Georgia State University Roof Temperature Study

By Marty Waterfill, CSI and Patrick Downey, RRC, CDT

ON JUNE 17, 1998, A STUDY OF THE INSTALLED ROOFING ON THE GEORGIA STATE UNIVERSITY (GSU) campus began. The research is being conducted by the Global Hydrology and Climate Center and is funded by NASA and the Universities Space Research Association (USRA).

The purpose of the study was to determine the roof surface temperatures on buildings located on the Georgia State University campus. Data collected at the roof surface using an infrared thermometer were compared to data collected earlier by an airborne remote sensor, the Advanced Thermal and Land Applications Sensor (ATLAS).

The two data sets were analyzed independently and comparatively for correlation between rooftop surface temperature and roofing type, roof surfacing, and roof age. The preliminary results determined that increased vegetation on or near rooftops, covering rooftops with lighter colored materials and maintaining the surfacing on older rooftops are ways to decrease temperature and therefore contribution to the urban heat island.[1]

BACKGROUND

The GSU campus is located in the center of downtown Atlanta and affords research institutions a unique opportunity to study the Urban Heat Island condition. Urban Heat Islands are a phenomenon whereby highly developed urban areas absorb solar energy, convert it to heat energy, and radiate the heat into the neighborhood.

In 1972 when the first thermal images of Atlanta were made, the downtown central business district and airport were the only noticeable heat islands. By 1993, two new heat islands had developed and all the zones were larger and hotter as indicated in *Figure 1*.

Four Atlanta Heat Islands have been measured 6 - 8 degrees Fahrenheit warmer than the surrounding, less developed neighborhoods. These higher temperatures contribute to greater air conditioning cooling expenses and increased air quality problems. "Using data from an orbiting Landsat satellite, we mapped the city's development from 1972 through 1993. The results were stunning: About 65 percent of what had been trees and forests is now part of the built environment," according to Gary Mull of American Forests.[2]

The temperature increase in Urban Heat Islands occur because natural surfaces such as tree cover, bushes, and grass that reflect solar energy or mitigate its effect have been replaced by heat absorptive materials. Dark-colored roofing, city streets, parking lots, and a host of other modern construction materials absorb solar energy.

The link between air quality issues and Urban Heat Islands has been established by Lawrence Berkeley National

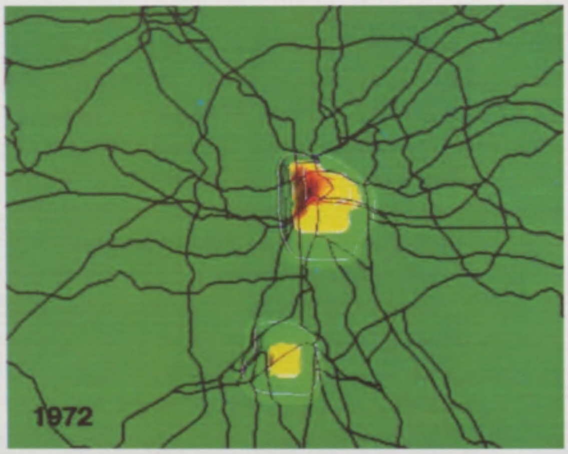
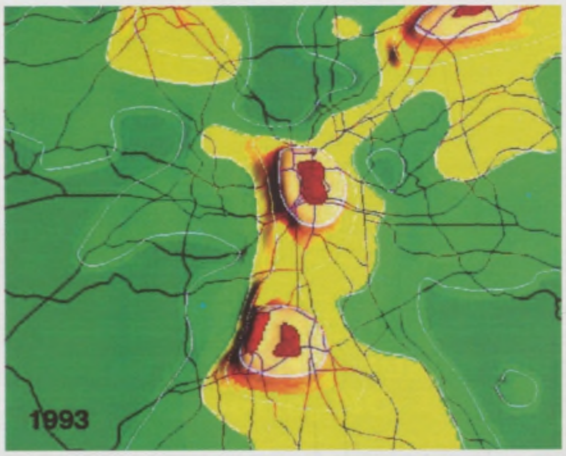


Figure 1: Urban Heat Island growth in the city of Atlanta, Georgia from 1972 (left) to 1993 (right) as shown through thermal images. (Source: American Forests)



Laboratories (LBNL). "In Los Angeles, for every degree the temperature rises above 70F (19C), the incidence of smog increases 3 percent. LBNL researchers estimate that if all the buildings in the greater Los Angeles area had cool roof systems, the total energy and smog savings would be about half a billion dollars per year."[3]

Air quality and energy conservation issues cross the boundaries of traditional special interest groups. Government agencies, institutions, and trade associations share a common interest in reducing the negative impact on our environment caused by Urban Heat Island conditions. The challenge is to create a set of circumstances that encourages individuals and organizations to act in their own self interest in ways that are less disruptive to our environment.

SURVEY METHODS

The roof surface conditions on twenty buildings were analyzed at the GSU campus. Hurt Park, a city park adjoining the campus, was also included in the study to serve as a control in comparing developed and natural urban settings.

There is a variety of different roofing systems installed on campus buildings. GSU has roofing materials that are typical of the most commonly used low-slope roof systems:

- Built-Up Roofing with gravel surfacing.
- Modified Bitumen with granular surfacing.
- Single-Ply systems with both smooth surfacing and river-washed rock surfacing.

The time of day and weather conditions were noted during each rooftop survey, as were the surfacing and roofing. Each roof assembly includes insulation board intended to slow the transfer of heat into and out of the building.

Approximately 10 readings of the surface temperature of each roof were taken. Readings were taken at intervals five feet apart and the measuring unit was held approximately four feet above the roof surface. The area selected was based on the unique circumstances of each rooftop. For example, roofs with large air conditioning units didn't allow a straight line sampling area. Areas included shaded areas or melted bitumen between the gravel surfacing. Some readings on low roof areas were taken from greater distances, as much as 60 feet up from the roof surface. The readings are judged to be accurate. They represent, however, a larger sample surface than those taken from four feet above the target area.

A number of variables had to be taken into account to produce a data set that allowed for an "apples-to-apples" comparison. "Extreme temperature measurements of melted tar or asphalt and shaded areas were excluded and the remaining temperature measurements were averaged. A standard deviation between the Fahrenheit scale points was computed. Because the readings were taken at different times of the day, ranging from 10:00 a.m. to 4:40 p.m., the incoming solar radiation received by each rooftop varied. These solar radiation data were obtained from the Atlanta Air Protection Agency."[4]

During the survey, the greatest amount of solar energy was received at solar noon on June 17th. That period was used as a base-line condition for incoming solar radiation throughout the two-day sampling period.

The remote method of data collection was undertaken on May 11 and 12, 1997. A Lear 23 jet aircraft was flown from Stennis Space Center with an ATLAS high resolution multispectral sensor. This type of sensor is capable of simultaneously measuring energy in different spectral bands. The infrared data collected in one of these spectral bands is used for comparison with the in situ (onsite) rooftop data collection.

The aircraft flew over the downtown central business district of Atlanta and collected data within a 48 km^2 area. Each reading was taken of an area measuring 30 square feet (10 M) during the time of day with the greatest solar radiation, between 11 a.m. and 3 p.m. The maximum air temperature during the fly-over test periods was 77 degrees Fahrenheit.

DATA READINGS TAKEN

The amount of solar radiation each roof received at the time of data readings varied, depending on the time of day and atmospheric conditions. This variation can not be easily manipulated to average the results for comparison because solar radiation is not related to temperature in the same way for each roofing system installed on GSU buildings.

The accepted method used to predict surface temperature for roof systems is based on the surface's albedo and emissivity. Albedo describes the amount of solar energy that is reflected from the surface as a percentage of the total amount that strikes the roof. For example, if the roof reflects 40 percent of the solar energy, it has an albedo of 0.60.

Emissivity is the term for how easily the roof "gives up" the heat energy it has absorbed. The higher the emissivity rating, the cooler the roof. The ideal roof will absorb a small percentage of the solar energy that strikes its surface and easily release the energy it absorbed.

In 1996, the State of Georgia amended the building energy code (ASHRAE 90.1 Standard) to recognize the roof assembly's energy efficiency beyond the R-value of its insulation. A qualifying, high-efficiency roof will have a minimum of 0.75 albedo and 0.75 emissivity.

Figure 2 contains the list of buildings studied, their roof type, year constructed, and the *in situ* temperature readings taken on June 17 and 18, 1998. Hurt Park is included to compare a natural vegetative site and typical commercial roof system. The temperature difference between the hottest roof (Commerce

Building Name	Roof Type	Year Built	Avg. Temp.
Kell Hall	CTP BUR	1977	113
Sparks Hall	CTP BUR	1995	115
University Center	CTP BUR	1963	146
Classroom South	Mod Bit white granules	1994	138
Art & Music	Mod Bit Ballasted	1979	Reroof in progress
General Classroom	ASP BUR	1971	112
Physical Education	CTP BUR	1973	136
Aquatic Center	CTP BUR	1973	146
Urban Life	CTP BUR	1998	137
Courtland Bldg.	CTP BUR	1977	151
30 Pryor	CTP BUR	1996	123
Library South	Mod Bit white granules	1994	150
Alumni Hall	CTP BUR	1997	132
One Park Place	EPDM Ballasted	1987	117
Science Building	EPDM Ballasted	1992	111
University Bookstore	EPDM Ballasted	1988	124
35 Broad Street	Mod Bit white granules	1978	141
29 Peachtree Center	ASP BUR	1997	118
Commerce Bldg.	EPDM black surfaced	1972	152
Student Center	ASP BUR	1998	150
Hurt Park	N/A		95

Key: CTP BUR (Coal Tar Pitch Built Up Roof), ASP BUR (Asphalt Built Up Roof), Mod Bit (Modified Bitumen multi ply roof) and EPDM (Single ply membrane of synthetic rubber).

Figure 2: Georgia State University Building and Roof-Top Data. (Source: Energy Emissivity Analysis of Georgia State Building RoofTops Report)

Building) and the Park was 57 degrees F. It should be remembered that the Park is located in the center of the downtown Heat Island.

The study compares the data taken *in situ* to that "remotely sensed," and it is in this comparison that the greatest variation in temperature readings is found. On average, the remotely-sensed data was 10% cooler than the readings taken on the roof. This difference is not only the result of different solar loads. The remote data undoubtedly include a "carry over" from areas beyond the roof, such as parking lots, streets, adjoining structures, etc., because of the remote sensor's 30 square foot minimum resolution.

CONCLUSIONS OF THE STUDY

The report makes the following conclusions:

- Remote sensing provides a way to collect rooftop temperature data, but also provides difficulties in analysis due to processing complications and image resolution.
- Lighter-colored roofing materials have increased albedo and therefore lower surface temperatures than dark-colored materials.
- Vegetation and shading significantly lower temperature on urban surfaces.
- Increased roof age correlates with higher surface temperatures.

The report makes the conclusion that increased roof age correlates with higher roof temperatures. This generalization is most accurate when gravel-surfaced coal-tar pitch roofs are considered. As the roof ages, there can be a flow of bitumen that allows the gravel to become more embedded, thus exposing the dark-colored bitumen to greater solar loading. This condition would be added justification for including a renewal of surface protection by redistribution of gravel in the roof maintenance program. *Figure 3* shows a new coal tar pitch BUR roof and a 21-year-old coal tar pitch BUR with exposed bitumen.

The authors would like to point out that aging of black-surfaced, single-ply roofing would typically increase the albedo of the material. There is a "graying out" of the black, single-ply roof that is caused by the buildup of dust and dirt across its surface. This benefits a dark, smooth-surface roof, but acts to reduce the reflectivity of a typical high-albedo, white, smooth-surface roof. Studies show that the black roof will increase reflectivity from as little as 5 percent to 30 percent. White roofs decrease reflectivity from as much as 80 percent to 60 percent as they age. The reflectivity of unsurfaced roofs tends to stabilize after the first year.

The more we understand the issues affecting Urban Heat Islands, the better we can shape our environment. The building envelope can be redesigned to benefit the occupant and the building's neighbors. "A combination of insulation and materials with high albedo appears to be the recommended treatment

Figure 3: New and aged BUR gravel-surfaced roofs.

throughout the Sunbelt region. Insulation materials slow the transfer of heat into and out of the structure, particularly important during cloudy days and cool nights. High albedo treatments are better at reducing the heat island effect because they can reflect most of the sun's energy away from a material's surface before it is converted into heat. Completing the project with strategically-placed shade trees covers all the bases, managing macro and micro energy conservation measures."[5]

Footnotes:

1. Apprill, Amy, *Energy Emissivity Analysis of Georgia State University Building Rooftops*, University of San Diego, San Diego, California, page 1, 1998.
2. Mull, Gary, and Cory Berish, "Atlanta's Changing Environment," *American Forests Magazine*, page 26, Spring 1996.
3. Akbari, Hashem and Sarah Bretz, "Cool Systems for Hot Cities," *Professional Roofing*, page 32, October 1998.
4. Apprill, page 4.
5. Downey, Patrick, "When You're Hot, You're Hot; When You're Not, You're Cool Construction Materials," *Interface*, page 12, September 1996.

About the Authors

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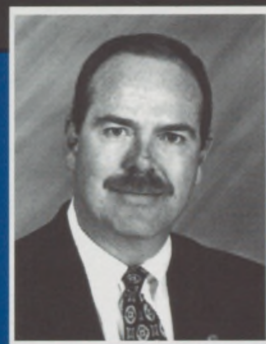

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