We are DOOMED!!

Climate Change and Population Dynamics

M. M. ARAL

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1000 AD, 300K

Reports of Excess Mortality Due to Heat Wave in Europe

Location	Date	Excess mortality (% increase)
England and Wales	Aug 4–13, 2003	2,091 deaths (17%)
Italy	Jun 1–Aug 15, 2003	3,134 (15%) in all Italian capitals
France	Aug 1–20, 2003	14,802 (60%)
Portugal	Aug, 2003	1,854 (40%)
Spain	Jul–Aug, 2003	4,151 deaths (11%)
Switzerland	Jun–Sept, 2003	975 deaths (6.9%)

~26 thousand just in Europe

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Other Events

Event	Qualitative Outcome
$2^{o}C$ Increase	Extermination of species
Cold nights	75% death of monarch butterfly population
Long summer days	80% water shortage for small birds
Caracas Venezuela	In December 1999 floods killed approximately 30,000 people
Central America	In 1998, Hurricane Mitch created massive mudslides and claiming 11,000 lives.
Sichuan Province, China	In 2006, experienced its worst drought in modern times, with nearly 8 million people and over 7 million cattle facing water shortages (no reports of mortality by the government)

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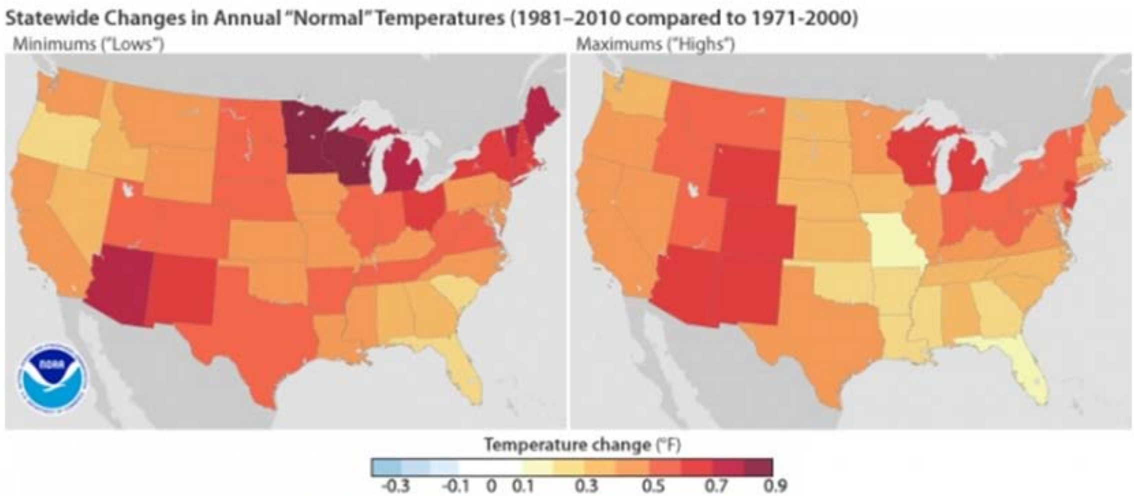
$$\text{MORT} = 0.32\text{tmax} - 0.03\text{TOS} - 7.76,$$

Greene et al. 2011

TABLE 1. Average number of summertime EHE days and EHE attributable-deaths/rates based on data from 1975 to 1995.

City	Population in 2000 (100 000s)	Avg No. of summertime EHE days (1975–95)	Forecast No. avg summertime EHE-attributable deaths from algorithm (1975–95 data)	Avg summertime EHE-attributable mortality rate per 100 000 residents (using algorithm 1975–95)
Hartford, CT	1.22	6	32	26.7
Newark, NJ	2.74	8	66	24.0
Providence, RI	1.74	7	40	22.9
Boston, MA	5.89	11	104	17.7
Greensboro, NC	2.24	8	36	16.3
Louisville, KY	2.56	8	39	15.3
Kansas City, MO	4.42	7	48	10.9
Birmingham, AL	2.43	5	24	10.0
Baltimore, MD	6.51	8	64	9.9
Cleveland, OH	4.78	5	45	9.4
Atlanta, GA	4.16	5	37	8.8

Min and Max are HIGHER



The new normals for each of the lower 48 states shows that the period of 1981-2010 was warmer than 1971-2000. Credit: NOAA.

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Climate Change Analysis Predicts Increased Fatalities from Heat Waves

May 3, 2011

Global climate change is anticipated to bring more extreme weather phenomena such as heat waves that could impact human health in the coming decades. An analysis led by researchers at the Johns Hopkins Bloomberg School of Public Health calculated that the city of Chicago could experience between **166** and **2,217** excess deaths per year attributable to heat waves using three different climate change scenarios for the final decades of the 21st century. The study was published May 1 edition of the journal Environmental Health Perspectives.

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Can we introduce quantitative analysis
to all these
somewhat qualitative information?

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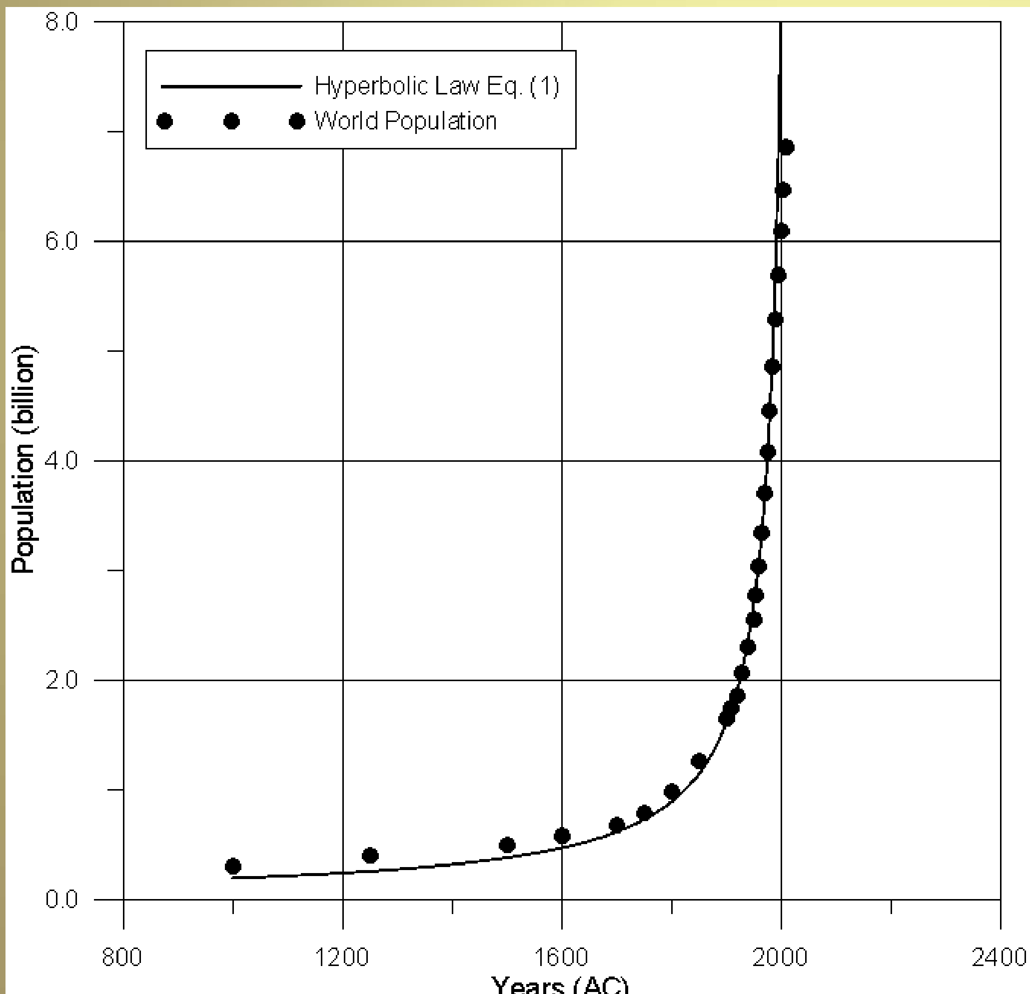
World Population (World Bank Data - 2013)



(von Foerster et al. 1960)

$$P = \frac{C}{t_o - t}$$

$$C = 200 \times 10^9 \ people - yr$$

$$t_o = 2025 \ yr$$

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World Population

- If the population data fits to: $$P = \frac{C}{t_o - t}$$

- Than: $$\frac{dP}{dt} = \frac{P^2}{C} \longleftarrow \frac{u}{v} = \frac{vu' - uv'}{v^2}$$

- Problem:
  - the predicted population increases exponentially which is not sustainable;
  - at the singularity point (t_o) the world population goes to infinity which would be difficult to interpret

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World Population

- Kapitza (1996): $\frac{dP}{dt} = \frac{P^2}{C} \longleftarrow P = \frac{C}{t_o - t}$

$$\downarrow$$

$$\frac{dP}{dt} = \frac{C}{(t_1 - t)^2 + \tau^2}$$

- Where:

$$\tau = human\ life\ time\ \ factor \approx 45yrs$$

$$t_1 = 1995$$

$$C = 1.63 \times 10^{11}\ \ people - yr$$

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World Population

- Solution - Kapitza (1996):

$$P = K^2 \, arc\cot\left(\frac{t_1 - t}{\tau}\right)$$

$$K^2 = \frac{C}{\tau}$$

$\tau = human\ life\ time\ \ factor \approx 45 yrs$

$t_1 = 1995$

$C = 1.63 \times 10^{11}\ \ people - yr$

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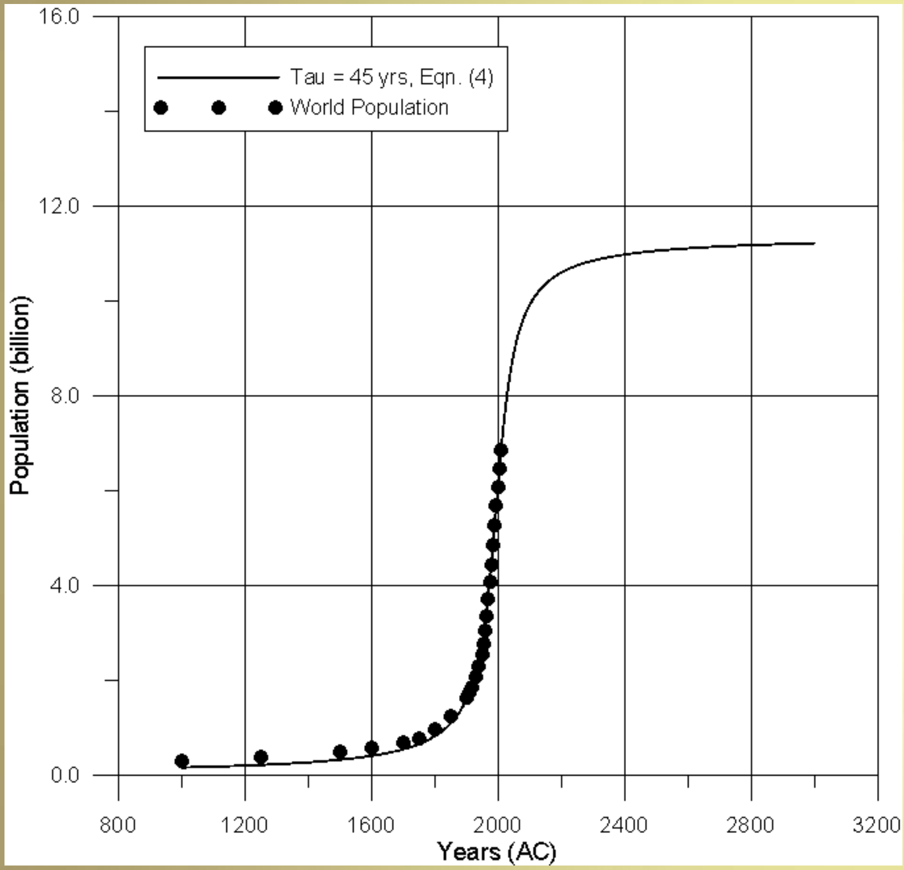
World Population

$$P_{max} = \pi K^2 = 11.36\, billion$$

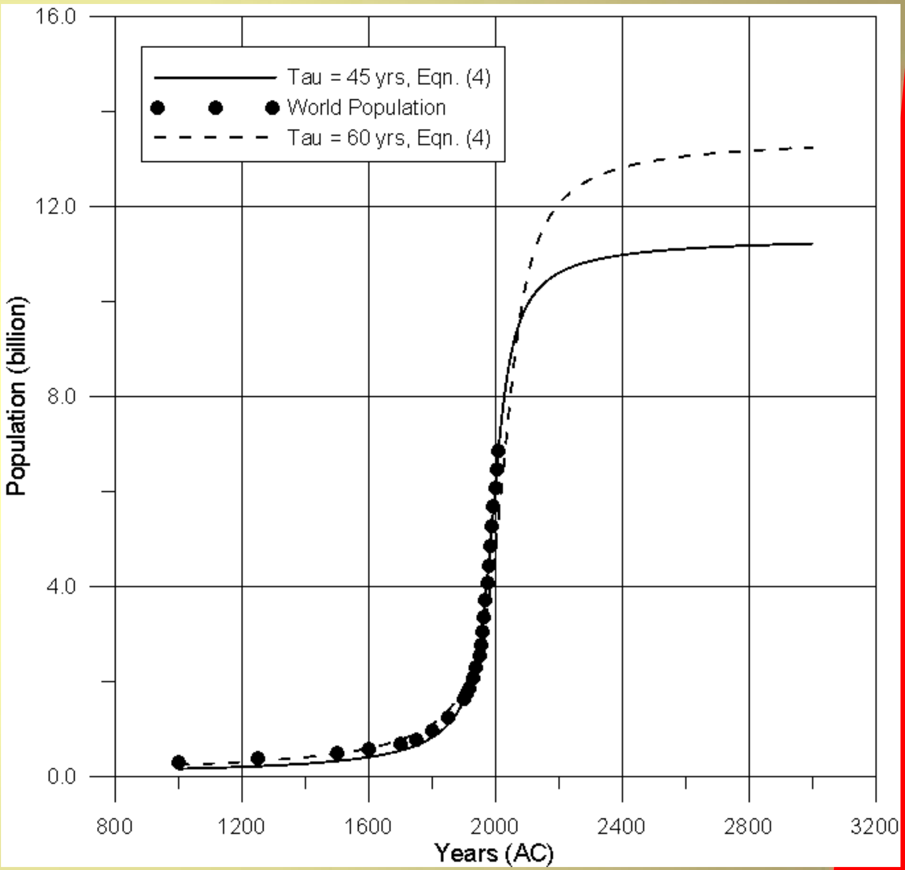


$\tau = human\ life\ time\ \ factor \approx 45 yrs$

$t_1 = 1995$

$C = 1.63 \times 10^{11}\ \ people - yr$

$$P_{max} = \pi K^2 = 13.51\, billion$$



$\tau = human\ life\ time\ \ factor \approx 60 yrs$

$t_1 = 2030$

$C = 2.53 \times 10^{11}\ \ people - yr$

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Missing Information?

$$P_{\max} = \pi K^2 = 11.36\, billion \qquad P_{\max} = \pi K^2 = 13.51\, billion$$

$$\frac{dP}{dt} = \frac{C}{(t_1 - t)^2 + \tau^2}$$

Environmental Systems or Human Growth capacity?

or

Sustainable Carrying Capacity?

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World Population

- Dolgonosov (2009)

Accumulation of valuable information (knowledge) needed for survival.

- technological growth –
- growth of the upper limit of Earth's carrying capacity –
- demographic growth –
- More people, more potential inventors –

$$\frac{dP}{dt} = rP^2\left(1 - \frac{P}{K(q)}\right)$$

$$K(q) = \frac{P_c}{1 - \exp\left(-\alpha \frac{q}{q_c}\right)}$$

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World Population

- Akaev and Sadovnichii (2010)

$$\frac{dP}{dt} = rP^2(t-\tau_1)\left[1-\frac{P(t)}{K(P,\tau_2,\tau_3)}\right]$$

$$K(P,\tau_2,\tau_3) = P_c + \gamma\left(P(t-\tau_2)-P_o\right)\exp\left(-\kappa\left(P(t-\tau_3)-P_o\right)\right)$$

$P_o = 1$ billion is defined as the bio-capacity of earth (Gorshkov. 1995) exceeded in 1980.

$P_c = 7.0$ Billion, stationary population size.

r, κ, γ Rate constants

$$\tau_1 \approx 25-40; \quad \tau_2 \approx 25-50; \quad \tau_3 \approx 75-150$$

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World Population

Model parameters for (Akaev and Sadovnichii. 2010) Equation:

	r	γ	κ	τ_1 (yrs)	τ_2 (yrs)	τ_3 (yrs)
Case 1	0.05	0.4	1.31	20-**25**-50	10-**30**-100	25-**100**
Case 2	0.07	0.85	0.51	20-**25**-50	10-**30**-100	25-**100**
Case 3	0.07	0.85	0.51	20-**25**-50	10-**30**-100	25-**50**-100
Case 4	0.07	0.85	0.51	20-**50**	10-**75**-100	25-**100**

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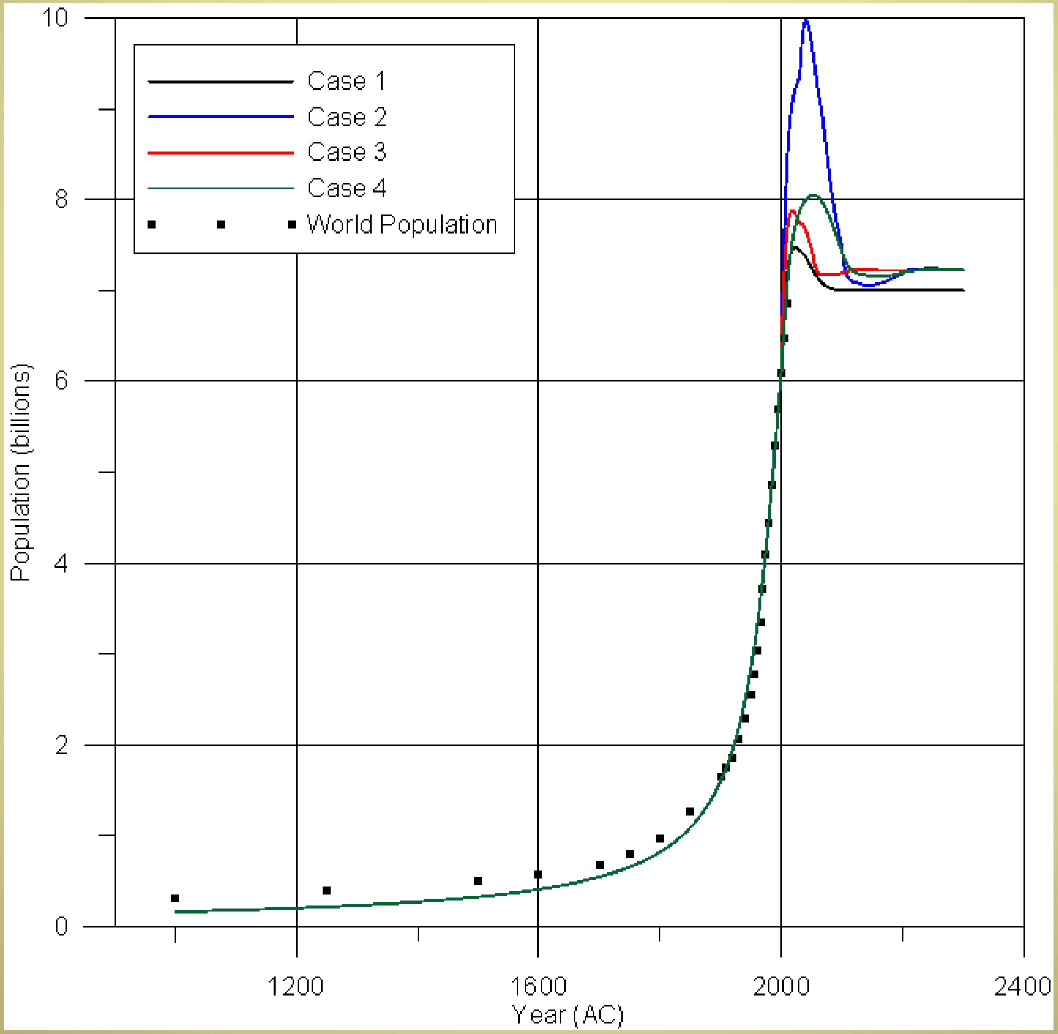
World Population:

$$\frac{dP}{dt} = rP^2 (t - \tau_1)\left[1 - \frac{P(t)}{K(P, \tau_2, \tau_3)}\right]$$



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Akaev & Sodovnichii (2010)

$$\frac{dP}{dt} = rP^2\left(t-\tau_1\right)\left[1-\frac{P\left(t\right)}{K\left(P,\tau_2,\tau_3\right)}\right]$$

$$K\left(P,\tau_2,\tau_3\right) = P_c + \gamma\left(P\left(t-\tau_2\right)-P_o\right)\exp\left(-\kappa\left(P\left(t-\tau_3\right)-P_o\right)\right)$$

$$r = f_1\left(t\right); \quad \gamma = f_2\left(t\right); \quad \kappa = f_3\left(t\right); \quad P_o\left(t\right)$$

External Stress?

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New Model with Climate Change term

$$P[0,\infty] \rightarrow [0,1]$$

Climate Change term

$$\frac{dP}{dt} = rP^2(t-\tau_1)\left[1 - \frac{P(t)}{K(P,\tau_2,\tau_3)}\right] - \left[\frac{P(t-\tau_3)}{(P_c + P(t-\tau_3))}\left(\frac{\beta T(t-\tau_3)}{T_o}\right)^2\right]$$

Same

Non-dimensional

$$\frac{dP}{dt} = rP^2(t-\tau_1)\left[1 - \frac{P(t)}{K(P,\tau_2,\tau_3)}\right]$$

$$K(P,\tau_2,\tau_3) = P_c + \gamma\left(P(t-\tau_2) - P_o\right)\exp\left(-\kappa\left(P(t-\tau_3) - P_o\right)\right)$$

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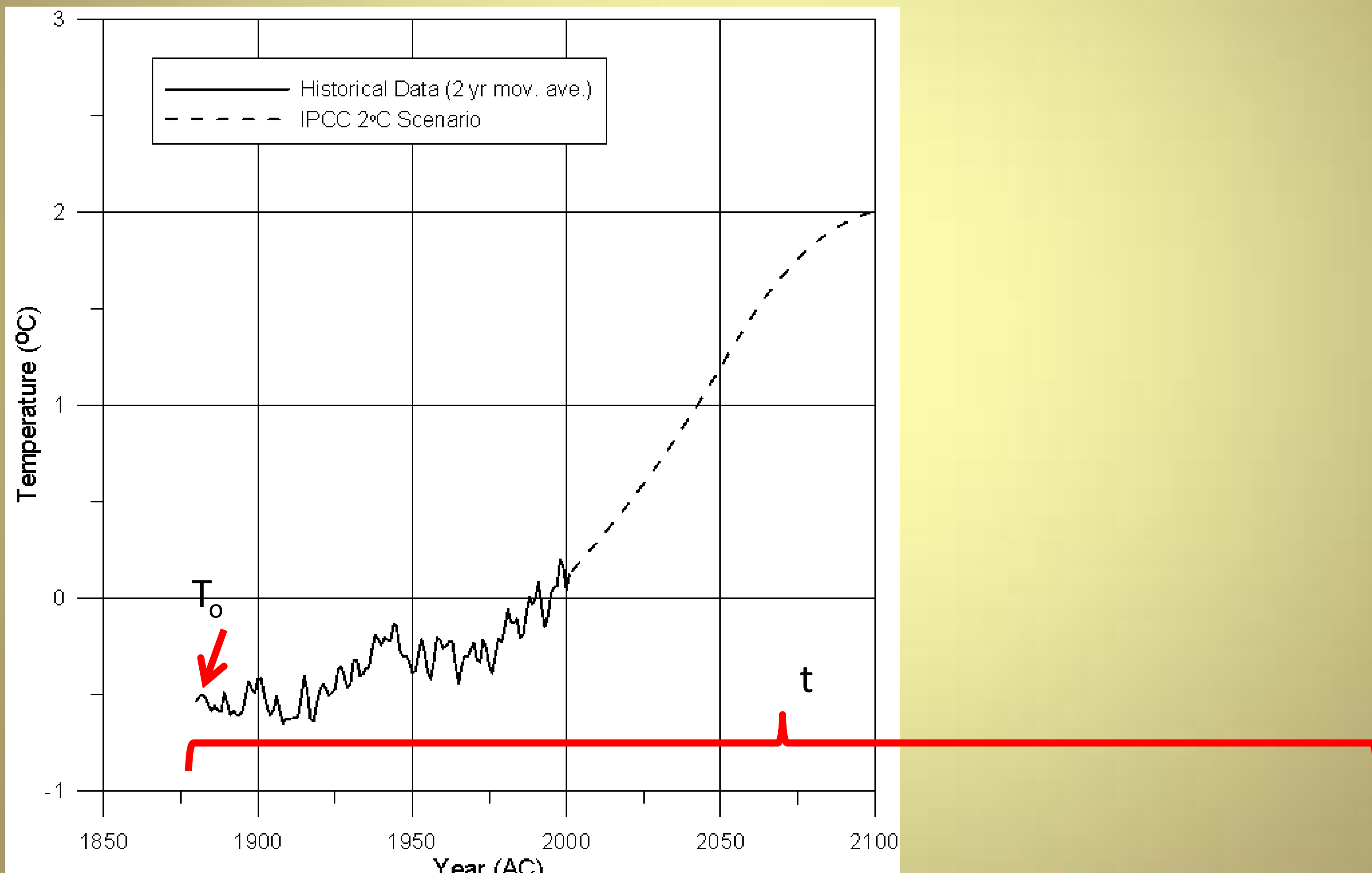
New Model: Temp Data

$$\frac{dP}{dt} = rP^2(t-\tau_1)\left[1-\frac{P(t)}{K(P,\tau_2,\tau_3)}\right]-\left[\frac{P(t-\tau_3)}{\left(P_c+P(t-\tau_3)\right)}\left(\frac{\beta T(t-\tau_3)}{T_o}\right)^2\right]$$



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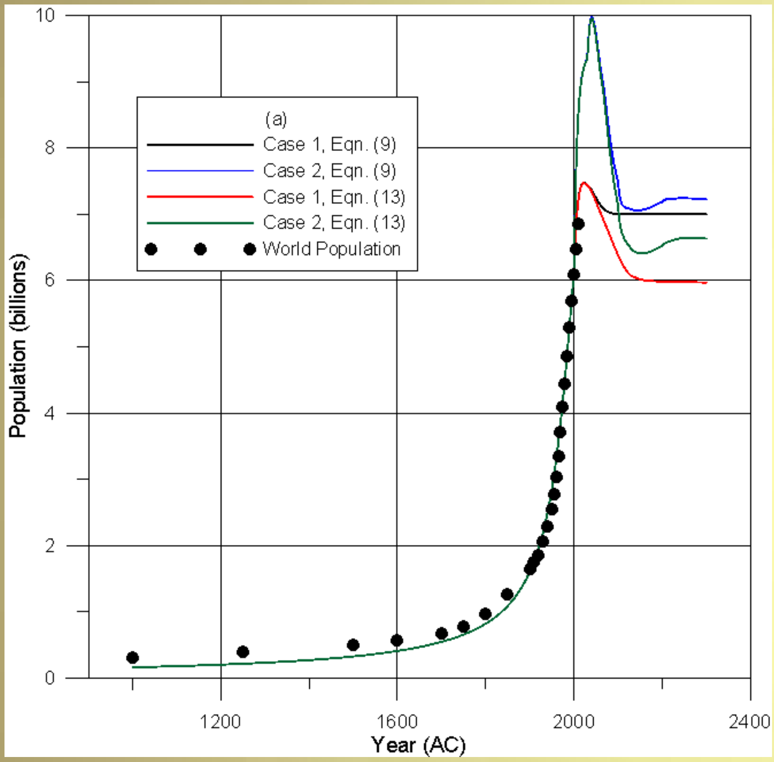
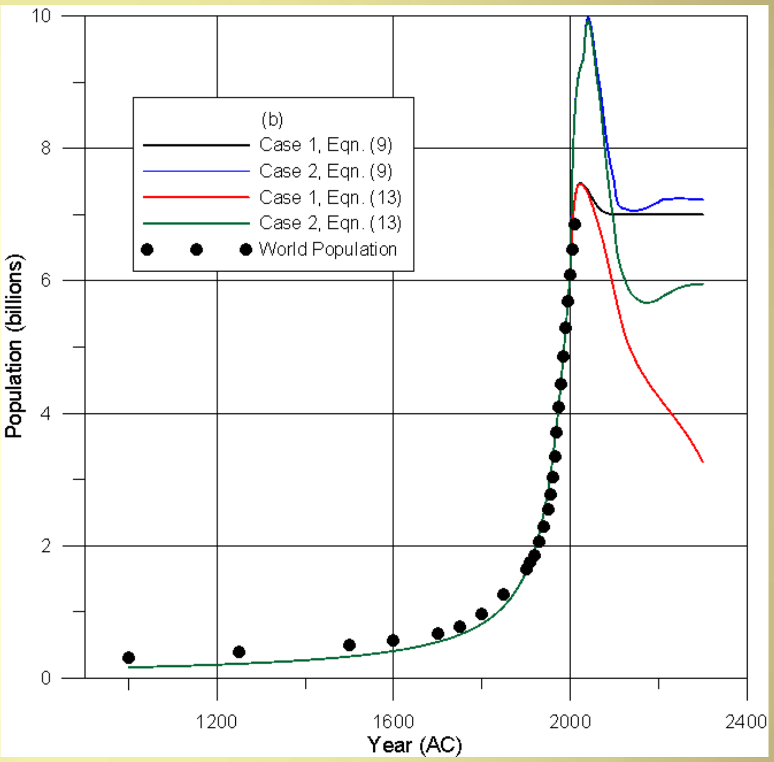
Akaev vs. New Model





World population predictions for:
(a) the 2°C scenario; and, (b) the 5.4 °C temperature scenario,
for *Case 1* and *Case 2* applications.

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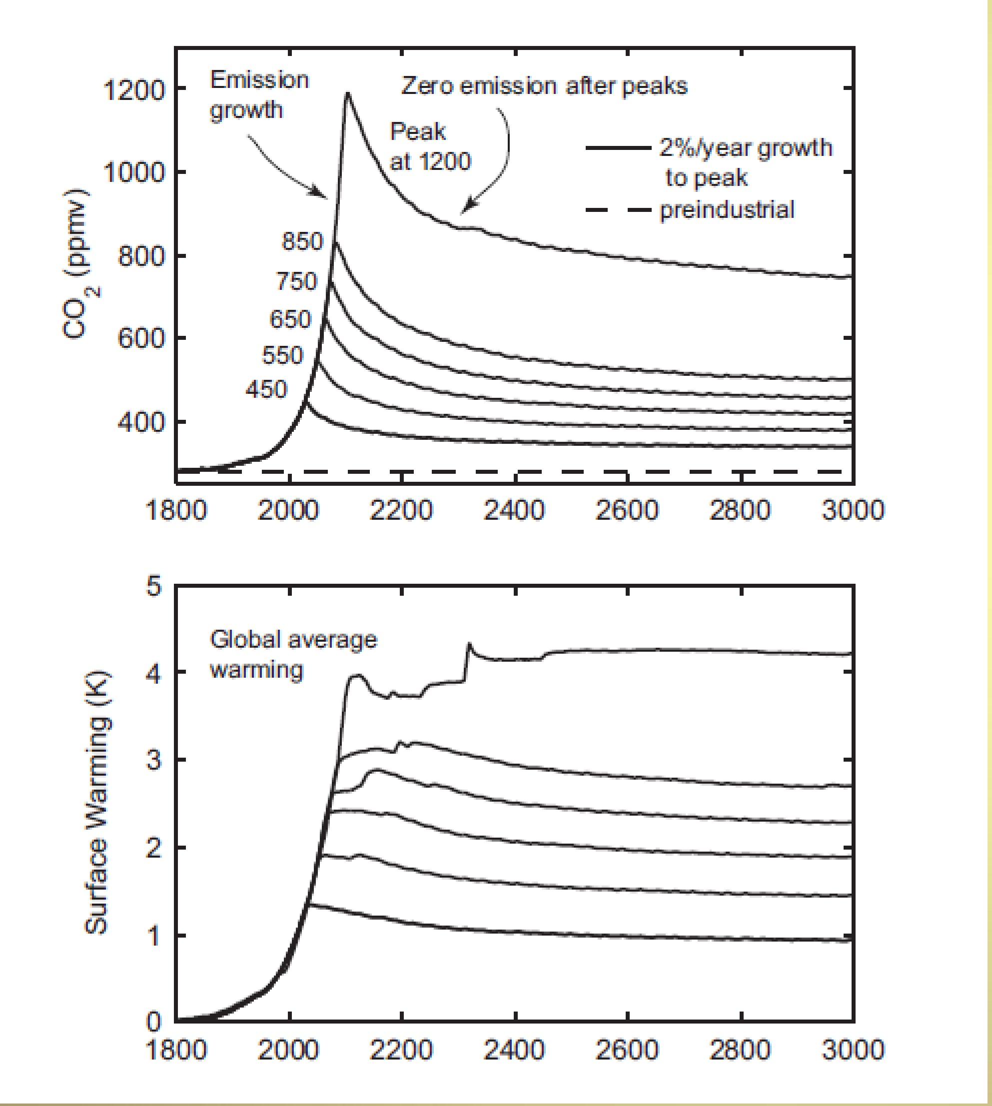
Persistent and High Temperatures Case



Solomon et al. (2009)

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Persistent and High Temperatures

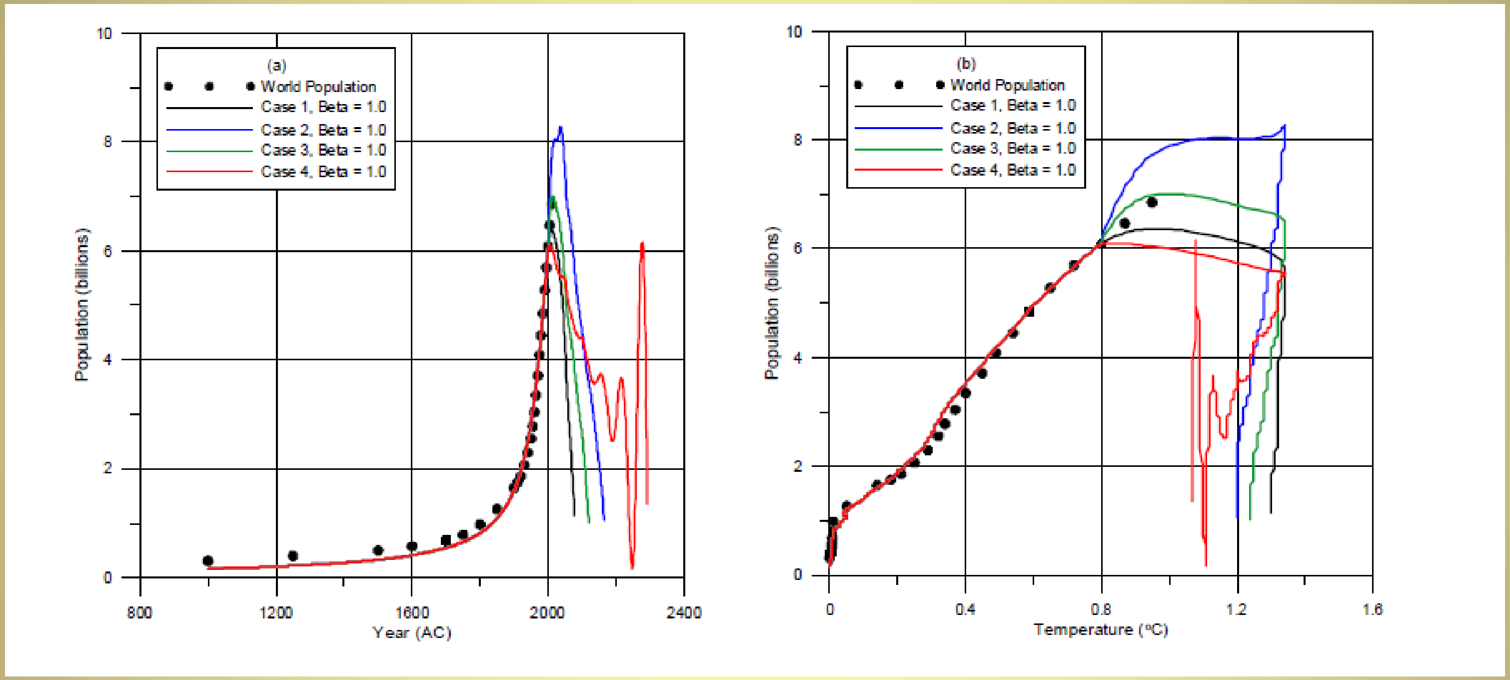

Fig. 1. World population stability estimates for 2%/year peak of CO_2 to level of 450 ppmv until year 2050 at P_c = 7 billion and persistent global temperatures beyond 2050 as predicted in Solomon et al. (*8*):
(a) Time series plot; and, (b) Stability phase plane diagram.

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Persistent and High Temperatures

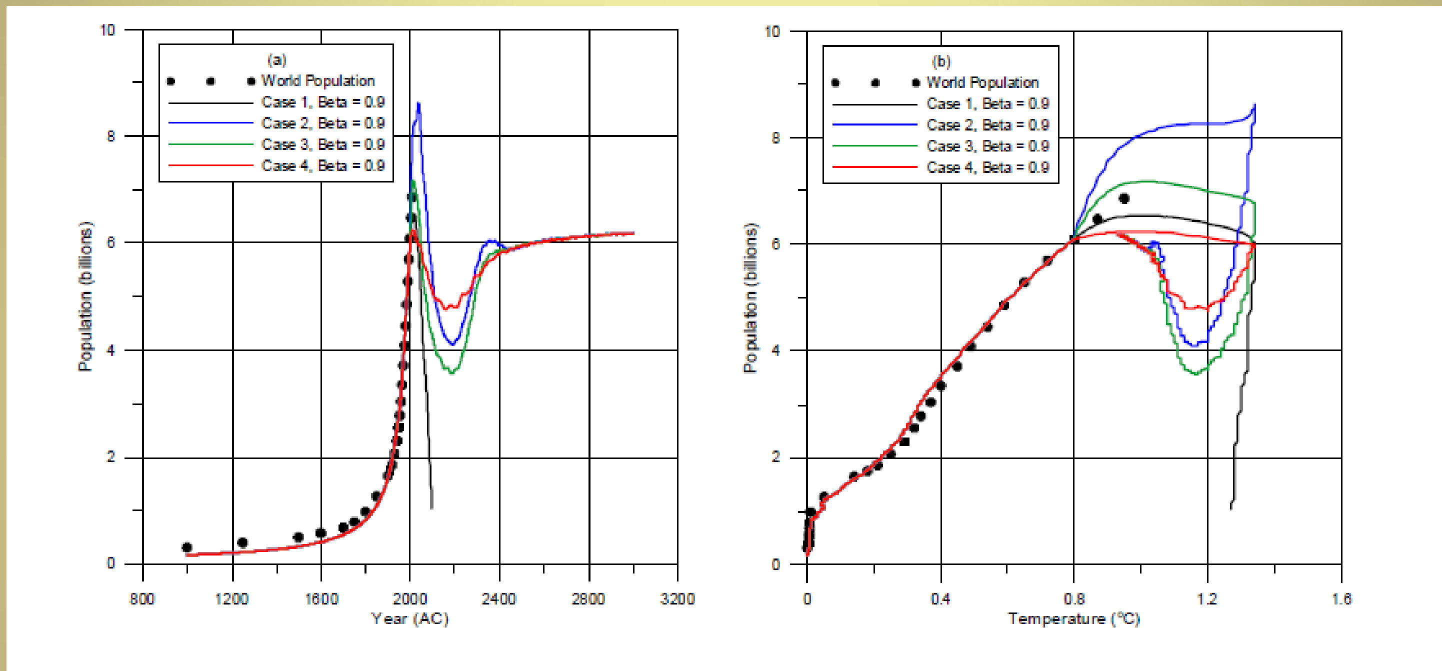

Fig. 2. World population stability estimates for 90% of the 2%/year peak of CO_2 to level of 450 ppmv until year 2050 at P_c = 7 billion and persistent global temperatures beyond 2050 as predicted in Solomon et al. (*8*):
(a) Time series plot; and, (b) Stability phase plane diagram.

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Persistent and High Temperatures

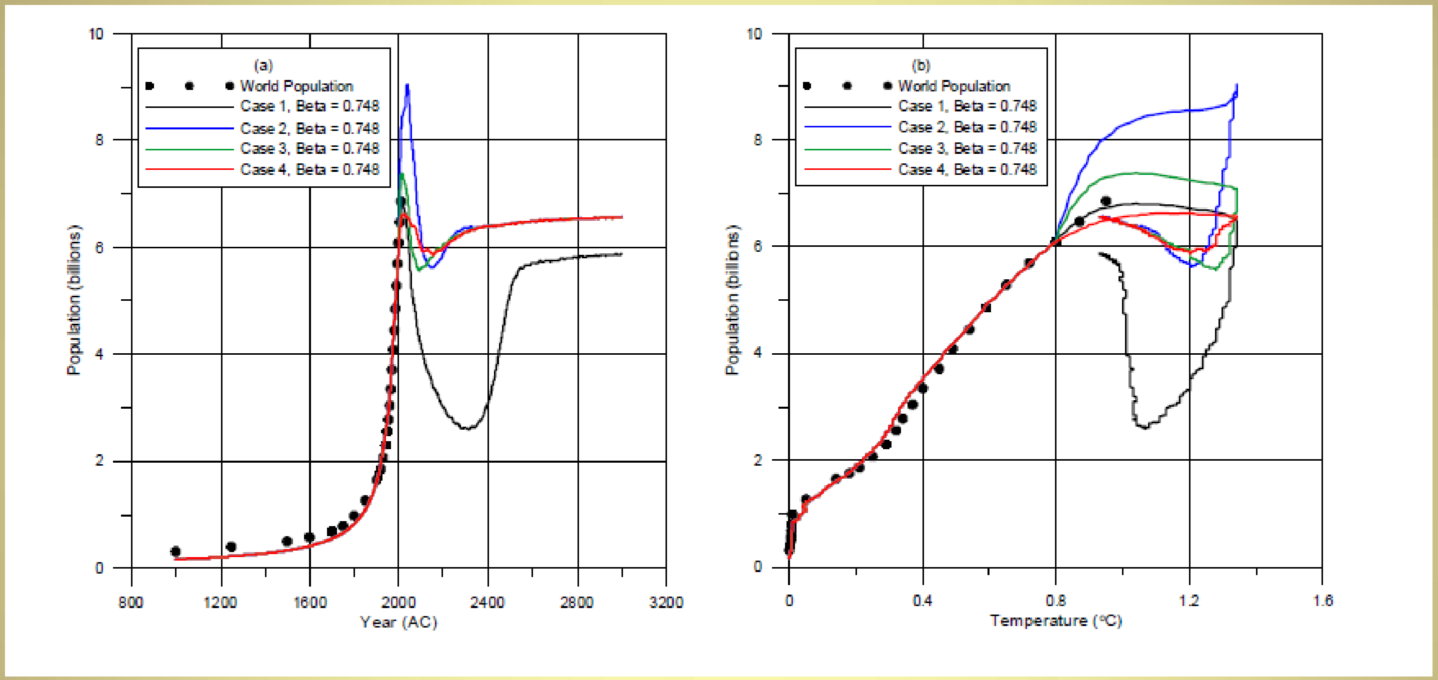

Fig. 3. World population stability estimates for 74.8% of the 2%/year peak of CO_2 to level of 450 ppmv until year 2050 at P_c = 7 billion and persistent global temperatures beyond 2050 as predicted in Solomon et al. (*8*): (a) Time series plot; and, (b) Stability phase plane diagram.

74% corresponds to ~1° C which is the predicted temp. to avoid ext. of species

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Prediction

- **Skeptics:** Will try to find an error in the model and the application and will not believe the story.
- **Pessimists:** Will say I am the dooms day messenger and that I am trying to scare people.
- **Optimists:** Will interpret the outcome as the potential source of scare tactics for governments and other administrators.
- **Prediction:** To avoid the fight between these groups this study will not be published…

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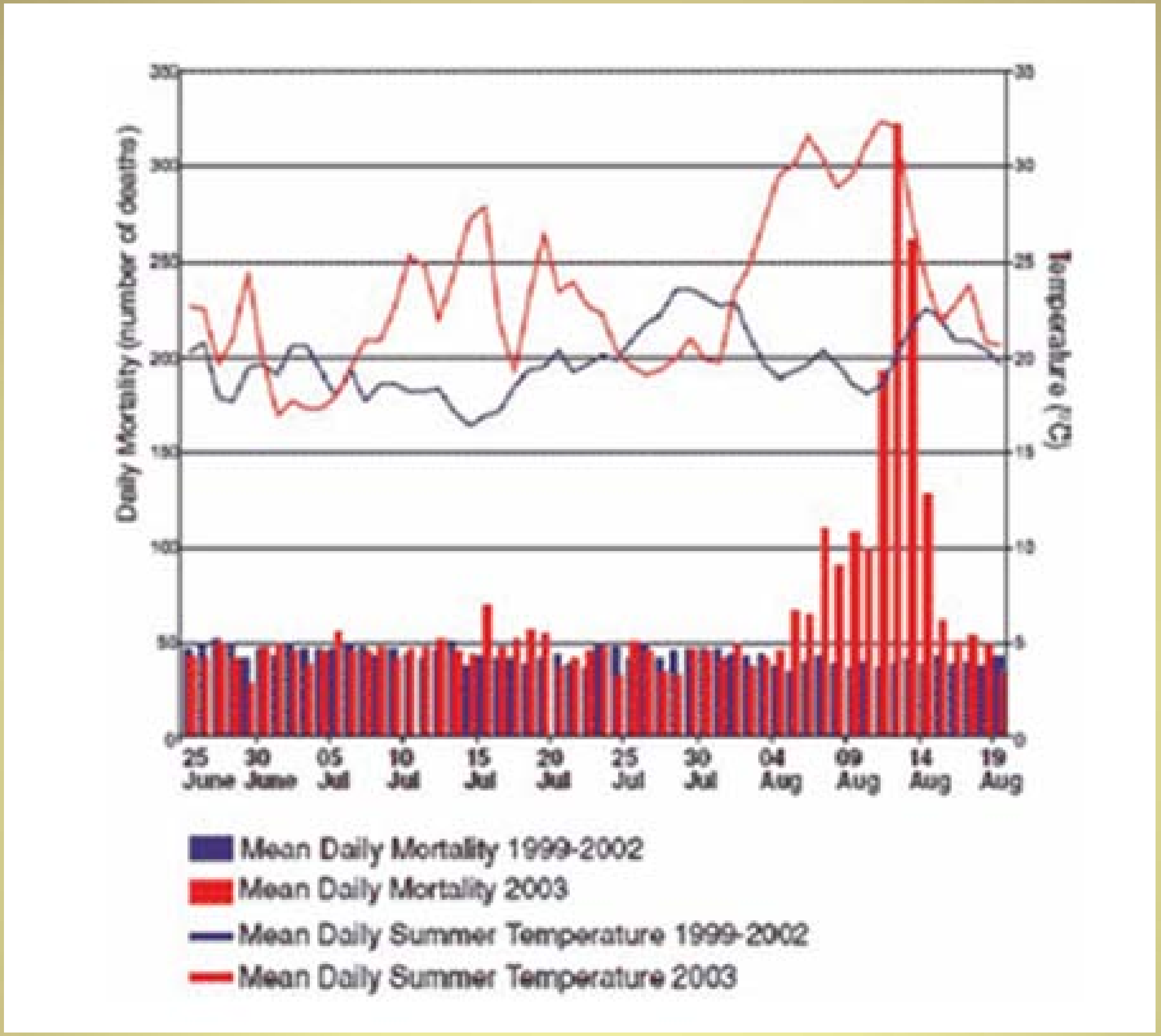

Thank You

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Climate Change and Human Population Dynamics

Mustafa M. Aral