Changing climate in your own backyard

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When you think of climate, you probably think of it on a large scale. Global climate change may come to mind, or the climate of a large region, like Northern Europe or the desert Southwest.

However, climate occurs at many different scales. Ben Ruddell, an assistant professor of engineering at Arizona State University, looks at climate on a much smaller level. He studies microclimates, which can range in size from a single garden or yard to a park or neighborhood. A microclimate is a small atmospheric zone where the climate differs from the surrounding area. For instance, a park is generally cooler and wetter than surrounding roads or a nearby dirt lot.

Ruddell is working to develop models for urban microclimates in order to engineer healthier, more comfortable and more efficient cities.

"We can make our cities better places to live," he says. "In the past, we've often made our cities less pleasant than their natural surroundings, but that doesn't have to be the case. There's no reason why cities can't be engineered to be more pleasant and healthy places in terms of climate."

One way that we have, unintentionally, made our cities less pleasant is by creating urban heat islands. This by-product of urbanization happens when manmade materials such as roads and buildings absorb the sun's heat and release it slowly at night. As a result, the city is hotter than the surrounding areas, making an "island" of hotter temperatures.

Perhaps not surprisingly, Phoenix has a pronounced heat island effect. But cities all around the world, from New York to Athens, are struggling with the effects of this phenomenon. In addition to feeling unpleasant, excess summertime heat increases both water and energy use. It can also have negative effects on human health.

But urban heat islands aren't uniform. Microclimates within a city are affected by myriad factors, such as shade, vegetation and moisture. Building materials are also very influential. Impermeable surfaces like concrete or pavement retain more heat than porous material.

A model that can predict the effects of changes made to microenvironments can help us engineer them for human health and comfort. For example, homeowners trying to choose landscaping options can weigh the temperature-reducing effect of lawns and trees against the amount of water they require. In the past, the data needed to create such a model was largely absent.

"There hasn't been much observation of the microclimate in cities at these very fine scales," says Ruddell. "The modeling work that has been done has often lacked adequate data – meaning we don't know whether the models are right or not. Also, what work has been done has mostly been in the Eastern U.S. and Europe – cold, wet climates that have very different rules from hot, dry climates like ours."

To figure out the rules that apply to arid urban centers, Ruddell's team is working with scientists on the Central Arizona – Phoenix Long-Term Ecological Research (CAP LTER) project to observe microclimates in neighborhoods throughout Phoenix to build a database. The data is used for modeling.

Another challenge of the project is developing modeling systems that can communicate the complex exchange of heat and moisture between the urban environment and the atmosphere above it, on multiple scales. Models that are currently in use don't effectively "talk" to one another. One focuses on the land surface and its water movement, the other on the atmosphere above the surface.

Enter Enrique Vivoni and Mohamed Moustaoui, the project's co-principal investigators, who are adapting models for use in urban areas. Vivoni, an associate professor in the School of Earth and Space Exploration, and graduate student Tom Volo created a system that models watersheds in natural environments. Moustaoui, an associate professor in ASU's School of Mathematical and Statistical Sciences, and graduate student Stephen Shaffer are modifying an atmospheric model for use in concert with the hydrology model.

"The atmospheric models used to simulate Phoenix generally ignore the fact that we're taking groundwater and river water and irrigating outdoor plants with it," says Vivoni. "A large percentage of water use in Phoenix is actually outdoor water use. I thought that was a fundamental problem to look at first. Before doing all this complicated hydrology and atmospheric modeling, let's focus in on the role of outdoor water use and plants."

Vivoni took a step back to focus on urban water and irrigation in a project headed by Volo. Volo's research paper details a hydrological model he adapted to determine the optimal irrigation for different types of landscaping in desert cities like Phoenix.

"Now we have a better handle on ways to apply irrigation water under this climate for different types of landscape designs," says Vivoni.

With a more complete picture of best irrigation strategies, Vivoni now wants to figure out how the water used in a city moves throughout it. Understanding how water moves both vertically and laterally in an engineered environment requires knowledge of Phoenix's many detention basins and gutters, and the vast network of storm drains.

"It's a fairly large task to take models meant for the natural environment and apply them to a place where we do so much engineering of the water system," says Vivoni.

But in tackling this enormous task, the team hopes to create a system that allows for better decision-making, on both the individual and municipal scales.

"In a sense, desert cities like Phoenix are both creating an urban heat island and reducing it through vegetative cover," says Vivoni. "If we were able to capture that dynamic in a coupled model of the land surface and atmosphere, we'd be able to design scenarios that tell us how we can reduce the urban heat island while implementing water conservation measures."

Take highways, for example – expansive corridors of impermeable materials that soak up the sun's heat and release it well into the night, creating an uncomfortable level of sustained heat. Vivoni imagines freeways lined with palms or mesquite trees, reducing that heat and making the surrounding areas more amenable. These bands of dense vegetation would affect the microclimates they border, potentially making them better places to live.

The information provided by an accurate model will empower individuals and small groups, such as neighborhood associations and city governments, to directly affect local sustainability and quality of life.

"We have the ability to control urban climate and engineer its outcomes," says Ruddell. "What our work has demonstrated is that we can improve health, comfort, energy use and water use by engineering the urban climate. In your own backyard and neighborhood, the things an individual citizen or community can control, like shade and landscaping, have a greater impact than global climate change."

Provided by Arizona State University

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