Summer in the city: Climate science reveals the impacts of heat

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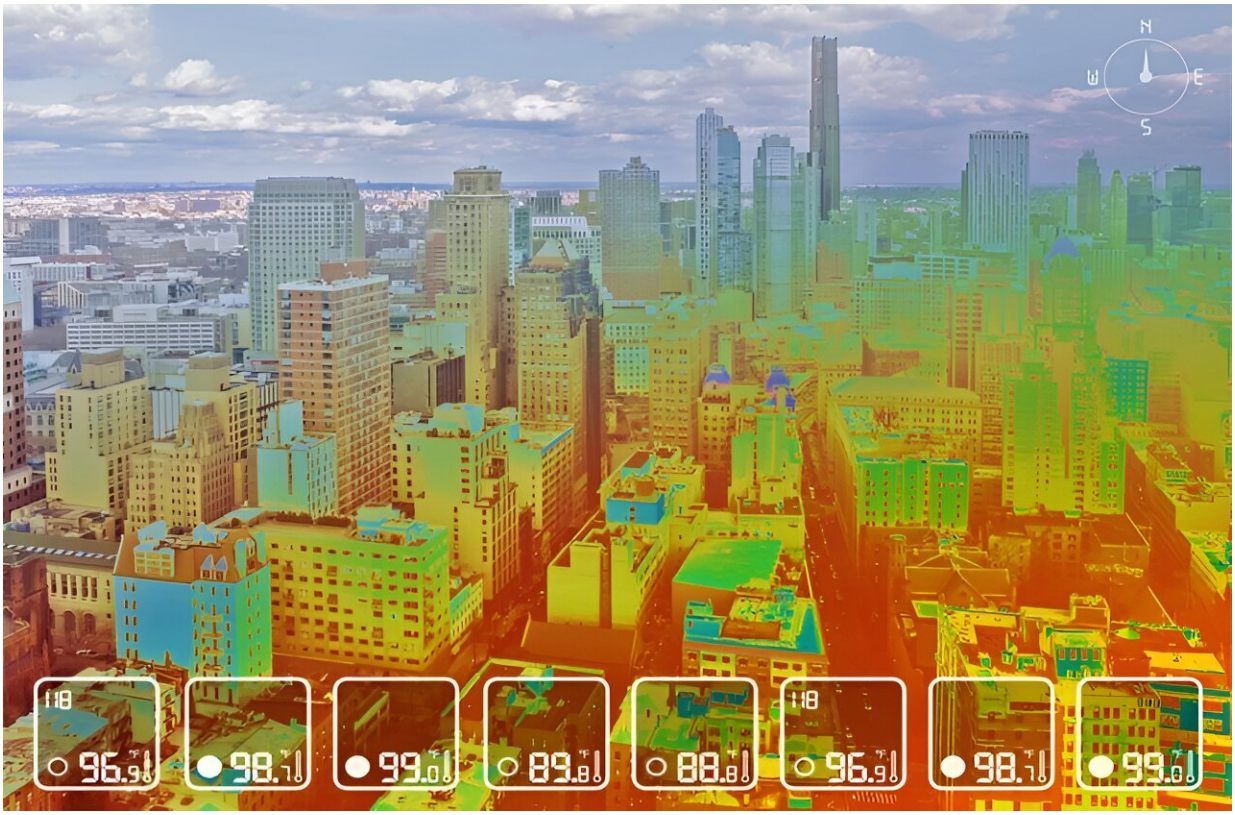

A photo of part of New York City with a heat map overlaid on top, with red showing the warmest areas. Credit: Timothy Holland | Pacific Northwest National Laboratory

The summer sun beats down. People without air conditioning must find refuge in schools and community centers. Outdoor workers struggle to

keep cool. Hot nights interrupt people's sleep, not allowing them to get the rest needed to recover from the warmth of the day. People with cardiovascular and respiratory illnesses have these conditions worsen.

While extreme heat seems less dramatic than severe storms, heat waves can be just as deadly. As the temperature rises, heat puts stress on our bodies. Our bodies keep us cool through sweating. However, the higher the temperature and humidity, the less effective sweating is. In many places around the world, extreme heat already causes more deaths than floods, wildfires, and hurricanes.

Researchers are working to understand how climate change is affecting extreme heat and how it hits different groups of people harder than others.

Heat waves

Heat stress is particularly harmful during heat waves. The heat wave that hit the Pacific Northwest in 2021 resulted in more than 1,000 deaths. It was the deadliest weather-related disaster in Washington State. A heat wave in Europe in 2003 caused by similar conditions resulted in more than 20,000 people dying across the continent.

These types of heat waves will become more frequent and more intense in certain areas due to climate change. As the world gets warmer, the surface temperatures of the Pacific Ocean increase unevenly. These temperatures follow a spatial pattern similar to that observed during El Niño events. Because heat rises, the warm air at the ocean surface moves upward and the colder air above it sinks.

As the heat moves upward, it gets released into the atmosphere. This release of heat leads to a type of air movement called atmospheric Rossby waves. These "waves" in the air make extreme weather more

intense. These waves can sit over locations for long periods of time, resulting in clear, cloudless skies. With no clouds or rain to cool things down, the heat becomes oppressive.

Using computer simulations known as Earth systems models, researchers from Department of Energy's Pacific Northwest National Laboratory (PNNL) looked at how future climate conditions could affect these waves.

They simulated different scenarios based on different levels of greenhouse gas emissions. Under the intermediate and high emission scenarios, they found that Rossby waves could settle over northwest North America more often. In addition, when these events occur, they could be far worse than the ones that have already happened. Scientists estimate that the amplitude of the Rossby waves could double in size by 2080 to 2099, compared to events in 1995 to 2014.

When combined with other factors like dry soil, this change could result in a huge increase in the intensity of heat waves. California, Idaho, Oregon, Washington, and other nearby states would be particularly hard hit.

Disproportionate risk from heat

While these heat waves are dangerous to everyone, certain groups of people are more at risk than others.

People who live in cities are particularly vulnerable to heat stress. More than half of the world's population and 83 percent of the United States' population lives in urban areas. Concrete buildings and paved areas in cities soak up heat during the day. The materials release the heat at night. Because rural areas have fewer buildings and more vegetation, their nights are much cooler.

To examine the extent of the "heat island effect," researchers at PNNL combined historical weather data with a climate model specific to urban areas. They studied the results of six summers in several major cities in the eastern U.S., including New York, Boston, Philadelphia, Atlanta, Miami, Chicago, Houston, Dallas, and Washington, D.C.

They calculated the heat stress, which includes the effect of both temperature and humidity on human health. They found that people who live in these cities experience two to six more hours of uncomfortably hot weather (above 80 F) in the summer than people in nearby rural areas. Many of these hours are at night. At night, the heat stress level can be from 3.5 to 9 degrees F hotter in urban areas. This is particularly dangerous because cooler nighttime temperatures allow people's bodies to recover from the heat of the day.

These urban-rural penalties are even worse during heat waves. While everyone experiences hotter than normal temperatures, there's a bigger increase for people in cities. A heat wave that's 11 degrees F higher than the expected temperature results in three more hours of uncomfortable warmth a day.

Even within cities, there can be big differences in heat stress from neighborhood to neighborhood. Areas that have more concrete and less green space are often significantly hotter.

The urban environment often runs along class and racial lines. In the 1930s, the Home Owners Loan Corporation run by the federal government gave urban areas grades for real estate development. This organization gave lower grades and therefore made fewer loans to neighborhoods that had more minority groups and lower income residents. Even now, these "redlined" neighborhoods have worse environmental conditions, including less tree cover and green space.

To look at how these conditions affect residents' heat stress today, climate scientists combined satellite data and simulations from numerical models. They looked at all 481 major cities across the United States.

Almost every city they studied had some form of racial segregation. When they overlaid hot spots of heat stress from 2014 to 2018 with historically redlined areas and census data, the differences jumped out. The average Black resident lives in an area that is 0.5 degrees F warmer in terms of heat stress than the city's average.

In comparison, the average white resident lives in an area that is almost 0.4 degrees F cooler. There were also major differences in income. In 94 percent of the urban areas, heat stress disproportionately affected poorer people. The bigger a city's income inequality, the bigger the difference in heat stress between income groups. Both these patterns also tended to follow the lines of historically redlined areas. Heat also compounds existing inequalities.

People who live in these areas are more likely to have health conditions that heat makes worse and less likely to have resources like air conditioning to deal with it.

Climate resilience

Knowing how heat waves will increase in the future due to climate change and how that affects different areas can inform efforts to improve climate resilience. If we know what conditions create heat waves, we can better predict them and help people prepare. By knowing what groups are most vulnerable to heat stress, urban planners and policymakers can prioritize resources.

Having information at the neighborhood level can help places choose solutions that make sense for them. While some solutions—like planting

more trees—may be effective in certain locations, they may not be appropriate for others.

In addition to the work specifically at PNNL, DOE's Office of Science is supporting efforts across the country to collect local data and help communities understand their specific needs. Four urban integrated field laboratories in Baltimore, Chicago, southeast Texas, and Arizona are exploring how the urban environment interacts with the climate system.

These field laboratories bring together expertise from universities, national laboratories, local governments, and neighborhood organizations. This local information can inform communities' decisions on how to best increase their resilience to climate change's impacts.

Whether helping us forecast the future climate or testing solutions to implement today, climate science is a key tool in helping us prevent and deal with the impacts of climate change.

Provided by US Department of Energy

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