>
<td>No AC in home, or inability to pay high electricity bills resulting from AC use</td>
<td>McGeehin and Mirabelli 2001; Reid et al. 2009; Semenza et al. 1996; Kilbourne et al. 1982</td>
</tr>
<tr>
<td></td>
<td>Heat island effect (low tree cover and high percentage of impervious surfaces)</td>
<td>Shonkoff et al. 2009</td>
</tr>
<tr>
<td></td>
<td>High settlement density, sparse vegetation; having no open space in the neighborhood</td>
<td>Harlan et al. 2006</td>
</tr>
<tr>
<td></td>
<td>Poor access to transit or car</td>
<td>Shonkoff et al. 2009</td>
</tr>
<tr>
<td></td>
<td>Residence in high-crime areas</td>
<td>McGeehin and Mirabelli 2001</td>
</tr>
<tr>
<td><strong>SOCIAL ISOLATION</strong></td>
<td>Lack of access to media</td>
<td>McGeehin and Mirabelli 2001</td>
</tr>
<tr>
<td></td>
<td>Non-English language speaking only</td>
<td>McGeehin and Mirabelli 2001</td>
</tr>
<tr>
<td></td>
<td>Social isolation, living alone, and/or not leaving home every day</td>
<td>McGeehin and Mirabelli 2001; Poumadere et al. 2005; Naughton et al. 2002; Semenza et al. 1996</td>
</tr>
<tr>
<td><strong>SOCIO-ECONOMIC FACTORS</strong></td>
<td>Women</td>
<td>Ishigami et al. 2007; Poumadere et al. 2005</td>
</tr>
<tr>
<td></td>
<td>Race other than white</td>
<td>Reid et al. 2009</td>
</tr>
<tr>
<td></td>
<td>African Americans</td>
<td>Basu and Ostro 2009; Ishigami et al. 2007; Whitman et al. 1997</td>
</tr>
<tr>
<td></td>
<td>Poverty</td>
<td>Poumadere et al. 2005; Reid et al. 2009; Harlan et al. 2006;</td>
</tr>
<tr>
<td></td>
<td>Less than high school diploma</td>
<td>MMWR 2005; CDC 2010; Riley et al 2016</td>
</tr>
<tr>
<td></td>
<td>Outdoor workers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Citizenship status</td>
<td>Shonkoff et al. 2009</td>
</tr>
</tbody>
</table>
Climate Change and Health — Extreme Heat

**CLIMATE DRIVERS**
- More frequent elevated temperatures
- Prolonged heat waves
- Seasonal timing of event

**ENVIRONMENTAL & INSTITUTIONAL CONTEXT**
- City planning: Urban heat island effect
- Access to support services & resources (electricity, water, cooling centers)

**EXPOSURE PATHWAYS**
- Exposure to elevated temperatures (daily maximum, minimum, and mean)
- Combined impact of temperature, humidity, wind, & sunlight

**SOCIAL & BEHAVIORAL CONTEXT**
- Social isolation, poverty, and homelessness
- Access to & use of air conditioning
- Outdoor work, recreation, and commuting
- Appropriate heat prevention messaging
- Chronic illness, medication use, or personal, physical, & cognitive constraints

**HEALTH OUTCOMES**
- Deaths, illness, hospital and emergency department visits
Health Outcomes

• Mortality = death

• Morbidity = any episode of illness, impairment or degradation of health
  • hospitalization, emergency room visits, 911-ambulance calls
Data Reliability

• Mortality
  • Are causes of death reliable? Attending physician fills out causes of death and can be inaccurate. Death certificate forms not designed by researchers

• Morbidity
  • Studies have found that hospitalization diagnosis are valid
  • Less known about validity of ER diagnoses
CAUSE OF DEATH (See instructions and examples)

32. PART I. Enter the chain of events—diseases, injuries, or complications—that directly caused the death. DO NOT enter terminal events such as cardiac arrest, respiratory arrest, or ventricular fibrillation without showing the etiology. DO NOT ABBREVIATE. Enter only one cause on a line. Add additional lines if necessary.

IMMEDIATE CAUSE (Final disease or condition ———> resulting in death)

a. Asphyxia by vomitus
   Due to (or as a consequence of):

Sequentially list conditions, injury, leading to the cause listed on line a. Enter the

b. Cerebellar hemorrhage
   Due to (or as a consequence of):

c. Hypertension
   Due to (or as a consequence of):

d. Primary aldosteronism

e. Adrenal adenoma

33. WAS AN AUTOPSY PERFORMED?
   □ Yes □ No

34. WERE AUTOPSY FINDINGS AVAILABLE TO COMPLETE THE CAUSE OF DEATH?
   □ Yes □ No

35. DID TOBACCO USE CONTRIBUTE TO DEATH?
   □ Yes □ Probability
   □ No □ Unknown

36. IF FEMALE
   □ Not pregnant within past year
   □ Pregnant at time of death
   □ Not pregnant, but pregnant within 82 days of death
   □ Not pregnant, but pregnant 43 days to 1 year before death
   □ Unknown if pregnant within the past year

37. MANNER OF DEATH
   □ Natural □ Homicide
   □ Accident □ Pending investigation
   □ Suicide □ Could not be determined
Climate and Heat-Health Modeling: Results From LAUCC Analysis

Laurence S. Kalkstein, Ph.D.
Professor Emeritus
President, Applied Climatologists, Inc.
Co-Founder, Los Angeles Urban Cooling Collaborative (LAUCC)
Quick Facts About Heat and Health

- Heat is the leading weather-related cause of death in the U.S.
- Urban area residents are particularly sensitive to heat, especially in non-tropical areas.
- The Urban Heat Island (UHI) contributes to this sensitivity.
- The vulnerability of people varies among cities and neighborhoods.
- Summer climate variability is more important than the actual temperature (more people die of heat in Los Angeles than Singapore!).
- Extended heat events and excessive nighttime temperatures are most important contributors.
- We can improve the city’s environment to lessen the negative health impact of heat.
Summer Daily Mortality
Chicago, June-August, 1979-1995

1995: Worst in recorded history
World Map of Sensitivities: Regions With Most Heat-Related Deaths
An Air Mass Approach to Evaluate Heat/Health Relationships

- We evaluate “weather situations”, rather than individual weather elements, using a unique procedure developed in our lab, the spatial synoptic classification (SSC).
- Puts each day into a particular air mass type.
- Two types particularly oppressive: DT and MT+

<table>
<thead>
<tr>
<th>Oppressive Hot Air Masses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dry Tropical (DT)</strong></td>
</tr>
<tr>
<td>Represents the hottest and driest conditions found at any location. There are two primary sources of DT: either it is transported from the desert regions, or it is produced by rapidly descending air.</td>
</tr>
<tr>
<td><strong>Moist Tropical+ (MT+)</strong></td>
</tr>
<tr>
<td>Hotter and more humid subset of common MT, and thus captures the most &quot;oppressive&quot; subset of MT days. Air mass originates over warm water bodies. Warmest nights of any air mass.</td>
</tr>
</tbody>
</table>
# Mean Mortality Increases Within Offensive Air Mass Types

<table>
<thead>
<tr>
<th>LOCATION (FREQ)</th>
<th>Dry Tropical (DT)</th>
<th>Moist Tropical + (MT+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New York (11%)</td>
<td>+16.6 (7%)</td>
<td>+16.9 (7%)</td>
</tr>
<tr>
<td>Los Angeles (4%)</td>
<td>+8.4 (5%)</td>
<td>+8.4 (5%)</td>
</tr>
<tr>
<td>Phoenix (1%)</td>
<td>+2.7* (7%)</td>
<td>None</td>
</tr>
<tr>
<td>Rome (11%)</td>
<td>+6.2 (14%)</td>
<td>+5.0 (12%)</td>
</tr>
<tr>
<td>Toronto (7%)</td>
<td>+4.2 (11%)</td>
<td>+4.0 (10%)</td>
</tr>
</tbody>
</table>

*DT+ air mass for Phoenix.
Can We Cool Our Cities?
Urban Greening: Shade and evaporative cooling

- Provides shade and reduces solar heat gain in the built environment.
- Improves energy efficiency through shading structures and air conditioning units.
- Converts solar radiation to evapotranspiration.

**URBAN TREES, COOLER CITIES**

Pavement and concrete in cities absorb energy from the sun and then radiate that energy out, heating the air in cities more than in the surrounding countryside. Urban trees provide shade, preventing pavement and concrete from heating up, and also cool the air by transpiring water. Trees can cool neighborhoods by up to 4 degrees Fahrenheit.
Reflective Roofing: Energy efficiency and comfort

- Reduces electricity use and cooling costs in year-round cooling environments
- Improves air quality by reducing the formation of ozone
- Provides a more pleasant home environment
Two Levels of Spatial Analysis

**Countywide:** Evaluate the entire county and assume similar “prescriptions” are employed throughout.

- Advantage: large sample size for mortality;
- Disadvantage: cannot break down results locally.

**District level:** Evaluate a number of socially-homogeneous districts within LA County separately.

- Advantage: can determine impact of socio-economic factors
- Disadvantage: sometimes population sizes are too small to do an adequate mortality evaluation.
We Evaluated Four Excessive Heat Events in L.A. County and For Individual “Districts”

• July 22-26, 2006: hot and humid, all MT+ days

• June 19-22, 2008: drier, mix of MT and DT days

• August 26-30, 2009: less extreme, wanted to evaluate more common heat event

• September 24-29, 2010: very hot, dry Santa Ana event dominated by DT days
## Mitigation Scenarios (albedo and vegetation)

<table>
<thead>
<tr>
<th>Rx</th>
<th>Tree Cover</th>
<th>Solar Reflectance (Albedo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rx 1</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Rx 2</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Rx 3</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Rx 4</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>
Model Results:
County Level Air Temperature Differences

County-level mitigation □ Rx 1; Low tree cover, high reflectance
2m Air T differences: Control - Rx1
Heat Wave: August 26, 2009
Countywide Result: Santa Ana Event of September 2010

- One day shifted from an oppressive DT air mass to a benign dry moderate (DM) air mass.
- This reduced mortality for that day from a 5% increase for the baseline (approx. 8 deaths) to 0.
- For the entire heat event, the increase in mortality went from 12.4% (12.4% of 600 total deaths = 74 extra deaths) to 8.8% (52 extra deaths).
- Thus, under the Case 4 scenario, we estimate 22 saved lives during this heat event.

### Table: Temperature and Mortality Increase

<table>
<thead>
<tr>
<th>Date</th>
<th>SSC Type</th>
<th>5am AT</th>
<th>Mean AT</th>
<th>Mortality Increase (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/26/10</td>
<td>DT</td>
<td>20.9</td>
<td>22.5</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>DT</td>
<td>20</td>
<td>21.6</td>
<td>4.9</td>
</tr>
<tr>
<td>9/27/10</td>
<td>DT</td>
<td>24.6</td>
<td>27.7</td>
<td>11.7</td>
</tr>
<tr>
<td></td>
<td>DT</td>
<td>23.7</td>
<td>26.7</td>
<td>9.5</td>
</tr>
<tr>
<td>9/28/10</td>
<td>DT</td>
<td>23.8</td>
<td>26.4</td>
<td>18.2</td>
</tr>
<tr>
<td></td>
<td>DT</td>
<td>23.1</td>
<td>25.8</td>
<td>15.4</td>
</tr>
<tr>
<td>9/29/10</td>
<td>MT</td>
<td>21.5</td>
<td>22.9</td>
<td>14.5</td>
</tr>
<tr>
<td></td>
<td>MT</td>
<td>20.6</td>
<td>26</td>
<td>12.8</td>
</tr>
</tbody>
</table>

| Mean 4-day (9/26-29) increase in mortality (%) | 12.4 | 10.5 | 9.7 | 9.5 | 8.8 |
| Net decrease in heat-related mortality in cases | n/a  | -16% | -22%| -24%| -29%|

Approximately 150 people die daily in Los Angeles County during summer.
District-Level Evaluation

• Districts developed by California State University Northridge
  – Dr. Kimberly Kirner, Anthropology Department
  – Dr. Regan Maas, Geography Department

• Los Angeles County was divided into smaller socio-economically homogeneous districts.

• Each district needed to have a population of at least 300,000 to minimize non-meteorological variations in mortality.
District Development Outcomes

• County divided into **18 unique and rather homogeneous districts.** Must be inclusive of entire zip code areas.

• **Some districts proved problematic;** eg. Missing data, low population densities.

• **We reduced the number of districts to be evaluated to 11.** Virtually all high-poverty districts were included within the 11.
## Cooling and Mortality Results: District 11, Los Angeles

<table>
<thead>
<tr>
<th>Date</th>
<th>Rx 0</th>
<th>Rx 1</th>
<th>Rx 2</th>
<th>Rx 3</th>
<th>Rx 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/22/2006</td>
<td>29.9</td>
<td>29.4</td>
<td>29.2</td>
<td>29.4</td>
<td>29.0</td>
</tr>
<tr>
<td>7/23/2006</td>
<td>27.0</td>
<td>26.5</td>
<td>26.2</td>
<td>26.5</td>
<td>26.1</td>
</tr>
<tr>
<td>7/24/2006</td>
<td>28.7</td>
<td>28.2</td>
<td>28.0</td>
<td>28.2</td>
<td>27.8</td>
</tr>
<tr>
<td>7/25/2006</td>
<td>24.6</td>
<td>24.3</td>
<td>24.2</td>
<td>24.3</td>
<td>24.1</td>
</tr>
<tr>
<td>7/26/2006</td>
<td>27.0</td>
<td>26.6</td>
<td>26.5</td>
<td>26.6</td>
<td>26.4</td>
</tr>
</tbody>
</table>

### Estimated mortality

<table>
<thead>
<tr>
<th>Date</th>
<th>Rx 0</th>
<th>Rx 1</th>
<th>Rx 2</th>
<th>Rx 3</th>
<th>Rx 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/22/2006</td>
<td>0.5</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.3</td>
</tr>
<tr>
<td>7/23/2006</td>
<td>1.0</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>7/24/2006</td>
<td>1.7</td>
<td>1.3</td>
<td>1.1</td>
<td>1.3</td>
<td>1.0</td>
</tr>
<tr>
<td>7/25/2006</td>
<td>0.7</td>
<td>0.5</td>
<td>0.4</td>
<td>0.5</td>
<td>0.3</td>
</tr>
<tr>
<td>7/26/2006</td>
<td>0.7</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SUM</th>
<th>4.52</th>
<th>3.49</th>
<th>3.11</th>
<th>3.49</th>
<th>2.73</th>
</tr>
</thead>
<tbody>
<tr>
<td>REDUCTION</td>
<td>23%</td>
<td>31%</td>
<td>23%</td>
<td>40%</td>
<td></td>
</tr>
</tbody>
</table>

**Assumptions are that these cases only apply to the individual district, and there are no albedo/vegetation increases in the remainder of the study area!**

Rx 0: 16.6% TCC, .10 pavement, .17 roof

Rx 1: 20% TCC, .35 pavement, .45 roof

Rx 2: 40% TCC, .20 pavement, .27 roof

Rx 3: 30% TCC, .25 pavement, .37 roof

Rx 4: 40% TCC, .35 pavement, .45 roof
Percent Reduction in Mortality by District
July 22-26, 2006

Rx 4: High Tree Canopy / High Albedo

Legend
Reduction of Mortality
- No Results
- < 10%
- 11 - 20%
- 21 - 30%
- 31 - 40%
- 41 - 50%
- >50%
Percent Reduction in Mortality by District
Sept. 24-29, 2010

Rx 4: High Tree Canopy / High Albedo

Legend
Reduction of Mortality
- No Results
- <20%
- 21 - 30%
- 31 - 40%
- 41 - 50%
- 51 - 60%
- >60%

LOS ANGELES URBAN °COOLING COLLABORATIVE
How Many Years Can We Delay Climate Change?

Mean max temperature reduction:

Rx 1: -1.1°C
Rx 2: -1.0°C
Rx 3: -1.0°C
Rx 4: -1.7°C

- Business-as-usual emissions (RCP 8.5)
- Moderate mitigation (RCP 4.5)
Summary of Results

• Lower income, more densely populated districts generally demonstrated the greatest increases in heat-related mortality (eg. Districts 1, 5, 11).

• These districts also showed the greatest benefits from use of “cool solutions”, based upon mortality reductions.

• There were some unexplained exceptions: eg. Low-income District 10 showed little impact, wealthier but hot district 16 showed greater impact.

• Use of “cool solutions” can delay climate change by at least several decades in Los Angeles.
Concluding Remarks

- The importance of heat upon human health cannot be overstated.
- We must gain understanding about the regionality of the problem, the impact of the urban heat island, and the potential impact of climate change.
- For those who are skeptical of climate change disaster, we must emphasize that heat is already the largest weather-related killer!
- Numerous urban areas have expressed interest in this work and we are actively engaged with them - Twin Cities, Madison/Milwaukee, WI, Miami-Dade and Broward counties, FL.
- Academics, the private sector, the government, and nonprofits must unite (like LAUCC) to tackle this problem and to come up with adaptation and/or mitigation policy options.
Project report, infographic and more information at treepeople.org/urbancooling