Microsoft

AI for Earth Grantee Profile

World Resources Institute

Reducing urban heat by mapping surface reflectivity

Summary

As the world's populations become more urbanized and as climate continues to change, urban heat islands play a significant role in an increasing number of deaths, as well as a wide range of other problems such as worsening health conditions, increasing energy consumption, and damaging infrastructure. Adopting more reflective materials for roofs and roads in urban areas could reduce the heat island effect and the resulting mortality risk. However, up to now, city planners have lacked a tool to map, measure, and monitor the changes in urban surface reflectivity over time, which is necessary to inform policy, budget planning, and decision making. A joint team led by the World Resources Institute is using machine learning resources provided by Microsoft AI for Earth to build this tool.

Mitigating urban heat islands through AI

The world's population has become increasingly and rapidly urbanized in the past century. With only 16 percent living in cities in the year 1900, by 2018 a United Nations report found that the urban population had reached 55 percent, and projected that by the year 2050, 68 percent of the population would be urban. Although there are many advantages to increased urbanization, one of the disadvantages is the urban heat island effect: the phenomenon of urban areas being significantly hotter than the surrounding area. Urban heat islands are due to a few factors, including the large number of surfaces covered by pavement or roofs that absorb a lot of solar radiation and then heat the air above them as well as the buildings below. This excess heat has many negative effects, from increasing energy consumption for cooling (which also increases the amount of waste heat in the environment) to increasing air pollution, and from these to making living conditions not just more uncomfortable but even hazardous to health and life. And those deleterious effects fall hardest upon the socially and economically disadvantaged, the people least able to afford the means to avoid the heat.

Climate change only compounds the problems of urban heat islands. In a 2014 report, the World Health Organization (WHO) estimated that over 92,000 more heat-related deaths could occur globally per year by 2030, and over 255,000 more by 2050. Although humans do acclimatize and adapt to local conditions, which could mitigate this threat, rapidly changing temperatures can still cause harm and death even among an acclimatized population, and beyond a certain optimum temperature range the risk of death increases regardless. And, the WHO notes, due to the limitations of the study, which focused on the population aged 65 and older that is most at risk from heat as the direct cause of death, it could be well underestimating the overall threat to health and life. The focus on mortality leaves out the potentially bigger costs from the effects of heat causing or worsening existing health conditions for a greater part of the population. It's certain that extreme heat waves are already causing more deaths annually than any other severe weather event, and as urban populations swell, this will only get worse unless action is taken to counter the urban heat island effect.

> "We have a warming world, and cities that exist within a warming world are heating up at twice the rate of the global average."—Kurt Shickman, Executive Director, GCCA

The WHO report notes, "Some mortality from high temperatures may be prevented by improvements to housing and the outdoor built environment, such as increasing green spaces and using albedo (painting roofs white)." Likewise, the US Environmental Protection Agency (EPA) recommends cool roofing and cool pavement products and materials, which reflect more solar energy than traditional materials, as strategies for reducing urban heat islands. However, although many cities have detailed heat vulnerability maps and access to other resources on some aspects of managing urban heat, they lack tools to show how changes in urban surface reflectivity are changing those heat vulnerabilities. Without such tools, it's difficult to budget for and justify spending on urban heat mitigation policies.

Evaluating surface reflectivity as a factor in urban heat

"We have a warming world, and cities that exist within a warming world are heating up at twice the rate of that global average," says Kurt Shickman, the executive director of the Global Cool Cities Alliance (GCCA). Since 2011, GCCA has been working to help cities reduce excess urban heat with passive cooling solutions. In that time, Shickman says, "One of the bigger gaps we've seen is that we haven't had an accurate, low-cost tool to evaluate the changes in roof, road, and other surface reflectivity until now." Filling this gap is the goal of a partnership between GCCA and the World Resources Institute (WRI), with support from the Microsoft AI for Earth program.

WRI is a global research organization that works with government, business, and community leaders to develop solutions for sustaining our natural resources, focusing on seven critical issues—including sustainable cities. Eric Mackres, the Data and Tools Manager for Urban Efficiency & Climate at WRI Ross Center for Sustainable Cities, explains, "We at WRI have been branching out into machine learning, computer vision work… and have been looking for more ways to help address urban heat and collaborate with Kurt's organization. We wanted to use this opportunity to partner up and try to answer some key questions with AI techniques."

When Mackres approached Shickman about a partnership to use AI on the problems of urban heat, Shickman not only suggested developing an analytical tool for surface reflectivity, but also noted some previous work had been done by Dr. George Ban-Weiss at the University of Southern California. Ban-Weiss's work had been limited to measuring roof reflectivity in a couple California cities in one time period, and used purchased research-quality imagery data. But to meet the challenge of urban heat mitigation, Mackres knew more would be needed. "We wanted to answer, could this be replicated with publicly available data, the kind you wouldn't have to pay for, and could it be done at a greater scale? Could it be done with developing a model that could be relatively quickly adopted or adapted to a new geography? And could it be done in a way that allows us to see changes over time? Those are our big questions with this project," says Mackres.

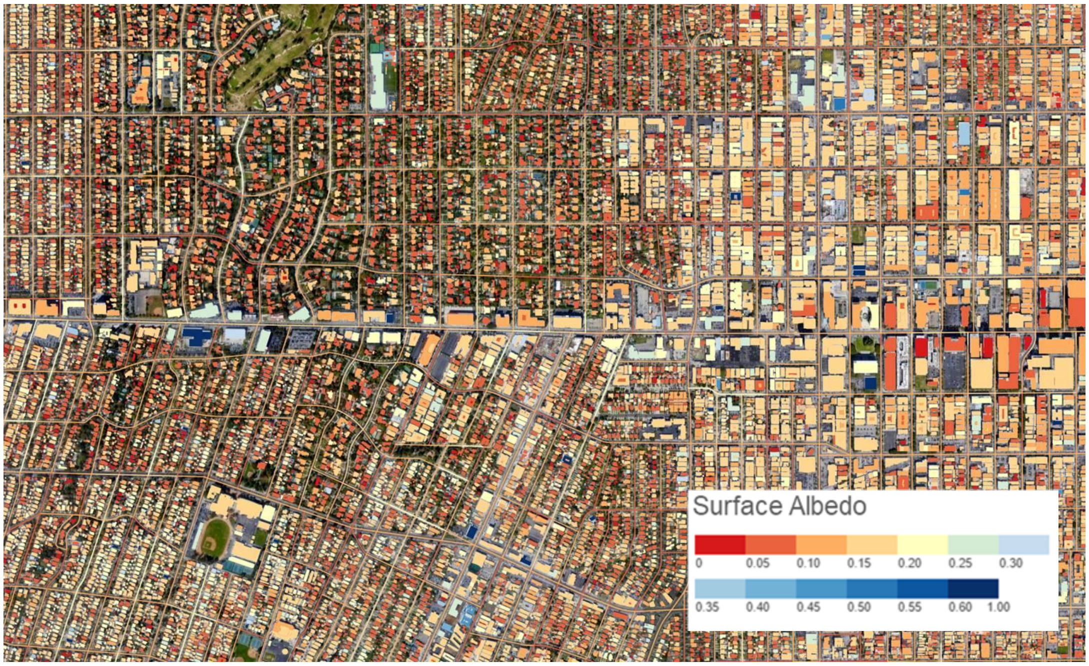
Mapping changes in reflectivity through machine learning

Bringing Dr. Ban-Weiss into the project, the team began working to replicate his initial work and to experiment with alternative modeling techniques. The tools provided as part of the Microsoft AI for Earth grant were an important part of this development work. Mackres says, "We did use a lot of the options within the Azure Machine Learning Studio that Microsoft hosts, which did make it easy to run a lot of different experiments on what kinds of model frameworks, what kinds of model architectures, made sense for this problem." Testing the models with one-meter resolution satellite imagery from the National Agriculture Imagery Program (NAIP) for the US and from the Airbus Pleiades satellite for the rest of the world, both accessed through the Descartes Labs platform, the team determined that they could indeed get good quality results with the freely available NAIP imagery and could also scale up to global coverage. Azure Data Science Virtual Machines and Azure Storage also provided the cloud computing resources to make the scalability possible.

> "…Azure Machine Learning Studio… [made] it easy to run a lot of different experiments on what kinds of model frameworks made sense for this problem."—Eric Mackres, Data and Tools Manager, WRI

The four-band (red, green, blue, and infrared) aerial imagery is the primary data needed to determine surface reflectivity, but to create a practical tool for cities looking to develop policies to manage urban heat, building footprints and road boundaries need to be mapped as well. In some cases, cities may already have that data; Los Angeles for instance provided this data to the team as part of the pilot project. In other cases, such as with Kansas City, the other metropolitan area participating in the pilot, the team relied on the Microsoft Building

Footprint dataset freely available for OpenStreetMap. With the aerial imagery, building footprint, and street segment datasets, and reflectivity estimates for each site generated by the AI models, the team built an online mapping tool in ArcGIS that visualizes the surface reflectivity on a building-by-building or road-by-road basis.



This map displays roof albedo (solar reflectance) estimates for Los Angeles. Higher numbers indicate greater reflectance. Reflective roofs are more energy efficient and cooler inside and out.

The first phase of the project is now complete, having produced an open source model that can be used across the US (which is a key step toward achieving its goals), and a time series of results for two urban areas. Refining the models to evaluate the changes in reflectivity over time in more places and to predict the resulting changes in urban heat is the next focus of the project. Mackres describes this as, "…going beyond monitoring temperature or monitoring reflectivity of surfaces in general to being able to be much more focused on specific interventions. And to be able to analyze that at different scales, from the citywide scale to a neighborhood or a district, and to some extent even on a roof-by-roof or street-by-street basis, to inform decision making." By seeing where and how urban heat is generated, and when and how changes in reflectivity affect that heat, authorities can better assess how different strategies are performing and choose what policies and solutions may work best for their cities. Shickman concurs, saying, "What this tool will do when it's rolled out nationally is give that extra layer of data for cities that are saying, 'I've got a limited budget, I want the ability to target our programs so that we can do a lot with a little.'"

About the World Resources Institute

World Resources Institute (WRI) is a global research organization that spans more than 60 countries, with international offices in Brazil, China, India, Indonesia, Mexico and the United States, regional offices in Ethiopia (for Africa) and the Netherlands (for Europe), and program offices in the Democratic Republic of Congo, Turkey and the United Kingdom. Our more than 1,000 experts and staff turn big ideas into action at the nexus of environment, economic opportunity and human well-being.

About Eric Mackres

Eric is the Data and Tools Manager for Urban Efficiency & Climate at WRI Ross Center for Sustainable Cities. He helps cities obtain the information and stakeholder agreement they need to develop and implement broadly beneficial strategies to optimize, electrify, and decarbonize their energy systems. He also coordinates data strategy across the Center and acts as the Cities data liaison to WRI's Resource Watch, Energy and Climate programs. Eric manages technical and use case development of globally relevant methods, tools, and datasets on energy performance and urban form characteristics of cities. His projects include AI-driven mapping of the heat and resilience aspects of urban surfaces, methods to develop "quick start" city energy and emissions inventories, scenario modeling to support locally beneficial plans for city transitions to 100 percent clean energy, and computer vision-based urban land use modeling.

About Kurt Shickman and the Global Cool Cities Alliance

Kurt Shickman is the Executive Director of the Global Cool Cities Alliance (GCCA), a non-profit organization that helps cities reduce excess urban heat with passive cooling solutions. Launched in 2011, GCCA works with more than 35 cities around the world to formulate and implement policy, identify relevant cooling strategies, and support progress monitoring and tracking. GCCA also manages the Million Cool Roofs Challenge, a US$2 million program to rapidly scale up markets for passive cooling technologies in developing countries where there is an acute lack of access to cooling services. Prior to joining GCCA, Kurt was the Director of Research for the Energy Future Coalition and the United Nations Foundation's Energy and Climate team. His work involved building broad and diverse coalitions of stakeholders around key clean energy and climate change policies at the local, state, and federal level with a particular emphasis on dramatically scaling up the deployment of energy efficiency in existing residential and commercial buildings.

Resources

Websites

World Resources Institute home site

Global Cool Cities Alliance home site
Urban Heat Mitigation project code and documentation on GitHub
ArcGIS web apps showing the results of Los Angeles County project

Press

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