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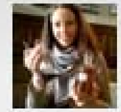
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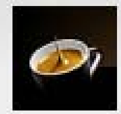
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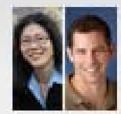
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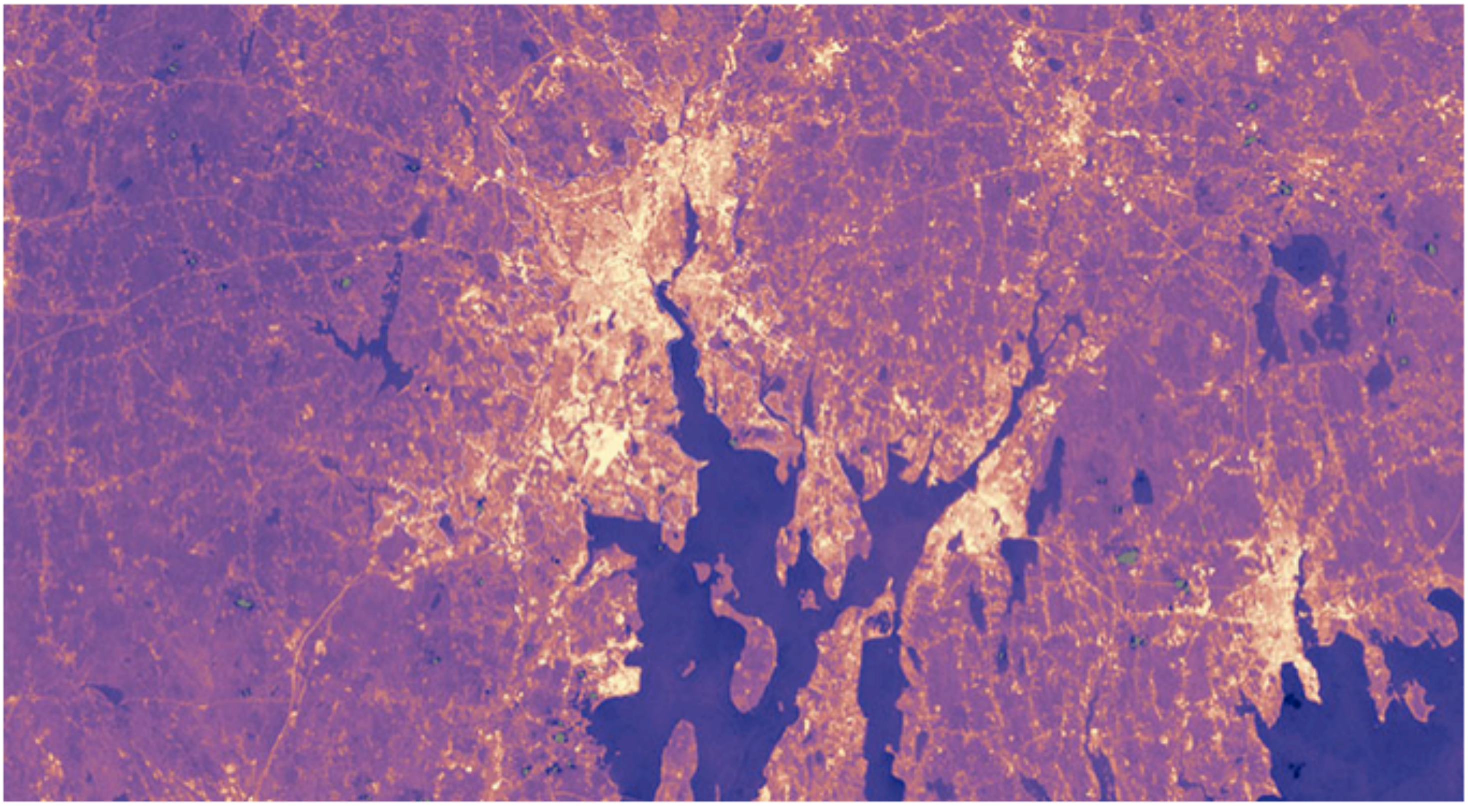
Urban Heat — Not a Myth, And Worst Where It's Wet



NASA Earth Observatory
This NASA image illustrates the temperature differential between the city of Providence and the surrounding region.

A new Yale-led study quantifies for the first time the primary causes of the "urban heat island" (UHI) effect, a common phenomenon that makes the world's urban areas significantly warmer than surrounding countryside and may increase health risks for city residents.

In an analysis of 65 cities across North America, researchers found that variation in how efficiently urban areas release heat back into the lower atmosphere — through the process of convection — is the dominant factor in the daytime UHI effect. This finding challenges a long-held belief that the phenomenon is driven principally by diminished evaporative cooling through the loss of vegetation.

The effects of impaired "convective efficiency" are particularly acute in wet climates, the researchers say. In cities such as Atlanta, Georgia, and Nashville, Tennessee, this factor alone contributes a 3-degree C rise in average daytime temperatures, according to the study, published July 10 in the journal *Nature*.

The phenomenon could have profound impacts on human health in cities worldwide as mean global temperatures continue to rise — and as more and more people move into cities — said **Xuhui Lee**, the Sara Shallenberger Brown Professor of Meteorology at the Yale School of Forestry & Environmental Studies (F&ES) and one of the study's authors.

"There is a synergistic relationship between climate conditions and the urban heat island," Lee said. "This relationship suggests that the urban heat island will exacerbate heat wave stress on human health in wet climates where temperature effects are already compounded by high humidity.

> *"There is a synergistic relationship between climate conditions and the urban heat island."*
> — Xuhui Lee

"This is a huge concern from a public health perspective."

For years scientists have recognized the primary causes of the UHI effect. In addition to the changes in convection efficiency and evaporative cooling, these include the tendency of buildings, pavement, and other structures to store more heat than vegetation and soil; heat generated by human-built industrial systems; and changes to the albedo of the Earth's surface. (Albedo refers to the proportion of sunlight or radiation reflected by the surface of the planet. Light-colored parking lots, for instance, reflect more sunlight back into space than darker surfaces.)

"One of the major barriers to mitigating the effects of UHI is the lack of quantitative attribution of the contributing factors," said **Lei Zhao**, a doctoral student at F&ES and lead author of the study.

Using satellite data of land surface temperatures and vegetation cover from cities in the United States and Canada, researchers calculated the mean temperature differentials between urban centers and their rural surroundings during both daytime and nighttime hours. They also used climate modeling to produce a more complex range of variables — from air density to aerodynamic resistance — which were then used to quantify the roles of each of the primary drivers of UHI (radiation, convection, evaporation, heat storage, and human-generated heat).

Their results reaffirmed the consensus view that, regardless of the local climate, the release of heat stored in human-built structures is the dominant contributor to the heat island phenomenon during the nighttime.

> *"In wetter climates urbanization reduces convection efficiency by 58 percent."*

But during the daytime, convection is the dominant factor, researchers found — particularly in "wetter" cities of the southeastern U.S. In those places, the smooth surfaces of buildings and other human-made features are far less conducive to heat diffusion than the densely vegetated natural areas that surround them, researchers say. Overall, in wetter climates urbanization reduces convection efficiency by 58 percent.

“The ‘rougher’ surfaces of the vegetation triggers turbulence, and turbulence removes heat from the surface to the atmosphere,” Zhao said. “But where there is a smoother surface, there is less convection and the heat will be trapped in the surface.”

Convection plays a key role in drier cities, too — albeit with far different consequences. In those settings — including in urban areas of the southwestern U.S. where surrounding vegetation is typically shorter and scrubbier — the rural areas are less effective at dissipating heat. As a result, the urban landscapes are actually 20 percent *more* efficient in removing heat than their rural surroundings, triggering a 1.5-degree C *cooling* within the cities.

“In those urban areas we sometimes see urban heat sinks instead of the typical heat island,” Lee said. “It’s a paradoxical phenomenon.”

According to the study, managing convection efficiency or heat storage of urban land is not a viable option since it would require fundamental changes to the morphology of cities, such as altering the height of buildings. A more viable option, researchers suggest, is more aggressive management of surface albedo — such as changing the color of parking lots, roads, and roofs. Doing so would reduce the amount of heat absorbed during the daytime hours and the amount of energy that has to be released at night.

Other authors of the paper, “Strong contributions of local background climate to urban heat island,” are **Ronald B. Smith** of the Yale Department of Geology and Geophysics, and **Keith Oleson** of the U.S. National Center for Atmospheric Research.

The paper was drafted while the senior author Lee was on sabbatical leave at Nanjing University of Information, Science and Technology. The model computation was supported by the Yale University Faculty of Arts and Sciences High Performance Computing Center.

– Kevin Dennehy kevin.dennehy@yale.edu *203 436-4842*

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