modeling urban heat islands and rural areas

Supercomputing Challenge 2024-2025
Final Report

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EXECUTIVE SUMMARY

For this Supercomputing Challenge project, the scientist decided to explore heat islands, in Urban areas vs. Rural areas. A Heat Island is an area of land where things are hotter than normal, usually caused by humans. The scientist decided to do this project to research the effects of Climate Change. After talking to Supercomputing Challenge mentors, the scientist decided to study heat islands, as it was something they had never researched before, as well as a part of Climate Change. The focus of this project was to graph and model how human activity leads to urban heat, and equal human activity within a rural area would create much less of that heat.

For the project itself, they used NetLogo[1], the programming software. While constructing the code, they ran into some issues with running it. Since the project revolves around heat over time, the scientist made every tile available to have heat on it, with a map in the background. It was Rural vs. Urban areas, so the Rural area heated up less, and the Urban area heated up much faster. This was complicated, however, since the heat would not appear over the top of the map drawn. The scientist required help, so they looked to this year's theme- AI. ChatGPT[2] was very helpful here, giving step-by-step instructions and improving the code. The code worked after some manipulation, and the rural area had less heat islands than the urban area, as hypothesized.

- The Urban area heated up faster than the Rural area
- The heat showed up on top of the map
- Humans walked around, and planted trees in the Rural area. (only the rural area)
  - Side note; the humans walk around planting trees, and the effect of the trees is that they cast shadows along the rural area, reducing the amount of heat. The trees cannot be planted in the urban area, since the asphalt and concrete roads and sidewalks everywhere prevent trees from being planted.

In the future, data could be gathered in real time in an area near the researcher's location, and modeled to determine if the model matches the data.

INTRODUCTION

Climate change is a big problem because the world is growing hotter and it's even hotter than it's been before.[3] One of the things that creates additional heat when combined with climate change in urban areas, like cities, are heat islands. A heat island is a specific place in which human activity has made the area quite warmer than it should be, hence the name "Heat Island".[4] One example is New York City, which has lots of skyscrapers and buildings, as well as asphalt roads and cars to drive over them. These things all contribute to extreme heat because the metal and glass of skyscrapers and buildings makes them get very warm when they interact with rays of light from the sun. The asphalt from roads also does this, making the roads extremely hot in summer conditions. "Studies estimate that heat islands increase daytime temperatures in urban areas in the United States by about 1°F to 7°F and nighttime temperatures by 2°F to 5°F."[5]

One of the effects of climate change, which is commonly just referred to *as* "climate change" is Ozone depletion. This is where toxic chemicals and gases are released into the atmosphere and start eating away at the Ozone Layer, one of the layers to our atmosphere. This layer is the layer that protects us from most radiation from the sun, and since it's being depleted little by little over time, it protects us less from the sun's radiation over time. Since more heat and radiation is being let into the earth from the sun, this causes earth's surfaces to heat up quicker, causing more drastic changes. Like Antarctica, for example. It's made up of mainly icebergs and glaciers, and since they're heating up more quickly, they will melt at a much faster rate than usual.

The melting of these ice formations creates higher tides and ocean levels. Some cities and towns on the bays of countries might be underwater, after a given amount of time.

When you combine both urban heat islands and climate change, some already hot areas become even hotter, which leads to difficult living conditions for people in urban areas since it is so hot.

METHODS

For the model, I wanted to create an area with buildings and an area with trees, simulating shadows and heat around these areas. NetLogo did not have a model that showed my vision perfectly. The mentors that were at the kickoff suggested that I use an existing model from the NetLogo models library and change it. The model I chose to use was called “Urban Suite: Pollution”.

This preset model was not the best choice for the project I envisioned, as the more human activity that happened, the less heat there was. But, urban heat islands are based on human activity, as most materials they use conduct heat. This model showed more about the Rural area and the shade vs. the heat, than the Heat islands themselves.

The NetLogo model before I changed it is shown in Figure 1. The red patches, as you can see, are called factories, which, in this model, are what create the pollution. The small black shapes there are the humans, which are going to walk around, collecting the pollution after stepping on a tile that is contaminated. Any gradient of red is a contaminated tile.

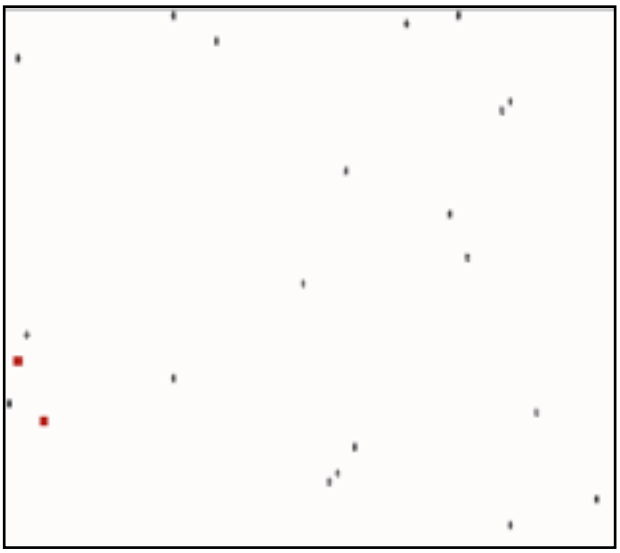

Figure 1: “Urban Suite: Pollution” model before running.

Once the model starts running, the humans move, plant trees, the factories will start producing pollution, as shown in Figure 2.

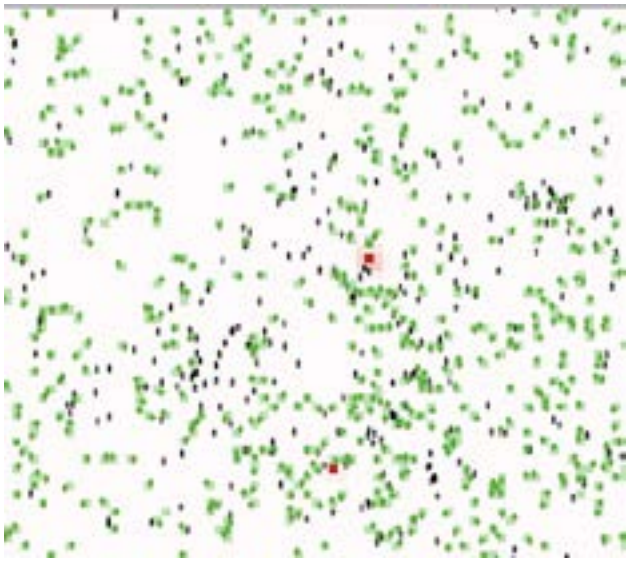

Figure 2: “Urban Suite: Pollution” model after running.

To create my model, I changed the variables and removed the “Pollution” elements so that it would be more about climate change. I ran into some issues along the way, though. For example, when I ran it, it looked as in Figure 3.

The green area on the left is the Rural area, and the gray area on the right is the Urban area. The green of the Rural area is to detect so that the humans can plant trees, and the gray of the urban area symbolises the concrete and asphalt of real cities, and also to make sure that the humans don’t plant trees in the Urban area.

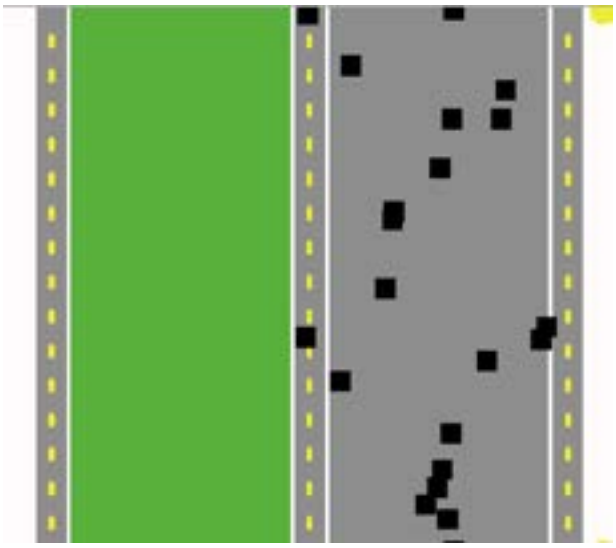

Figure 3: Initial model with turtles after running.

The issue is that there are no humans on the screen at the moment. This issue occurred because the humans were dying off immediately. I meant for them to eventually die, after running out of health, but they immediately disappeared. From the controlling area, it looked normal. (Figure 4)

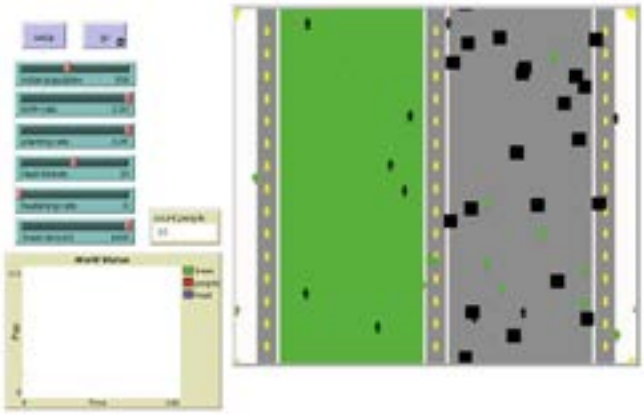

Figure 4: Initial model before running, with control panel.

You can see that on the left side of the screen, it says “count people: 10”. That shows how many people are on the map. But, when I run it, you can see that it says “0”. (Shown in Figure 5)

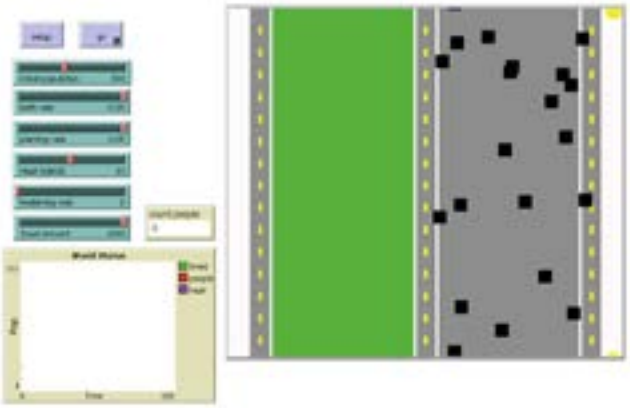

Figure 5: Initial model after running, with control panel.

So, to fix this code, I removed the fact that humans could die altogether, since they don’t die for many years. This simulated the real world better.

But now, the heat would not appear over the top of the roads & landscape. I had to fix this issue by, instead of using turtles, which are small shaped objects that you can move from any place to any other place, specifically to draw things, using patch colors. Patches are those small squares on the map which carry a color, shape, or function. I had used turtles before, to draw out the land. But, that wasn’t working, since the heat I’d coded in was for patches, which are below turtles. So, I made the heat from pcolor (patch color) instead of turtles. The result now is shown in Figure 6.

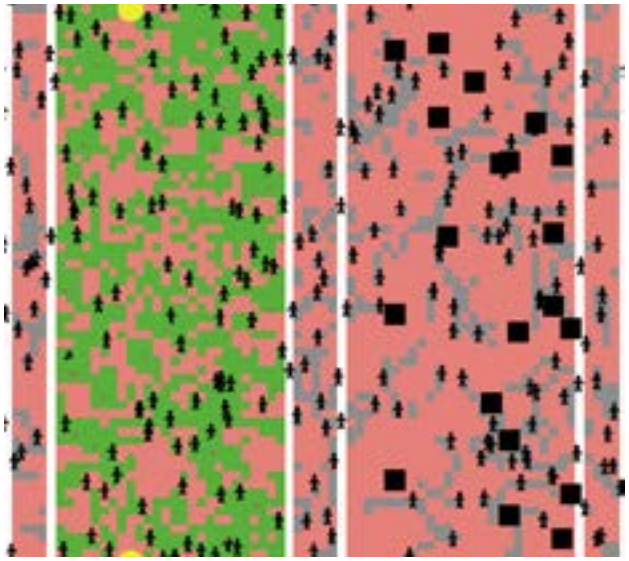

Figure 6: Final model, after running.

This is what it looks like while running in the final model. You can see that the rural area has much less heat (the red gradient squares) than the urban area, which was expected. The hotter parts (buildings and roads) of the urban area heat up MUCH faster than the cool grass of the rural area.

PROCEDURE

To create my project, I first booted up NetLogo. The reason I chose to use Netlogo for this project was because at the Supercomputing Challenge Kickoff, we practiced using it at New Mexico Tech and the mentors there recommended using NetLogo because it's easy to use and since it was my first time participating in the Supercomputing Challenge.

The Models Library is a section of the file tab that contains many models created by others, that you can use to either copy coding elements, edit to make the model into a different one, or to use and see what it looks like. The Models Library is open to everyone who uses NetLogo. It is a complex set of folders containing a lot of models. (Figure 7)

Figure 7: NetLogo Models Library

When we open the Urban Suite tab, we can find the model that I used- Urban Suite: Pollution. (Shown in Figure 8)

Figure 8: NetLogo Urban Suite tab

This is the model that I used to start creating my own. While creating it, I had quite a few issues with my model. Since this year's theme was AI, I had ChatGPT help me with my coding errors. It helped me rewrite small snippets of my code and also told me about a few commands in NetLogo that I didn't know about.

Using AI was important to help me with my project. AI helped me write small snippets of code, gave me important info, and taught me commands. It took over a month to get my code right. It's mainly courtesy to NetLogo, for having the Models Library open to the public. That really helped because it taught me how to have the humans walk around and plant the trees.

VERIFICATION AND RESULTS

The Pollution model that I modified had five variables that you could change to get different results. The initial population and the amount of trees were important to keep in my model because the others were specific to pollution, because trees cast shade, and because the number of people reduces the heat when they walk over a heated patch.

In the final model, the number of buildings is tied directly to the amount of humans that can be changed by the “initial population” slider. The more humans, the more buildings there will be. Unfortunately, because the removal of heat is caused by humans, even though there are more buildings, there is less heat created in the model. (These are shown in Figure 9)

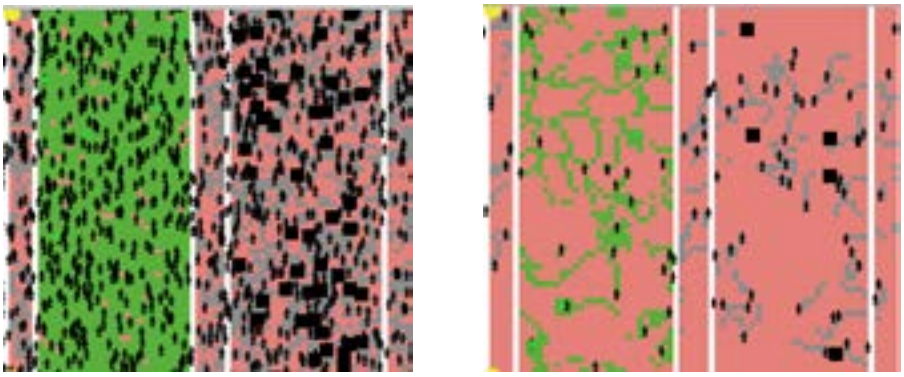

Figure 9: Final model

(Left) Initial population = 1000

(Right) Initial population = 100

The rural side works better because the trees cast shade, adding to the overall result of less heat in the rural area. The less trees included in the “trees-amount” slider, the more heat there will be, since there are less trees to cast shade.

If we use the minimum number of trees, 5, the number of heated patches increases in the rural area. As we increase the number of trees, the number of heated patches decreases in the rural area. Eventually, when we reached the maximum number of trees to cover the rural area completely, the number of heat patches essentially did not change as the number of trees in the model increased.

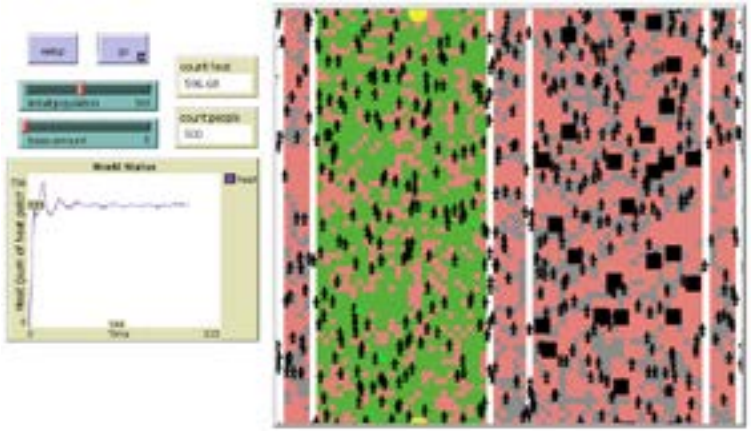

Figure 10: Final Model

Number of Trees = 5

The maximum number of heated patches evened out at approximately 600.

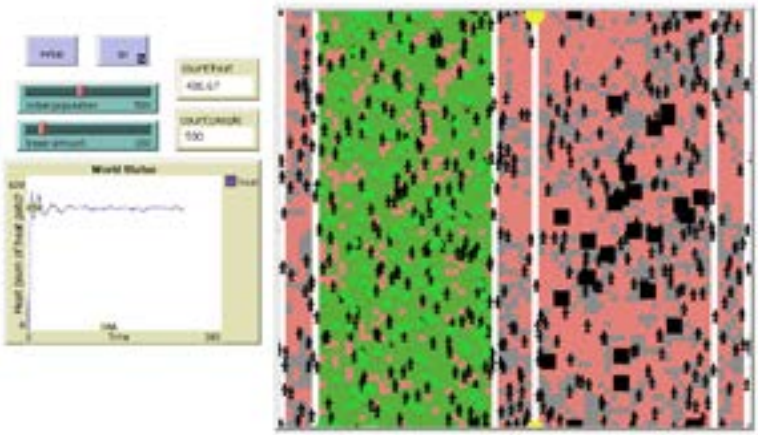

Figure 11: Final Model

Number of Trees = 150

The maximum number of heated patches evened out at approximately 500.

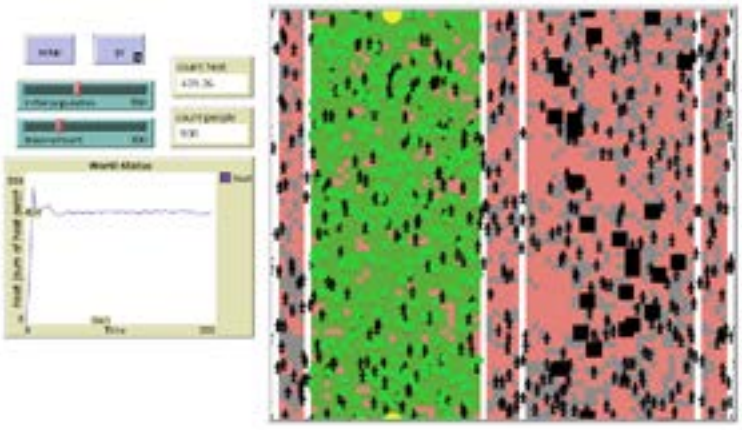

Figure 12: Final Model

Number of Trees = 300

The maximum number of heated patches evened out at approximately 430.

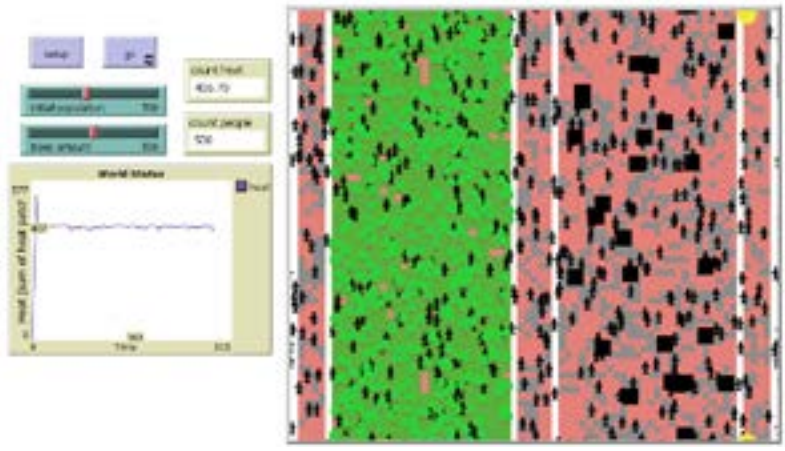

Figure 13: Final Model

Number of Trees = 500

The maximum number of heated patches evened out at approximately 400.

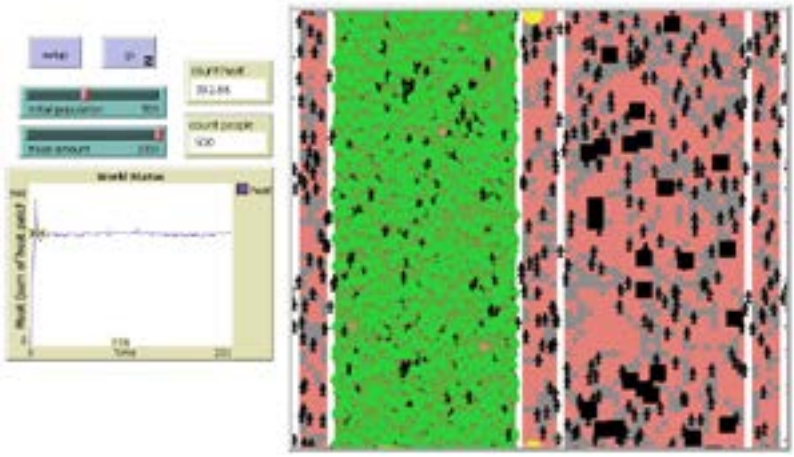

Figure 14: Final Model

Number of Trees = 1000

The maximum number of heated patches evened out at approximately 400.

Note: The amount of trees after 500 did not cause much of a change in the number of heated patches.

CONCLUSION

Before creating my model, I hypothesized that the Rural area would be cooler than the Urban area, and I was correct. This is also something that happens in real life, where the Urban areas, with buildings and warmer surfaces, are definitely warmer than the cool grass of the Rural areas. When you tamper with the variables, they will change according to what it is connected to. For example, when you change the amount of trees, the amount of heat present drops or rises. And, when you change the initial amount of humans present, it changes the amount of buildings that will appear.

In the future, this work could be done with real data, from real Urban Heat Islands around New Mexico, or anywhere else. This could be used to see if the data I'd gathered from my model matches real-world data, instead of just a simulation. I could use ChatGPT to help me gather the data, around where I live.

In Urban areas, some ways to cool urban heat islands is to prevent the heat from being absorbed by using paints that don't absorb but rather reflect heat, planting large areas with vegetation, and using solar panels to convert light into energy. Instead of using cars, we could provide more public transportation, which would reduce the amount of traffic and heat in specific areas.[6]

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I would like to thank:

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3. Mrs. Alex Jonko: Thanks for giving me feedback for my final report! Great working with you through Mrs. Unal, (she's the best).
4. My Mom: Mom, you helped a lot! You helped me edit my final report, and you helped me when I was sad, because I couldn't fix something in my code. (That was really tough, by the way.)
5. Zeus: Hi kitty! You kept stepping all over my keyboard. It messed me up a little bit, but it sure did entertain me!
6. My dad: Helping me make a fancy PDF that is 508 compliant, whatever that means.
7. ChatGPT: thanks for writing my References page, and for helping me fix my code!

THANK YOU JUDGES!

Thanks for listening to all my presentations, and for whoever reads this, thank you too.

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