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

Marika Lohmus
Thomas Jefferson High School for Science and Technology
Alexandria, Virginia

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Abstract

It is a commonly accepted fact that as the population increases, the carbon footprint of the combined population 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 current 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 green house turtles 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 and detailed 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 average global temperature increase and decrease is determined by a System Dynamics Model (figure 2) whose atmospheric absorption coefficient is the only variable being changed by the program itself. 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 10,000. Each person agent is given a salary according to the U.S. Census demographics information (the average annual salary and the percentage of people under the poverty line). 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. Each patch also has a death rate which increases with increasing temperatures and sea levels.

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

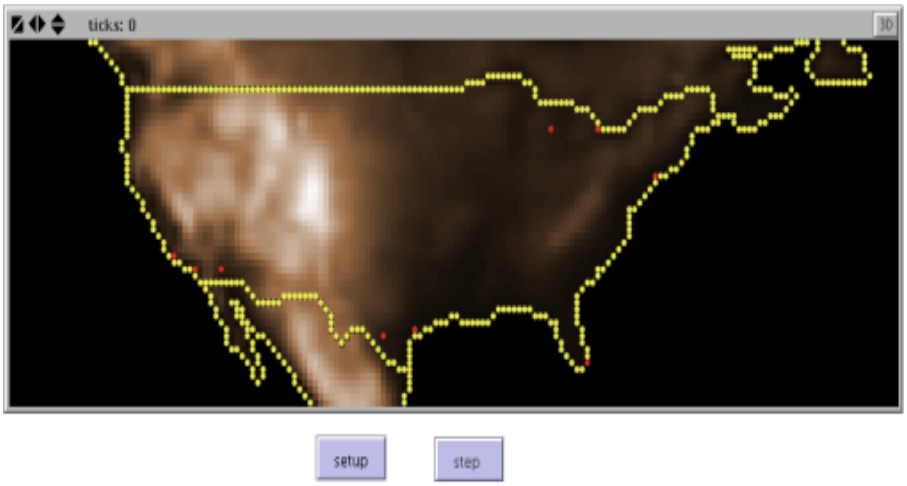

Figure 1: Image of the screen with the altitude map

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 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.

The Intergovernmental panel on Climate Change has been set up to in-

clude scientists from all over the world that work to combine data on the possible outcomes of climate change. They create various scenarios which account for possible population increase or decrease and also technological advancements. All of them propose different greenhouse gas compositions in the atmosphere and how they are increasing or decreasing. ("Global Climate Projections", Meehl, G.A., Stocker, T.F.)

3 Preliminary Testing and Analysis

The user has the option of two maps: the elevation map and the temperature map. The elevation map currently shows increasing sea levels based on a random variable which is added to the previous sea levels. The darker the map, the higher the sea level. Testing has showed that New Orleans, the East coast of Texas and the entire Florida region will be under water first. Central - Western United States is the most resistant to sea level changes.

The temperature map is based on a numberical data set of all the mean annual temperatures of major cities. The cities are indicated as green houses (Figure 2) and the people as yellow or red human figures. The number of agents assigned to each city has been determined by U.S. Census 2007 predictions. The people move around according to a random number generator - otherwise, unless the conditions are unfavorable, they would never move. I will change the code to have the agents move according to the salary as my next step.

Current testing shows an oscillating effect between the temperature and the population. As the population increases, the atmospheric absorption coefficient increases and thus the temperature increases. However, as the temperature increases, the death rate of each patch increases and thus the population decreases. The whole system is based on a negative feedback loop, meaning that this program supports the Gaia Hypothesis.

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

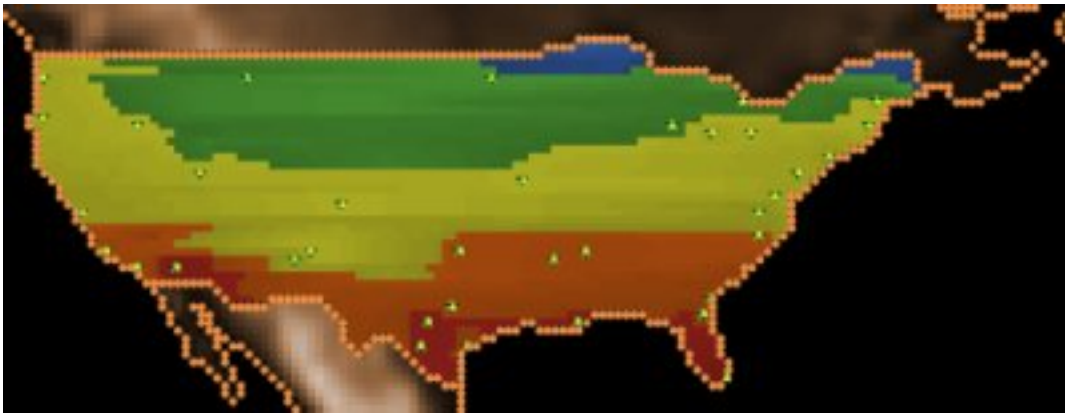

Figure 2: Image of the screen with the temperature map

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. The poorer population will not have as many options to move away from unfavorable conditions, and thus the people below the poverty level will have a harder time coping with climate change. More affluent agents will be able to move to favorable areas.

The Gaia Hypothesis states that the Earth acts as a controlling body. If there is a forcing in one area, then the Earth will change another to counterbalance it. The Earth will most likely try to get rid of the cause of the climate change - the humans. However, there are various problems that will conflict with the validity of this program. First of all, as technology and thus medicine improve, the rates of the increasing and decreasing death rates will change. It is possible that the increasing death rates due to the increasing temperature will be counterbalanced by the improving health care. Also, this program is assuming that the entire population of the United States is that of the major cities combined and that everyone starts out living in a large city.

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