What Are BSEC Researchers Doing?
Miriam Avins and the BSEC Team

BSEC is a 5-year research project to identify ways Baltimore can adapt to climate change and also reduce its contribution to climate change, in ways that improve equity. It's clear that the climate is changing and so must we. The changes we need will require money and policy change; both require solid data. The goal of BSEC is to provide that data and identify sound policies and approaches, to increase the likelihood that Baltimore will be able to pay for the changes needed.

This explainer delves into some of the research, with an eye toward showing why the research is needed and how the scientists are going about it. Cities are poorly understood, both because they often receive less attention from the relevant fields and also because of the large scale of the models that scientists use to understand climate. BSEC is creating a far more fine-grained and interdisciplinary understanding of how Baltimore neighborhoods experience climate change now and are likely to experience it in the future, with the goal of motivating responses that improve outcomes in historically underserved neighborhoods.

How hot is Baltimore?
We know that cities are hotter than their surrounding areas, but until a few years ago there was an enormous lack of data about the actual differences between suburbs, leafy city neighborhoods, and the ultra-urban neighborhoods with the most paved surfaces and fewest trees. The federal Department of Transportation has sensors at major highway intersections outside the city, and the Weather Service has two sensors in the Baltimore area – one at BWI airport and the other at the Science Center. In the citizen science realm, there were about 70 small weather stations hosted at people's homes, nearly all in majority-white neighborhoods. (This is an example of racist results that emerge from the accepted ways of doing things rather than through specific motivation.)

In the past decade, scientists have been addressing this lack, and the work has been significantly boosted by BSEC. BSEC has placed 40 small weather stations in the city, focusing on majority-black neighborhoods. In addition to temperature, these measure humidity and rainfall. These stations require community buy-in for determining safe locations and for data sharing. BSEC is also using mobile devices, carted around by bike, to map how temperature varies between streets and parks.

With this data, which is shared here, BSEC can produce a map of temperature variation across the city – a map that will continue to be refined. This can be useful to neighborhoods and policymakers as they push for solutions, and is also a key input to the work of many researchers working on topics including ways to cope with worse heat, rainfall patterns that cause more flooding and disrupt the growing season, and risks to air quality.

How hot will it get?

Weather stations on the ground measure what people experience. They do not explain what causes those conditions, or how our climate will change. For that, scientists build models.

Models are ways of representing what we think we understand about some aspect of the world. They include underlying scientific principles (such as gravity), information about the system being studied (such as the composition of the atmosphere), and variables we are curious about (such as wind speed and direction and relative humidity). Models are typically run on computers, and the output is a projection of what happens to the system when we adjust the variables. BSEC researchers use models to improve their understanding of what Baltimore's possible futures look like. A disadvantage of models is that they are only as good as the information that goes into them.

As scientists started to study climate change in the 1960s, they built computer models that simulated climate change at the global scale, for two reasons. First, climate is a very large-scale phenomenon. Second, computers then could handle much less data than they can today. As the overall process of climate change has become clear and as computers have become more powerful, scientists have focused on smaller components of climate systems. Some of the questions are: how does the greater heat in cities affect air quality and rain? How does it affect weather outside cities? How much hotter will cities be than surrounding areas as the climate continues to warm?

To better model how climate change will affect heat in Baltimore, BSEC researchers are turning to weather models. These have the same underlying scientific principles, but improved information about the urban surface – buildings, plants, roads, soils, etc. They typically have a finer resolution as well. Using these models, they can see neighborhoods, pick out the influence of the Chesapeake Bay and heat from Washington, D.C., etc. BSEC researchers are running these models many times in different neighborhoods with different ways of describing the variables to improve their accuracy for the whole city. Finally, the researchers will be able to use the future scenarios projected by climate models to zoom in on the neighborhood-level climates conditions of the future.

You can learn more about how BSEC researchers are collecting the data they need here and in other sections of this explainer.

Soil and the Climate

Models are only as good as the data they are built on. BSEC researchers are providing data about Baltimore's urban soils for the models being built and refined by several other groups of researchers. Here's why soil matters to all of us, and how it affects climate change.

Much of the soil in Baltimore is sealed under paving and buildings, where it cannot support plant life or efficiently absorb water. Baltimore can prioritize the health of our open soils. This can mean different things. For places where growing plants is the priority, the key characteristics are nutrients, lack of contamination, and that the soil isn't compacted so that the roots can grow easily. In places where absorbing runoff is the priority, such a texture is most important.

BSEC researchers have taken soil samples taken in people's yards, vacant lots, parks, and forest patches. As they analyze them in the lab, they'll be giving key information to the researchers who are building models of the climate and the movement of water. The information will also be useful to the researchers who are looking at how to build the tree canopy to withstand climate change.

MORE ABOUT SOIL – THE FOUNDATION OF LIFE

Soil is the foundation of life on solid ground. Plants need soil, so it is the basis of the food web and agriculture. It also is the basis of physical habitats for people, other animals, and plants. Soil is itself home to many types of organisms. In addition to supporting plant life, soil absorbs water and makes it available to plants, and filters the water that slowly trickles into underground aquifers. Soils also move water back into the atmosphere, both from evaporation from the soil surface and through plants' transpiration of water. Both of these processes cool the air.

What we as humans want from the soil is sometimes different from what's good for other beings. An example is soil that is firm enough to support a building or intensive farming that lets the topsoil blow away. At times, people's changes to the soil to meet short-term goals have resulted in erosion, contamination, compaction, and other kinds of degradation that last a long time.

Soil can store a lot of carbon. Plants take up carbon dioxide from the atmosphere and transfer carbon to deeper soil via their roots. Decomposing plant material can also be transformed to soil organic carbon. This ensures long term fertility of soils. It also means that major disturbances of soil, such as burning or clear cutting or the thawing of the permafrost in the north, can release very substantial carbon to the atmosphere. This points up the need to be mindful about disturbing the soil.

Heat can increase air pollution. What will that look like for Baltimore?

The air between the earth's surface and the bottom of the clouds is called the "boundary layer" of the atmosphere. This is the air we breathe, and also the part of the atmosphere with the most pollution. The depth of this layer depends (among other things) on conditions such as temperature, humidity, wind and air quality. This layer of air is deep when the ground is hot and causes air to move around a lot (like hot water churning in a pot about to boil) and shallow when the ground is cold. (The layers of fog that hug the ground on a still, cool morning result from slowed air movement.) Some of the pollution in the air is from direct emissions of gases and tiny particles from sources such as cars, industry, and cooking. Some pollutants are actually formed in the air through chemical reactions. How will climate change (as well as climate mitigation and adaptation strategies) affect both the direct emissions and the pollutants formed in the air?

A hot atmosphere allows for more chemical reactions to happen. Cities heat up more during the day than less densely populated places, and they hold onto that heat more at night. This creates more opportunities for pollutants to form through chemical reactions. These may be different than the pollutants found outside cities.

Air conditioners play an interesting role. On the one hand, people who cool their houses by opening their windows are exposed to more pollutants than people who use air conditioners. On the other hand, if we respond to increasing heat by greater use of air conditioners powered by fossil fuels, this can lead to more emissions of pollutants, generating more pollution.

Additional sources of air pollution that may increase include wildfires whose smoke travels great distances, and the pollutants generated by outdoor grilling when it's too hot to cook indoors.

BSEC is investigating air quality in several ways. First, while the federal government counts total PM2.5 (particles in the air that are 2.5 microns in diameter and less), BSEC researchers are studying the different kinds of particles and how they are distributed across Baltimore. Some particles of pollution are more harmful to people than others. Other researchers are correlating these levels with hospital visits to determine if there are components of PM2.5 that cause more inflammation and other health issues.

BSEC researchers are also working to refine a model that can predict how air quality will be affected by increased heat in Baltimore.

Gas leaks (methane)
Natural gas, the fuel many people use in their homes for stoves, water heaters, heat, and more, is primarily made up of methane. Natural gas is also increasingly used to run power plants. While carbon dioxide is the greenhouse gas that gets the most attention, a molecule of methane (made of carbon and hydrogen) is nearly 30 times as powerful at trapping heat in the atmosphere than a molecule of carbon dioxide. Since one molecule of methane has a greater impact on climate than one molecule of carbon dioxide, so reducing the amount of methane going into the atmosphere can quickly slow climate change. As with carbon dioxide, the concentration of methane in the atmosphere has increased significantly due to human activities.

Baltimore has miles of underground pipes that deliver natural gas to buildings. Because Baltimore is an older city, many of these pipes are made of cast iron that can crack as they age, leading to leaks. Baltimore Gas & Electric (BGE) is working to upgrade and repair these pipes with new, plastic pipes, but many miles of the City's pipes are still old and in need of repair.

The federal government has estimated the average amount of natural gas that leaks from pipes, but this estimate is likely far too low for older cities. BSEC is working to refine the estimate for Baltimore (and thus for other older cities), building on work of other researchers. Using mobile sensors in a van, BSEC has detected natural gas leaks. BGE is collaborating with BSEC to evaluate whether fixes are effective, or if the gas simply leaks elsewhere.

Using stationary air sensors that are mounted in specific locations, a "methane sniffer" in a backpack for use by car, and a van with multiple instruments, researchers are mapping methane links. The goal is to create a map of methane leaks across Baltimore, and to specify the average leak rate. This information can be used to make improvements and to push for policy change. For example, are there areas of the city that should be priorities for full electrification?

Keeping Houses Cool
In the summer, temperatures can run up to 7-9 degrees Fahrenheit higher in the neighborhoods where the people with the lowest incomes live, compared to Baltimore's coolest places. This means that air conditioning is needed most in the neighborhoods where people have the least to spend on it. How can the impact of energy costs be reduced so that

people can be comfortable in their homes and also avoid substantial greenhouse gas emissions?

While it's important to design new buildings with energy efficiency in mind, researchers estimate that 80% of the buildings that will exist in 2050 are already built. This means that retrofitting – making changes to a building – is the key to reducing energy and increasing comfort. The goal is "passive survivability": increasing the ability of buildings to stay comfortable without total reliance on air conditioning. In Baltimore, it is particularly important to improve the comfort of rowhouses, the predominant housing type in the affected neighborhoods.

Strategies to cool houses are already well known. These include shading systems for windows, insulating and air-sealing exterior walls, and replacing dark roofing materials with white or more heat-reflective alternatives. What is not well understood is the extent of energy savings that these can provide. Researchers are building computer models to study this. They are also incorporating factors beyond the buildings themselves. For example, how do shade trees affect energy use and comfort? And what about changes in street pavement type? Any adjustment that increases a building's resilience to heat also reduces energy use, thus reducing greenhouse gas emissions.

Researchers are also looking at the specific factors that lead to energy poverty (paying an unaffordable amount on energy). These include factors related to homes, such as the kind of construction, and factors related to people, such as age and household demographics.

What role do trees have?

Grassroots neighborhood-level responses to climate change often focus on trees, and for good reason. Trees' leaves slow rain and guide it to the ground, where the roots make the soil more absorbent. Trees cool the air by providing shade and through transpiration, the process by which water leaves the insides of leaves. And trees also store carbon, returning it slowly to the soil when they rot in place. Trees also provide beauty and contribute to social and environmental well-being, providing homes for animals such as birds.

There are two important issues regarding the role of trees to address climate change. First, their benefits have not been well studied at the neighborhood or city scale. Second, climate change is affecting which species can thrive in which places. That is, what trees should we be planting today to gain their benefits now and over the next 50 years? BSEC scientists are addressing both issues with their research.

Thanks to the work of Baltimore City's Forestry Division, Baltimore Tree Trust, and others, scientists have a lot of data on what species are growing where. They're building on this by taking measurements of how well the trees are doing. When the weather is too hot or too dry, trees close the tiny holes on their leaves (stomata) to hold in water; unfortunately, this also stops photosynthesis, the process by which trees turn sunlight into the sugars they use for energy. Scientists are measuring how much specific trees in Baltimore are photosynthesizing. They are measuring the nutrient content of the leaves, such as nitrogen and other elements that come from the soil. They are also recording information about the trees such as height and circumference, which can be used to estimate age and total carbon storage.

They will use all this data to create recommendations. They aim to identify a diverse palette of species that are suitable for different environments, such as street trees, areas with low tree canopy, and other niche environments. The goal is to create resiliency through diversity, so that if one kind of tree is greatly harmed by a disease or insect (as recently happened with ash trees), most of the trees will still be fine.