Better climate modeling and data can help Baltimore weather a hotter, stormier future

June 22 2023, by Gabriel Popkin

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If you were to stand at the intersection of Maryland Avenue and West 24th Street in Baltimore's Old Goucher neighborhood and travel back in time 10 years, you would probably be shocked at the transformation.

Back then, pavement blanketed the neighborhood. Of the few trees growing along streets, many were sickly or misshapen. Concrete, asphalt, and buildings soaked up the sun's rays in summer to create a sweltering heat island, sending temperatures soaring up to 10 degrees above those of surrounding areas.

Heat is a "silent killer," researchers say, and can be especially dangerous for older and vulnerable people who are unable to escape into air-conditioned spaces. Old Goucher had a particularly susceptible population: people who came to be treated at the area's methadone clinics.

Today, Old Goucher is verdant—an increasingly lush oasis amid the concrete jungle. Streets are lined with trees and understory vegetation. Islands of soil have been carved out of sidewalks. Along one block, more than 100 tons of asphalt and concrete were jackhammered and trucked away, replaced by an exuberant if somewhat unruly garden. When people enter the neighborhood, "they feel better," says Kelly Cross, a resident and president of the Old Goucher Community Association. "It feels somehow different. They can't put their finger on it. But we know why."

Cross and his husband, Mateusz Rozanski, who moved here in 2012, have catalyzed much of the change. They simply wanted to make their neighborhood more livable, and they say the greening has helped attract new coffee shops, bars, and restaurants.

But in the era of global climate change, their work is about to take on much broader significance. Old Goucher has become a key site for one of the best-funded equity-focused urban climate research efforts ever undertaken.

In spring 2022, the U.S. Department of Energy surprised and thrilled climate scientists with a call for proposals for a new and ambitious Urban Integrated Field Laboratories (UIFL) program to deploy the power of modeling and measurement on behalf of climate-stressed cities. Ben Zaitchik, a researcher in the Johns Hopkins Department of Earth and Planetary Sciences, emailed colleagues at universities and agencies around the region and pulled together a team. The researchers proposed something unusual: a climate research project that would evolve in conversation with local community members. "I thought there was a zero percent chance we would win" one of the coveted awards, Zaitchik says.

But the proposal did win, alongside those from three other cities, out of dozens of entries. The team will have a tidy sum—nearly $25 million—to create what Zaitchik hopes will be "the most meaningful urban environmental monitoring system in the world." Zaitchik plans to blanket selected Baltimore neighborhoods, including Old Goucher, with sophisticated instruments to measure temperature and flows of gases, wind, moisture, and heat to create an unprecedented urban climate data set. Researchers in Chicago; Beaumont and Port Arthur, Texas; and Phoenix will similarly be instrumenting their cities.

The task is urgent. Cities around the country and the world are swiftly warming while humanity is rapidly urbanizing. Yet city planners and officials lack data and models to help them protect residents from this warming and its increasingly severe impacts on health and well-being. As a result, cities often have poor visibility into the climate future, putting in place measures that might not have the desired benefits or that could in some cases make things even worse.

"We really need to get it right, now," Zaitchik says. "The investment choices that we make, and the way we deliver on them for cities in the coming five to 10 years, are really going to be determinative for the future of some of these communities."

At the same time that it seeks to aid cities, the Energy Department wants the four program sites to generate data that will help it answer a separate but related question: How do cities affect the climate? Dense urban mosaics of buildings, streets, and green spaces heat and cool the air and change moisture and wind in complex ways that affect not just cities themselves but also surrounding areas. But cities have thus far been a major blind spot for the massive computer models that researchers use to forecast the future of the global climate.

Meeting these science goals will be hard enough. But Zaitchik's team has designed its project to do something arguably even more ambitious: engage Baltimore community members to shape their climate-related priorities and guide their work. The project will be steered by a committee composed of city officials and community leaders like Cross and Rozanski.

While community-based research has deep roots in public health and social science, it is much less common in physical science fields, such as climate studies, where researchers typically design projects around questions they and their funders are interested in. It's also a departure for the Energy Department, says Jennifer Arrigo, an official who oversees the UIFL program. Co-production of research between scientists and communities "is something new for us." But if it succeeds, it could pay off big for Baltimore, the nation, and the world.

Like many cities, Baltimore's present-day climate woes have roots in decisions made centuries ago—long before anyone dreamed that humans could alter the global climate. As the city transformed into an industrial powerhouse after the American Revolution, housing blocks were jammed cheek by jowl to accommodate fast-growing ranks of workers who multiplied the city's population a thousandfold in a century. In much of the city, little space was set aside for trees or greenery. Wetlands were drained and streams straitjacketed to create dry land for building. The harbor was hemmed in.

Developments in the 1930s cast racial and socioeconomic discrimination onto the city's physical infrastructure. That's when a government-sponsored housing organization published maps of more than 200 U.S. cities, including Baltimore, with red lines encircling neighborhoods they deemed high risk. The designation made it hard to obtain home loans in those areas, severely depressing property values. Even though redlining, as the practice came to be known, was outlawed in 1968, impacted neighborhoods to this day remain poorer, with lower-quality housing and infrastructure.

Fast-forward to our fast-warming present, and historical decisions and discrimination combine to create a perfect storm of unequal climate risk. Temperatures in Baltimore soared above 90 degrees on 50 separate days in 2021. By 2080, scientists say the region's climate could warm up by 9 degrees Fahrenheit, making it more like Mississippi than Maryland. Extreme rainfall events and flooding are also on the rise, making a mockery of yesteryear's stormwater infrastructure and sending stormwater and sewage cascading into basements.

Depending on where you live, such events can be mere inconveniences or life-threatening catastrophes. Last year, urban forest researchers reported that the tree canopy in formerly redlined neighborhoods lags that of areas ranked as low risk by nearly half, making them far more exposed to punishing heat waves. Other studies have shown that the lack of shade disproportionately exposes residents of formerly redlined areas, who are predominantly people of color, to heat and illness. Such disparities are starkly apparent in Baltimore. Broadway East, for example, has just a sixth of the tree canopy of leafy, affluent Roland Park.

Heat also begets other woes. When air conditioners roar to life en masse during hot spells, utilities fire up fossil fuel–powered plants that emit pollution. Ground-level ozone also forms at higher rates, and hot, stagnant air can trap it in cities. Heat and resultant air pollution are linked to a host of health problems—asthma, chronic obstructive pulmonary disease (or COPD), kidney disease—that disproportionately affect certain groups, such as older adults and those who work outdoors. Extreme heat also raises the risk of pre-term birth. Partly as a result of these factors, life expectancy between Baltimore neighborhoods varies by as much as 20 years. The dangers posed by extreme heat, especially for vulnerable residents, are "something that's constantly on my mind," says Ava Richardson, director of Baltimore's Office of Sustainability.

City officials have taken action. For example, they are planting thousands of trees, aiming to increase the city's overall tree canopy to 40% while addressing historical inequities. Trees are often lauded for their ability to cool cities and reduce flooding, so much so that Congress has directed over a billion dollars to "tree equity" for shade-deprived neighborhoods.

But trees are far from a perfect urban climate solution. Their pollen can exacerbate asthma, and certain species emit chemicals that can worsen air pollution. The watering and care they require can also present challenges for cash-strapped city agencies, and poorly maintained trees can become burdens for residents. The truth is, no one really knows how planting programs such as Baltimore's will ultimately affect the urban climate because no one has done the city-scale climate modeling to find out. "We actually don't know how much trees cool a neighborhood," Zaitchik says.

And trees are far from the only climate solution cities have at their disposal. Some studies suggest that white roof paint that reflects sunlight and "cool paving" technologies that don't absorb heat can reduce urban heat islands for a fraction of the cost and complexity of trees. Permeable pavers allow stormwater to seep into the soil rather than run off into sewers and basements, while rooftop gardens can absorb stormwater before it hits the ground and cool buildings by transpiring water back to the atmosphere. In some cases, simply installing air conditioning in homes could more directly advance health and equity.

Just as cities themselves change from one block to the next, climate solutions must also be tailored to each neighborhood's physical characteristics as well as the community's needs, says Genee Smith, a professor in the Johns Hopkins Department of Environmental Health and Engineering. Smith focuses on environmental justice and health disparities and is co-leading the project's community engagement component. "What works for one area of the city," she says, "three blocks over might be a horrible idea."

Zaitchik agrees. "We know it's too hot, so let's work on mitigating heat," he says. "Sure, but there are different ways to mitigate heat depending on what your objectives are." Weighing the costs and benefits of different strategies is "something we're not very good at."

Given how Zaitchik's career started, it's perhaps surprising that he has emerged as the nucleus of the Baltimore Social-Environmental Collaborative, or BSEC, the group leading the Energy Department–funded UIFL. His early research took him to far-flung locations: Honduras for master's work on landslide risk, then the Middle East, where he did his dissertation research on drivers of drought. During a two-year stint with the State Department, he joined the U.S. delegation to the 2009 U.N. climate talks in Copenhagen, where President Barack Obama memorably burst into an 11th-hour negotiation for an agreement that ultimately disappointed just about everybody.

The conference made an impression. It showed Zaitchik that climate change was large and entrenched enough to stymie even the world's most powerful leaders. Clearly, the world would need to find ways not just to reduce greenhouse gases but also to adapt to a fast-warming climate that was starting to cause the sorts of disruptions scientists had long warned about: superstorms, droughts, and dangerous heat.

Since joining the Johns Hopkins faculty in 2010, Zaitchik has continued studying heat and climate risks facing some of the world's most vulnerable regions—East Africa, the western Amazon, South Asia—but he has also turned toward home. Starting in 2014, he and colleague Darryn Waugh began positioning sensors to monitor air temperature in Baltimore neighborhoods. Their results revealed some of the intricacies that urban climate modelers will need to grapple with. For example, sensors placed in trees revealed that even tiny pocket parks the size of a typical Baltimore row home could be significantly cooler than surrounding areas. In another study, Zaitchik and his colleagues found that the summertime heat island effect actually lessens in warmer conditions, possibly because water vapor traps heat on hot, humid nights, preventing rural areas from cooling down.

From the Energy Department's perspective, cities are a conundrum. Climate models chunk the globe into squares no smaller than a square kilometer, to make simulations simple enough to run on a supercomputer. ("Simple" is relative. Even at this resolution, climate models rank among the most computationally intensive software on Earth.) Square-kilometer grids might work OK for farmland or the ocean, but cities vary at far smaller spatial scales: One block could be dense apartment buildings, another single-family homes with yards, and a third a park. Because all that variation gets blurred out in models, there's a lot that scientists don't understand about how cities affect the region around them.

For example, Vivek Shandas, an urban ecologist at Portland State University, has found that coastal cities often heat up faster in the morning, whereas outlying forests often heat up in the evening. No one has a good explanation for this phenomenon. He says the data the Baltimore team collects on how air moves between buildings in a city will be invaluable for solving mysteries like this.

The program is also thrusting the Energy Department into an area where it's had little prior engagement: environmental justice. The program was specifically designed to help so-called Justice40 communities that are especially impacted by climate change, pollution, and environmental hazards.

To pull off such a wide-reaching effort, Zaitchik ended up pulling together experts from 11 institutions, including universities stretching from Virginia to New York, the U.S. Forest Service, and two Energy Department labs. Experts from physical science, plant science, social science, and public health are represented. Nine "theme teams" will tackle specific topics such as atmospheric dynamics and air quality, and health and community engagement. "It really is interdisciplinary … across both natural and social sciences," says Mike Bader, a Johns Hopkins sociologist who leads the university's 21st Century Cities Initiative. "That is unique."

The project will catalyze much larger datasets on the intersection of climate and health, says Meredith McCormack, a public health researcher at Johns Hopkins and co-lead of the health team. Previously, she had worked with Zaitchik and Waugh to study how heat affected the severity of asthma and COPD for about 100 Baltimore residents. "Now," McCormack says, "we can study people on the scale of thousands."

From the Energy Department's perspective, Baltimore was attractive for several reasons, Arrigo says. As a coastal as well as a midsize industrial city, Baltimore has a physical infrastructure and geography that are representative of many American cities. It also has a long history of urban ecology and climate research owing to the Baltimore Ecosystem Study, a two-and-a-half-decade research effort that was until recently funded by the National Science Foundation.

The hope is that the four sites will provide templates that cities around the country and even the world can use, says Cristina Negri, director of the Environmental Science Division at Argonne National Laboratory, who is heading the Chicago project, which will focus on quantifying the impact of potential climate interventions in neighborhoods on Chicago's south and west sides. If researchers can get all three pieces—measurement, modeling, and community engagement—working in sync, Negri says, "then you can export this model elsewhere."

The Baltimore effort launched in January with an urban climate party of sorts. Scientists, city officials, and nonprofit and community leaders crowded into cramped quarters at a refurbished warehouse in East Baltimore. The crowd, jazzed about the opportunities opened up by the influx of funding, enthusiastically listened to presentations from a parade of community groups. But the event also surfaced challenges project leaders might face in aligning community and research priorities. One speaker passionately argued that researchers should focus on small particles shed by car and truck tires, a pollution source that air quality experts argue has a relatively limited impact, Zaitchik says.

Others suggested that flooding was a larger concern than heat and zeroed in on trash and debris clogging storm drains as a critical problem. "That's not something that's on my radar screen, when I think of my job as a climate scientist," Zaitchik says. "But it's absolutely something we're going to look at."

Basement flooding during extreme rain events, and resultant health impacts from factors like mold growth, is another issue "that's risen on our priority list because of community input," Zaitchik adds.

The team is now gearing up to deploy an armada of gear throughout Baltimore. Sensors in streams will measure flow and water quality. A lidar system (think radar but with lasers) installed at a Morgan State University property in Clifton Park will measure particles in the atmosphere. A sonic ranging unit on the shore of the outer harbor will capture the impact of Chesapeake Bay breezes on extreme rainfall events in the city. Sensors mounted on towers in Broadway East and Park Heights neighborhoods will measure how various urban surfaces—trees, pavement, bare soil—influence heat and water exchanges between the ground and the atmosphere. Temperature and air-quality sensors will be spread across residential areas, providing data on how much the land surface heats, moistens, or cools the atmosphere. Instruments will measure both indoor and outdoor air quality. Supply chain snarls and other factors have slowed the rollout, but Zaitchik hopes the bulk of the equipment can be in place by the end of summer.

The data collection will be concentrated in neighborhoods representing distinct points along the continuum of urban climate change mitigation and adaptation. One is Broadway East, a densely built neighborhood that has suffered from disinvestment and population loss and that is just beginning its climate adaptation journey. On a recent crisp, sunny spring morning, researchers gathered in a vacant city block where row houses stood as recently as several years ago. A nonprofit named the 6th Branch now runs a small tree nursery and has converted abandoned ground into crop fields and a small berry orchard. Zaitchik is eager to measure how the local microclimate changes as growing trees and plants add more shade and water transpiration capacity to the neighborhood.

Old Goucher, meanwhile, will help researchers assess the effects of a decade of tree growth and other changes. Rozanski says it feels "like somebody dropped an air conditioner into the neighborhood" since he and Cross launched their greening effort. Researchers from the Baltimore Social-Environmental Collaborative will attempt to quantify and model that air-conditioning effect and determine both the exact interventions that caused it and its benefits for residents' health. A third site—possibly Roland Park—will represent a sort of "end point" of urban greening efforts.

The project team is also standing up a steering committee that will include city officials such as Richardson, community leaders such as Cross and Rozanski, and nonprofit representatives. This committee will meet regularly with project leaders and will be vested with the power to reorient or even veto research directions they feel do not reflect community priorities. The goal is "to make sure that we are not allowing the science to run away with us, if you will," says Tonya Sanders Thach, a professor of planning at Morgan State University who is heading the committee's formation. "We want to make sure the community always has a say. We want to make sure the community is always benefiting from the science being done."

Experts and city officials are excited about the science that's coming down the pike but clear-eyed about the challenges they will face in translating it to real-world benefits.

The project "will definitely generate a lot of new insights. From a scientific point of view, it will accelerate and catalyze a lot of new understandings," says Portland State's Shandas. "I'm not convinced it will necessarily translate over to the planning side."

Baltimore City's Richardson agrees that it will take effort and intention to produce science that makes a difference for planners. "There's a lot of data in general that's out there," she says. "Data alone does not drive decisions; it doesn't drive progress."

Meeting the needs of Energy Department program managers, Baltimore officials, and residents will indeed be a balancing act, Zaitchik says.

Whereas scientists often publish a paper and then leave others to apply the findings, with this project, "the science we're going to do needs to be of the nature that improves outcomes—by really informing what interventions matter."

Provided by Johns Hopkins University

Citation: Better climate modeling and data can help Baltimore weather a hotter, stormier future (2023, June 22) retrieved 27 April 2024 from https://phys.org/news/2023-06-climate-baltimore-weather-hotter-stormier.html