# Simulation of Global Warming in the Continental United States Using Agent-Based Modeling

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**Abstract**

It is a commonly accepted fact that as the population increases, the carbon footprint of the United States increases, further accelerating the effects of global warming. However, not many studies have been constructed correlating the effects that global warming will have on population. The purpose of this experiment is to combine that effects that population will have on greenhouse gas output and then the effect that the resulting temperature and sealevel changes will have on the population. The goal of the experiment is to show the detrimental effects that global warming will have in the United States if nothing is done to limit the greenhouse gas output. The results of this experiment would be useful to environmental scientists all over the world, not just in the United States, since similar population changes should be happening globally.

**Keywords:** global warming, greenhouse gases, agent-based modeling, netLogo, population changes

## 1 Introduction

The main portion of the experiment will be shown on an interactive screen with a map of the United States. The map is set up using two different

variables. Each patch on the map has an elevation number which sets up a visual representation of the United States (figure 1) and also tells the program the elevation of a certain area of the map. The second variable gives each patch in the program a certain temperature, which is the current average temperature for the entire year of the area. The red dots on the map represent the largest cities of the States, and linear interpolation is used to fill in the temperature data between these states. There is a fairly large margin of error in filling out the temperature data between the cities, since temperature does not increase and decrease linearly. However, it is extremely difficult to have an accurate representation of the entire Unites States based on temperature.

There are two changing agents in this experiment - the patches and the population. As the population increases, there is a general algorithm to calculate the greenhouse gas output. As the greenhouse gas composition in the atmosphere increases, the average surface temperature of the Earth (here, concentrated to the United States) also increases. The sea levels will rise, and the visual representation of the map will change according to the new sea level. Also,the temperature of each patch will slowly start to increase. The second variable in this experiment are the people. One agent will represent a population of 1,000. If time allows, I can set up the population according to demographic data, giving each of these agents their own money variable. If the temperature in their area becomes unbearable, they will move somewhere with a more favorable temperature. Also, as the sea levels increase, more and more people will move from that area. If the agent runs out of money, it will stay in a certain area and has an increased chance of dieing of heat stroke or drowning. Also, I will try to add a variable to represent the increasing chance of infectious diseases spreading through a population in a warmer area.

# 2 Background

I learned the majority of information about global warming, climate change, and the greenhouse gas effect from geosystems class, where we used Stella to create a System Dynamics model of climate change and various representations of population change. Most of the common formulas come from these Stella models and from an online University of Michigan class based on global change. There are various versions of global warming models available on the internet, but none of them concentrate on the effects of people on

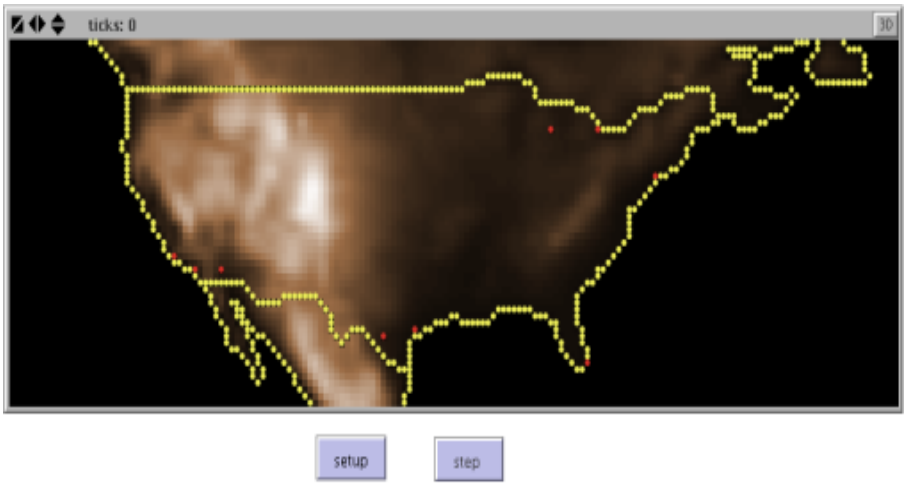


Figure 1: Image of the screen with the altitude map

global warming and climate change on the population. The basic elevation map was taken from a previous project by Josh Unterman on the Continental Divide. This project was provided by NetLogo in its Models Library, a set of previously completed experiments. The elevation map already had converted the different elevations of Northern America to color values that provided me with a useful map onto which I built a temperature map.

Agent-based modeling is a popular way to represent human behaviors through simple heuristics and basic societal rules. David Batten, in his paper "Are some human ecosystems self-defeating?" discusses the potential downfalls and problems of such modeling and proposes that the agents should be able to communicate with one another in addition to their environment. Each agent needs to have a set of values, which in this case is the temperature and elevation of the patch that they are currently inhibiting and of the ones around them. Romulus-Catalin Damaceanu performed his research on studying wealth distribution using NetLogo, which used similar parameters and private variables as will be used in my simulation of the global warming and population effects.

# 3 Preliminary Testing and Analysis

Currently, about half of the temperatures of the United States have been mapped using linear interpolation, which is using two end points (temperatures of major cities) to figure out and fill out the linear relationship between them, and also averages, which is using a top value and a middle value, finding the average mean,and filling it in on the map. Those two methods were written using Python. Once the map is finished, however, I wil be able to add code to actually change the image as greenhouse gas levels increase and decrease.

# 4 Expected Results and Discussion

The main purpose of this experiment is to show a possible bleak future scenario of what will happen when nothing is done about global warming. The expected results are unknown, but will most likely show that over time, the population will first increase due to favorable conditions. However, as the population increases, more greenhouse gases are produced and thus the climate changes and heats up. As infectious diseases start to spread and sea-levels start to rise, the population will decrease, now decreasing the amount of greenhouse gases in the atmosphere. The climate will now cool down, and the death rate will once again decrease, enabling the birth of more agents. There should be a slow oscillating relationship between the population and greenhouse gases in the atmosphere. However, the majority of the population will move north, away from the coastal areas to escape high temperatures and flooded cities.