The Anthropocene Generalized: Coupled Evolution of Planets And Civilizations

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Goal

We seek to find a series of differential equations that can generalize our populations coupled evolution with our planet. We look specifically at our current geological age, called the anthropocene, in which we are beginning to see the climate respond negatively to our exponential evolution of population and technology.

Method

- To model rise in **population (N)**, we use **exponential growth**
  - **coupled** by introducing a temperature dependence to the growth rate, r, as shown in Fig 3.

- To model rise in **temperature (T)** , we use an **energy balance model**, which takes in a variety of planetary inputs, including pCO2 levels, to approximate an average planetary temperature
  - **coupled** by introducing an annual, per-capita CO2 contribution, ε, whose purpose it is to quantify a civilizations carbon footprint

Progress

- **Calibrated our model** with population and pCO2 values from the past two centuries, as shown in Fig 1. & Fig 2.
  - Adjusted the relative growth rate, r, by fitting our exponential model to global population data
  - Calculated our civilizations carbon footprint by adjusting ε in order to model current pCO2 values
  - Added an annual reduction of pCO2 by weathering with the variable ω, whose purpose it is to quantify our environments recovery timescale

Equations

$$C_v \frac{dT}{dt} = \psi(1-A) - I + \nabla \cdot (\kappa \nabla T)$$

$$\frac{dP}{dt} = \epsilon N - \omega \qquad \frac{dN}{dt} = rN$$

Visualizations of Method

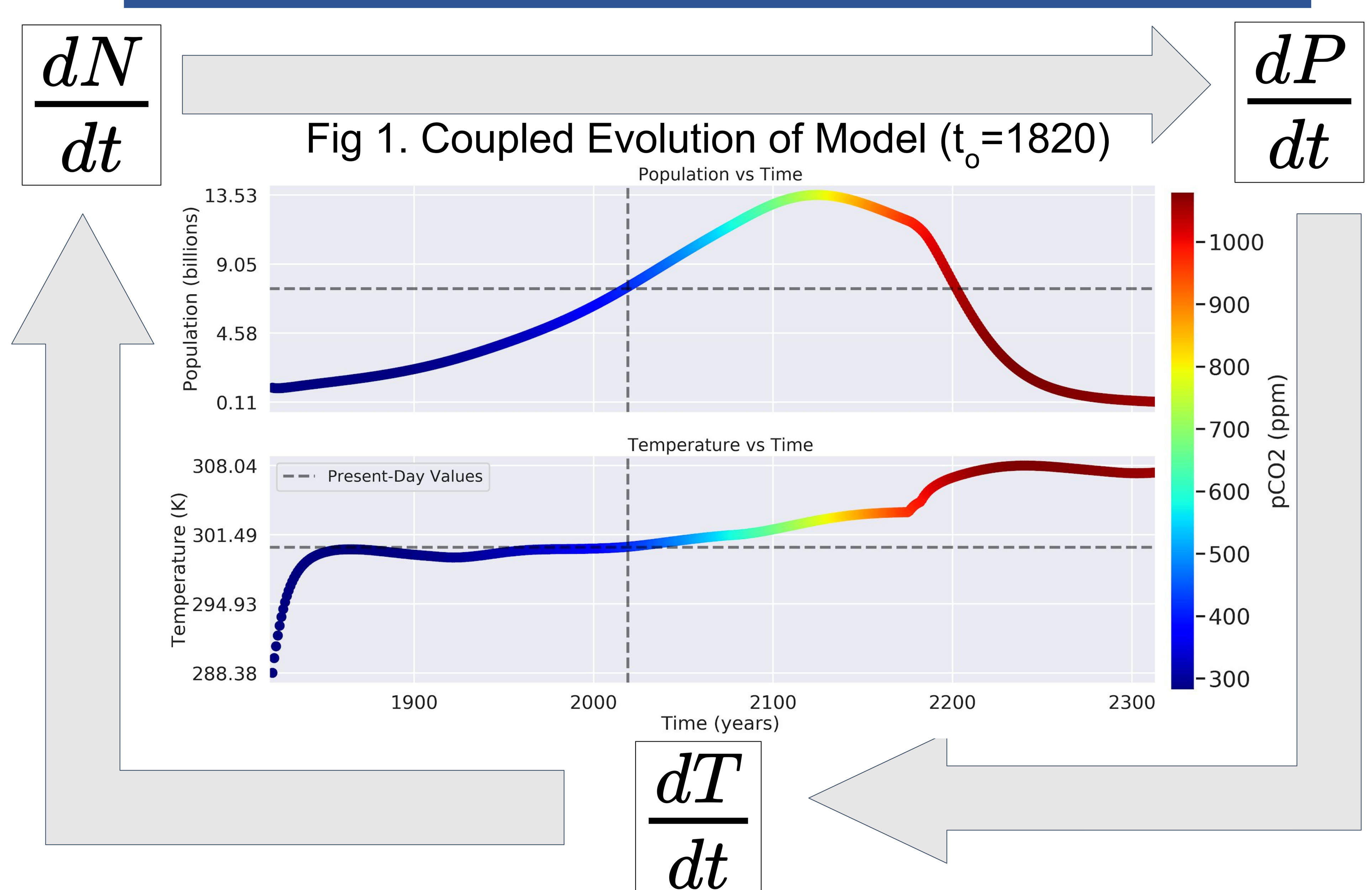

Fig 1. Coupled Evolution of Model (t_o=1820)

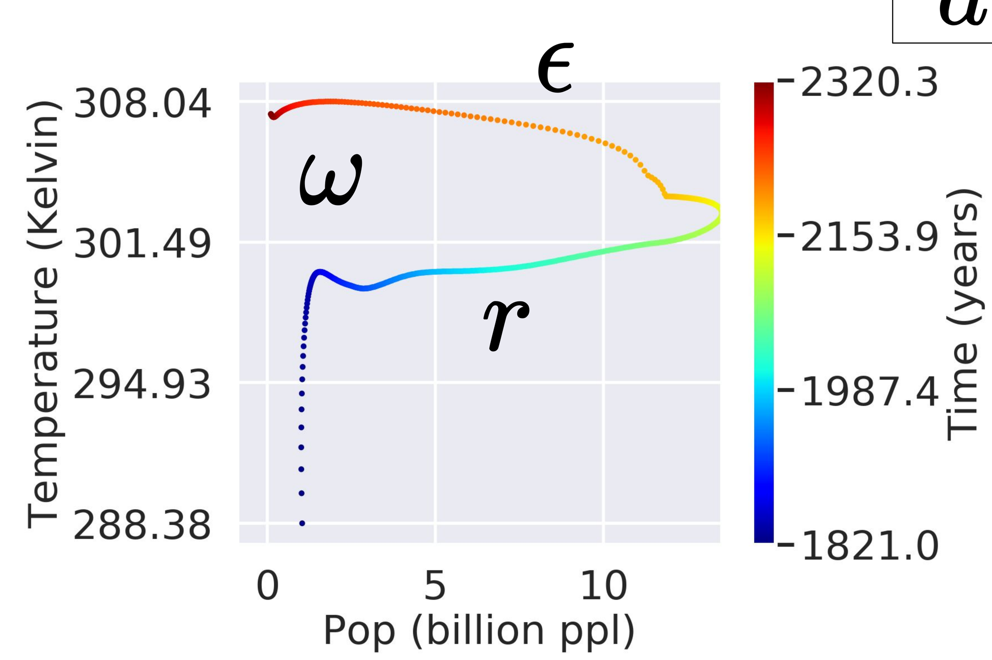

Fig 2. Phase Diagram of Temp vs Pop

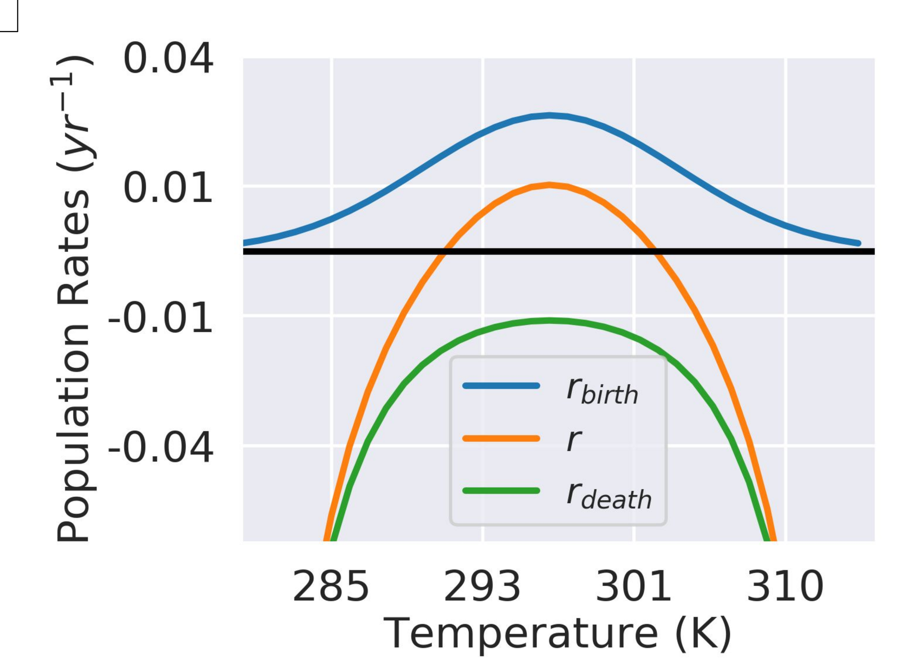

Fig 3. Relative Growth Rate (r) vs Temp

T	Temperature
N	Population
P	Partial CO2 Pressure (pCO2)
r	Relative Growth Rate
ϵ	Annual Carbon Footprint = $3.459 * 10^{-4} \frac{ppm}{ppl}$
ω	Recovery Rate = $1/2 \frac{bar}{yr}$
κ	Diffusive Parameter = $0.38 \frac{W}{m^2 K}$
ψ	Solar Flux = $1360 \frac{W}{m^2}$
C_v	Heat Capacity = $2.1 * 10^8 \frac{J}{m^2 K}$
I	Outgoing Infrared Radiation (function of T,P)
A	Albedo (function of T,P)

Next Steps

- Increase Accuracy:
  - find true weathering timescale (ω)
  - find true temperature dependence of r
- Determine the climate sensitivity of various energy resources
  - Is global warming inevitable?
- Put a dTdt dependence onto the deathrate
  - To quantify acclimation
- Find the most probable trajectories using earth-like inputs
- Introduce parameter E as a proxy for technology, eventually increase with time
  - will raise peak of r, as well as increase per-capita CO2 contributions (ε)
- Solving these equations using current Kepler exoplanet data across a wide parameter space could allow us to estimate the final factor in the drake equation; average lifetime of technological civilizations

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