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

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Abstract

As the population increases, the carbon footprint of the United States increases, further accelerating the effects of global warming. This project studies the effects that global warming will have on population. The purpose of this experiment is to combine the effects that population will have on greenhouse gas output and then the effect that the resulting temperature and sea-level changes will have on the population. The objective 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.

Background

Agent-based modeling is a method used to represent human behaviors through simple heuristics and basic societal rules. The Intergovernmental Panel on Climate Change (IPCC) has created complex models simulating possible cliamte change, but none of them seek the effects on population size and of population on climate. In this type of simulation, each agent needs to have a set of values, which in this case is the temperature and elevation of the agent-patch that they are currently inhabiting, their salaries and money and those of the agents and patches around them. Most of the common formulas used in this project come from an online University of Michigan class dealing with System Dynamics ("Global Change 1", 2009). The basic elevation map was taken from a previous project by Uri Wilenski on the Continental Divide (Wilensky, 2007), and a temperature map was based off of it using average annual temperatures and linear interpolation.

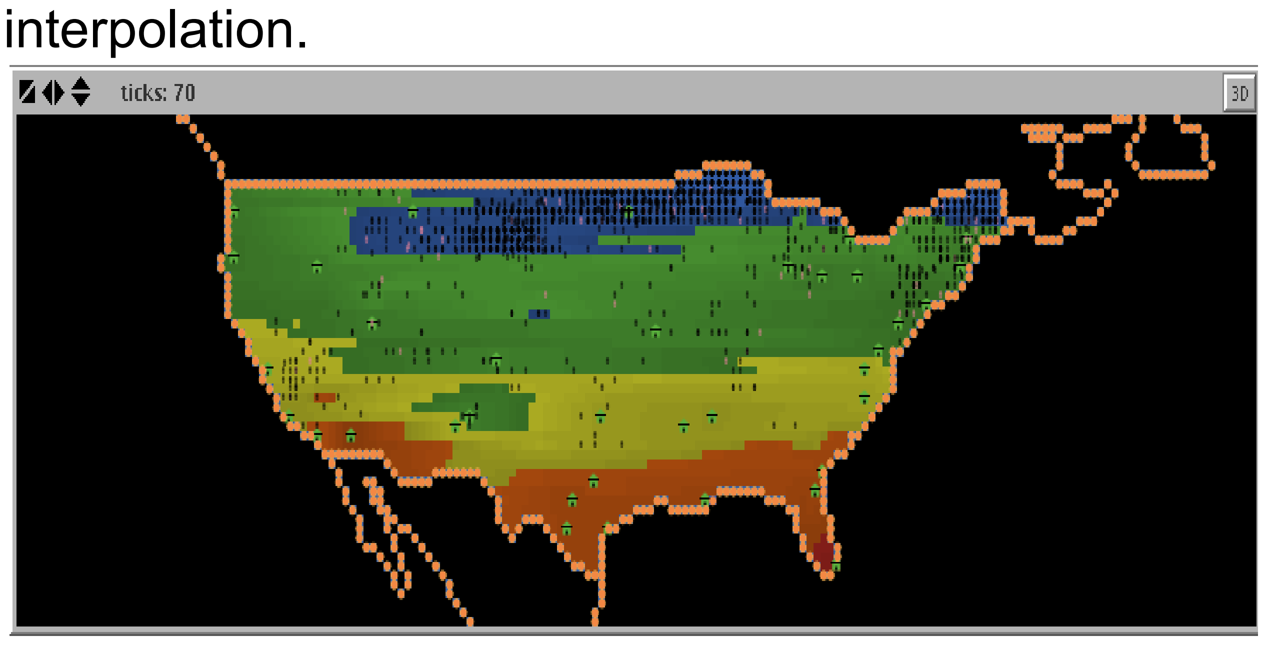

Fig. 1: Interface map after 70 ticks with the temperature map turned on. Most agents have moved to cooler areas.

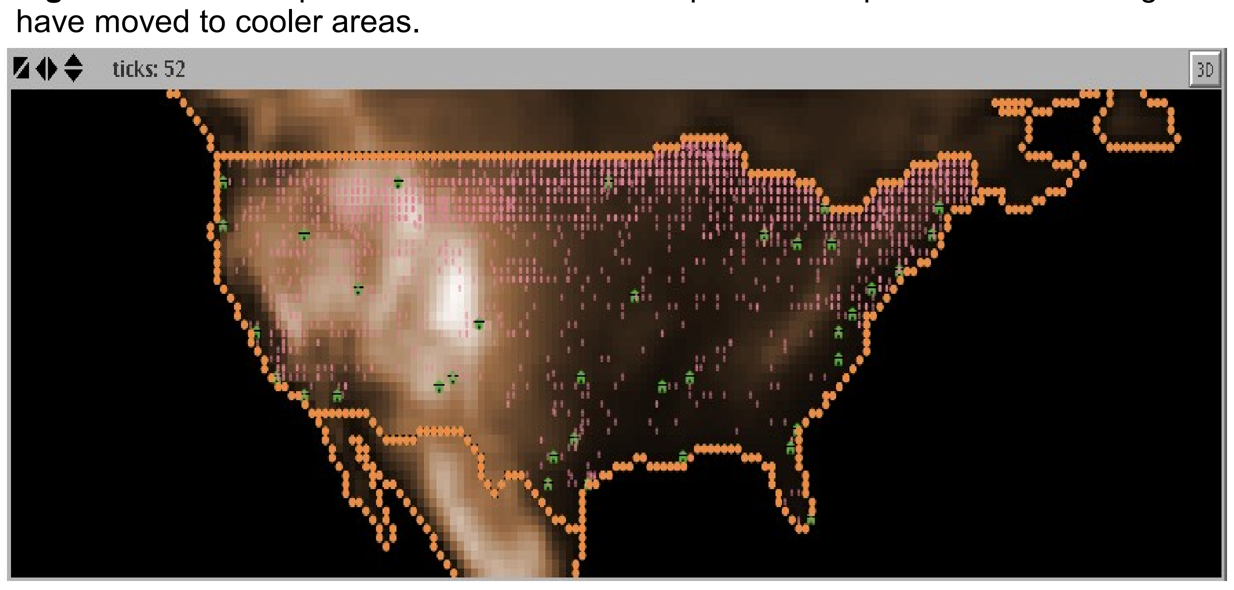

Fig. 2: Interface map after 52 ticks with the elevation map turned on. Agents are pink to ease viewing.

Variables

Patches (Land): Elevation, temperature, birth rate, and death rate.
Agents (Population): Salary and money
Cities: Name, average salary, and a percent of people living under the poverty line.
Constant Variables: Birth Rate, greenhouse gas output per person
Changing Variables: Temperature, death rate, number of agents, sea-level

Figure 3 shows the oscillating tendency of the temperature and population. The red line is the temperature in Kelvin and the red is the number of agents. Clearly an increase in agents leads to an eventual increase in temperature.

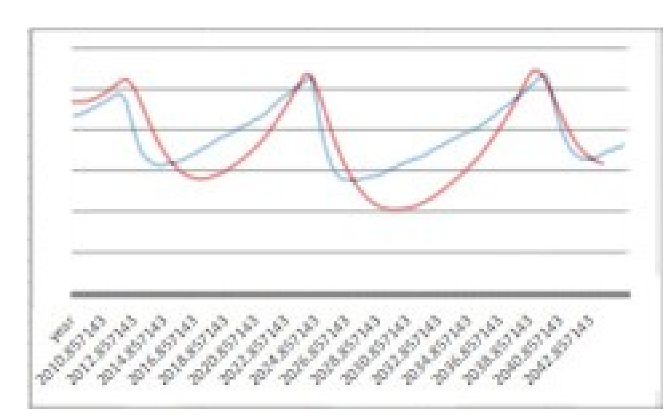

Fig. 3: Overlapping image of temperature and number of turtles vs. time (years)

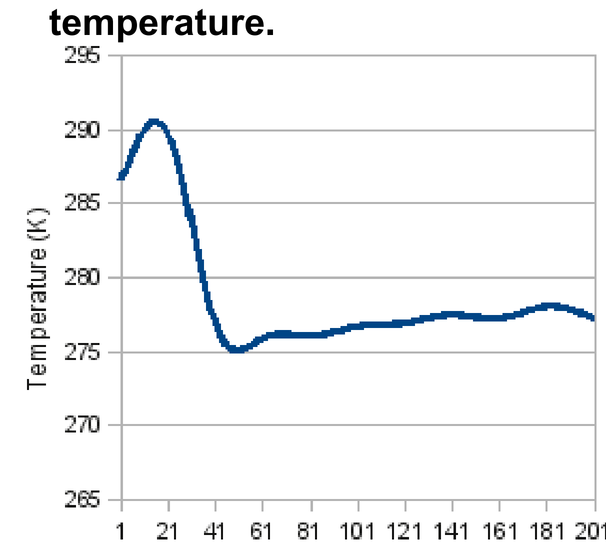

Fig. 4: Change in d(death rate) and average temperature

Figure 4 shows how a change in d(death rate) would change the average temperature. A clear change is between d(dr) of 21 and 41, indicating that if death rates change dramatically, the planet will face higher tempetratures.

Figure 5 graphs the direct relationship between average temperature and birth rate. The higher the birth rate, the larger the population, driving up the average temperature. A birth rate higher than 0.6 caused the program to crash.

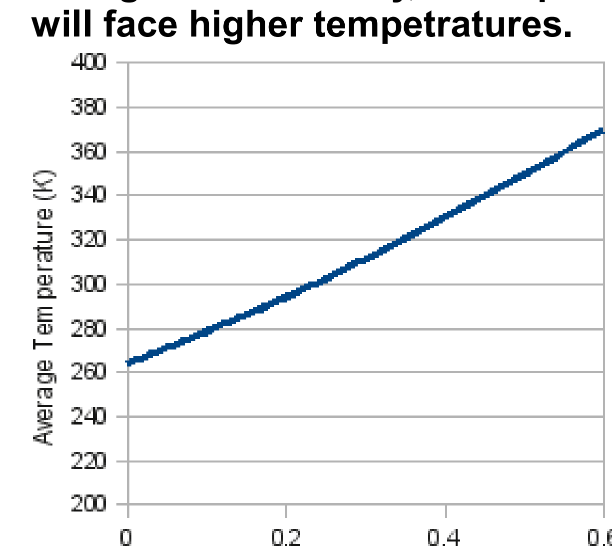

Fig. 5: Change in birth rate and average temperature

Results

The main purpose of this experiment was accomplished by showing the possible changes in temperature (Figure 1) and elevation (Figure 2). The clearest result was the slow migration of the agents north, away from the rising temperatures. The temperature and number of agents oscillates over time (Figure 3) and slowly start to reach an equilibrium.

As the population increases, the total greenhouse gas output increases, further increasing the temperatures. However, with increasing temperatures the death rate increases, killing off agents. The number of agents reaches a peak (holding capacity) after which the population steeply decreases.

The d(death rate) indicates the ratio of the change in temperature and death rate. If technology improves and people are able to live longer, then d(death rate) would be higher.

The birth rate could increase if people feel financially comfortable with having more children. This project has supported the Gaia Hypothesis, which states that the Earth is a self-regulating system. Humans have disturbed this system by increasing natural and anthropogenic greenhouse gases, and thus the planet will act to off-set this change. The fact that in most scenarios, an equilibrium is reached supports the hypothesis.

References

1.Wilensky, U. (2007). NetLogo Continental Divide model. http://ccl.northwestern.edu/netlogo/models/ContinentalDivide. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

2. "Global Change 1" (2009). Retrieved from http://www.globalchange.umich.edu/globalchange1/current/labs/