Planet-Civ Update

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Current Model

1 Model Variables/Constants and Units

- T = Average Global Temperature (Kelvin)
  - T_{eq} = Equilibrium (initial) Temperature, calculated with the energy balance model ($Kelvin$)
- P = Global Carbon Dioxide Partial Pressures (ppm)
  - P_0 = Initial Carbon Dioxide Partial Pressures (ppm)
  - ϵ = Annual Per-Capita[1] Carbon Footprint ($\frac{ppm}{10^6 ppl * yr}$)
- N = Global Population ($x10^6$ ppl)
  - N_0 = Initial Global Population ($x10^6$ ppl)
  - $\alpha_{birth,0}/\alpha_{death,0}$ = Initial Per-Capita[1] Birth/Death Rates ($1/yr$)
  - $\alpha_{birth}/\alpha_{death}$ = Current Per-Capita[1] Birth/Death Rates ($1/yr$)
  - F_r = Fragility of Civilization ($\frac{1}{yr * Kelvin^2}$)
  - E_n = Technological Abilities of Civilization

2 Model Outline

First, let the energy balance model reach an equilibrium between incoming and outgoing radiation, this gives us the equilibrium temperature. The model continues by setting the initial temperature to this equilibrium value, as well as setting the birth and death rates to their initial values. The main loop now begins, where each loop represents one year.[2]

i) Call[3]: $\frac{dT}{dt} = EBM(P)$

ii) $\alpha_{birth} = \alpha_{birth,0} + E_n(P - P_0)$

iii) $\alpha_{death} = \alpha_{death,0} + F_r(T - T_{eq})^2$

iv) Call: $\frac{dN}{dt} = min(\alpha_{birth}N,\ \alpha_{death,0}N_{max}) - \alpha_{death}N$

v) Call: $\frac{dP}{dt} = \epsilon N$

a) If time has reached the end, program is finished

b) If time hasn't reached the end, go back to the first step.

[1] Per-Capita Meaning Per-Million People

[2] Note: made population have a minimum of 1 million people, to avoid values of 10^{-100}

[3] $EBM(P) = \frac{\psi(1 - A) - I + \nabla \cdot (\kappa \nabla T)}{C_v}$

3 Example: Modeling Earth ($t_0 = 1820,\ P_0 = 284,\ N_0 = 1,129$)

- $N_{max} = 13,000$
- $\alpha_{birth,0} = 0.019$
- $\alpha_{death,0} = 0.015$
- $F_r = .005$
- $E_n = 300$

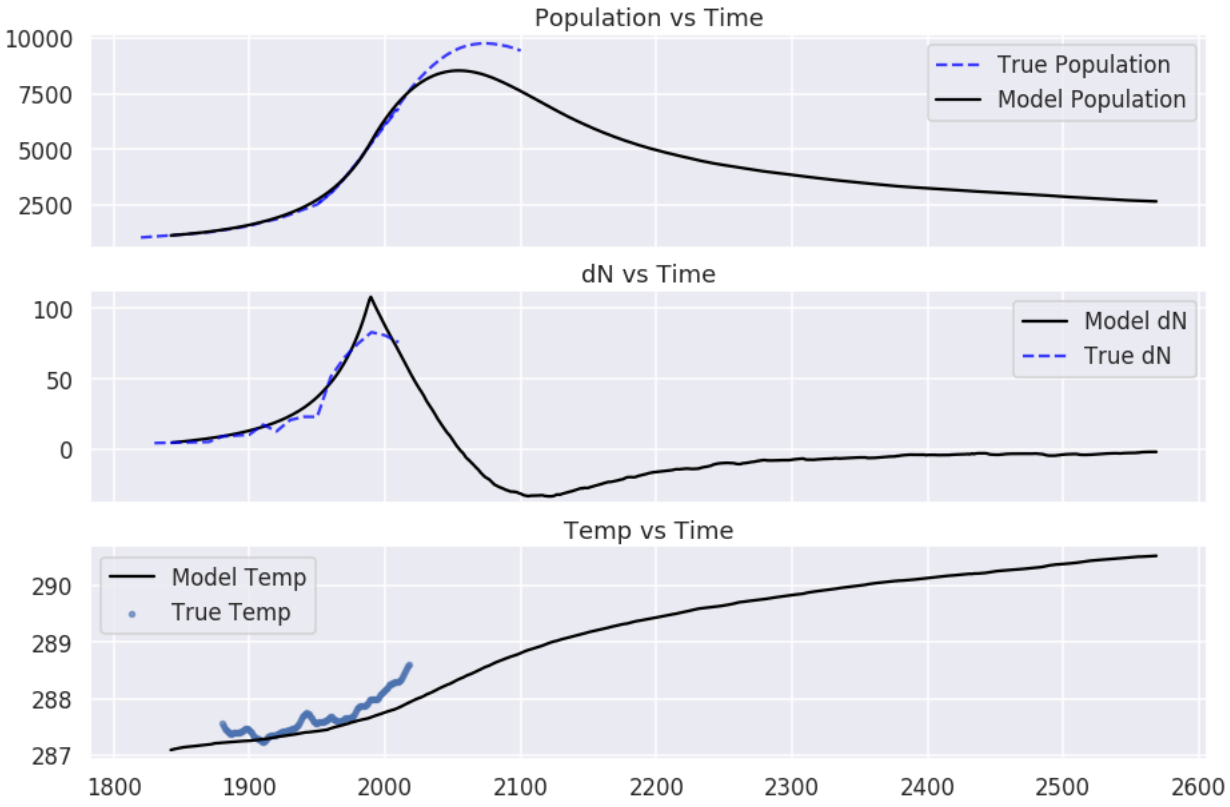

Figure 1: Model Output (solid black line) vs Real Global Data (dotted blue line) for 750 Years

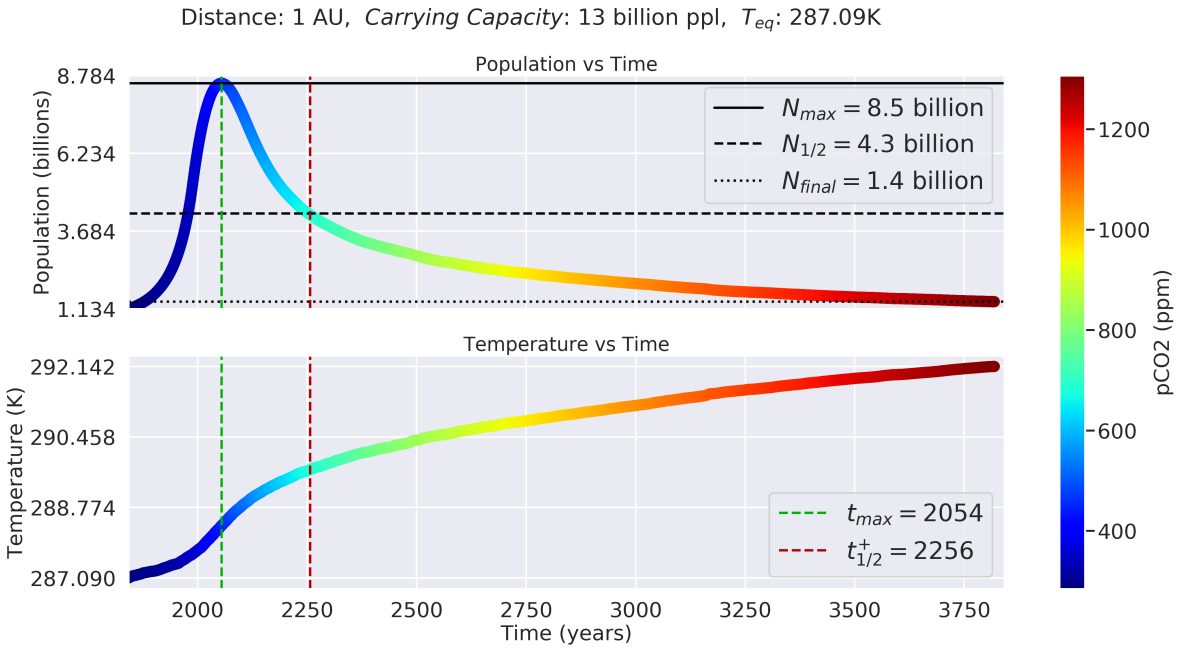

Figure 2: Model Output for 2000 Years

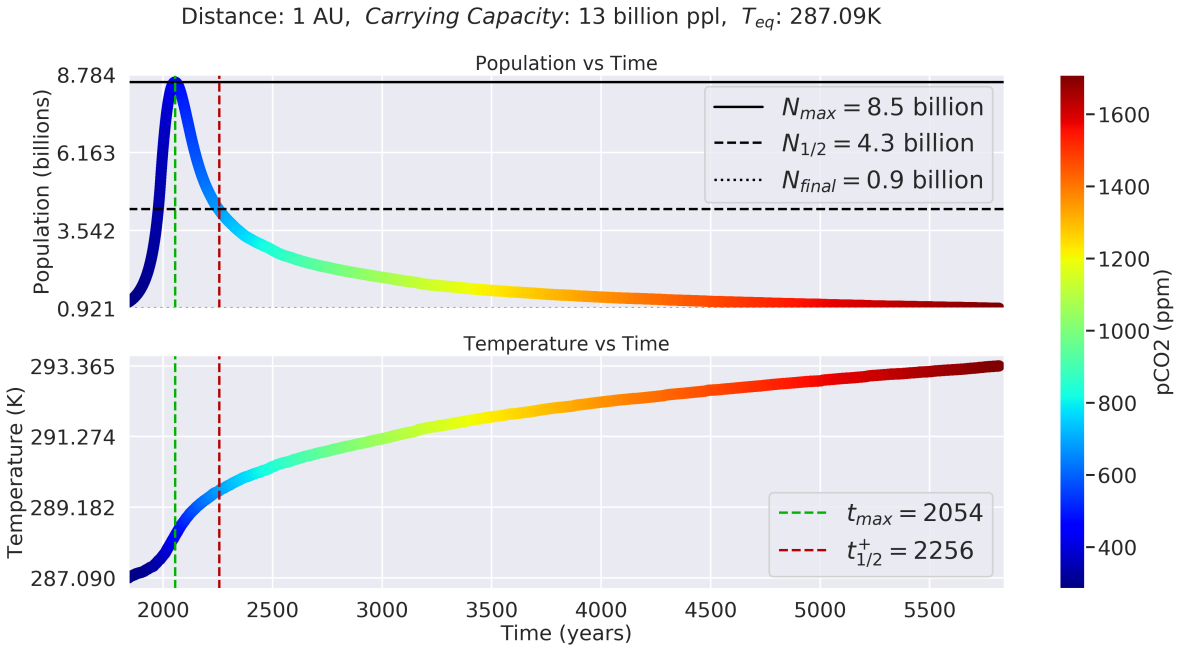

Figure 3: Model Output for 4000 Years

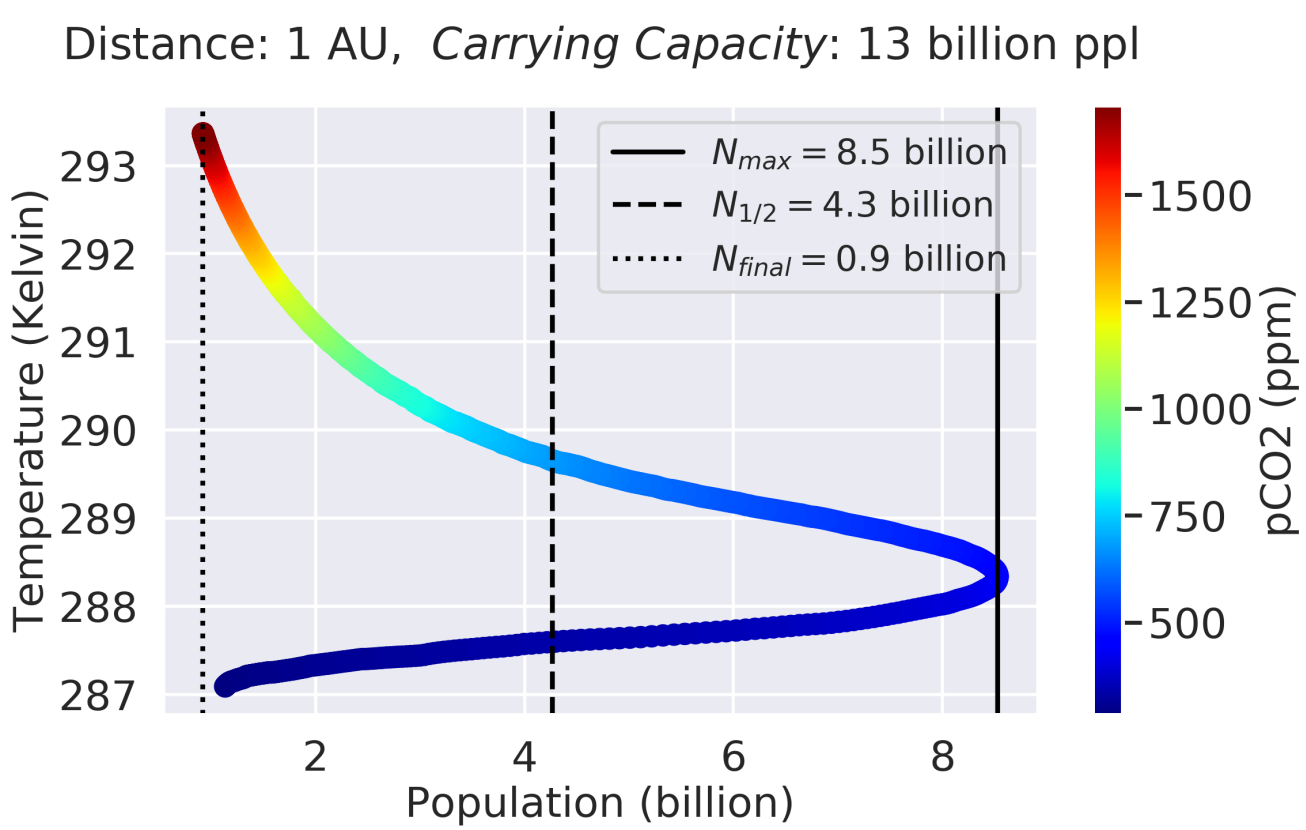

Figure 4: Phase Diagram of Model Output (4000 years)