We are DOOMED!!

Climate Change and Population Dynamics

M. M. ARAL
Reports of Excess Mortality Due to Heat Wave in Europe

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

~26 thousand just in Europe
### Other Events

<table>
<thead>
<tr>
<th>Event</th>
<th>Qualitative Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>2ºC Increase</td>
<td>Extermination of species</td>
</tr>
<tr>
<td>Cold nights</td>
<td>75% death of monarch butterfly population</td>
</tr>
<tr>
<td>Long summer days</td>
<td>80% water shortage for small birds</td>
</tr>
<tr>
<td>Caracas Venezuela</td>
<td>In December 1999 floods killed approximately 30,000 people</td>
</tr>
<tr>
<td>Central America</td>
<td>In 1998, Hurricane Mitch created massive mudslides and claiming 11,000 lives.</td>
</tr>
<tr>
<td>Sichuan Province, China</td>
<td>In 2006, experienced its worst drought in modern times, with nearly 8 million people</td>
</tr>
<tr>
<td></td>
<td>and over 7 million cattle facing water shortages (no reports of mortality by the</td>
</tr>
<tr>
<td></td>
<td>government)</td>
</tr>
</tbody>
</table>
MORT = 0.32t_{max} - 0.03T_{OS} - 7.76,

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

<table>
<thead>
<tr>
<th>City</th>
<th>Population in 2000 (100,000s)</th>
<th>Avg No. of summertime EHE days (1975-95)</th>
<th>Forecast No. avg summertime EHE-attributable deaths from algorithm (1975-95 data)</th>
<th>Avg summertime EHE-attributable mortality rate per 100,000 residents (using algorithm 1975-95)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hartford, CT</td>
<td>1.22</td>
<td>6</td>
<td>32</td>
<td>26.7</td>
</tr>
<tr>
<td>Newark, NJ</td>
<td>2.74</td>
<td>8</td>
<td>66</td>
<td>24.0</td>
</tr>
<tr>
<td>Providence, RI</td>
<td>1.74</td>
<td>7</td>
<td>40</td>
<td>22.9</td>
</tr>
<tr>
<td>Boston, MA</td>
<td>5.89</td>
<td>11</td>
<td>104</td>
<td>17.7</td>
</tr>
<tr>
<td>Greensboro, NC</td>
<td>2.24</td>
<td>8</td>
<td>36</td>
<td>16.3</td>
</tr>
<tr>
<td>Louisville, KY</td>
<td>2.56</td>
<td>8</td>
<td>39</td>
<td>15.3</td>
</tr>
<tr>
<td>Kansas City, MO</td>
<td>4.42</td>
<td>7</td>
<td>46</td>
<td>10.9</td>
</tr>
<tr>
<td>Birmingham, AL</td>
<td>2.43</td>
<td>5</td>
<td>24</td>
<td>10.0</td>
</tr>
<tr>
<td>Baltimore, MD</td>
<td>6.51</td>
<td>8</td>
<td>64</td>
<td>9.9</td>
</tr>
<tr>
<td>Cleveland, OH</td>
<td>4.78</td>
<td>5</td>
<td>45</td>
<td>9.4</td>
</tr>
<tr>
<td>Atlanta, GA</td>
<td>4.16</td>
<td>5</td>
<td>37</td>
<td>8.8</td>
</tr>
</tbody>
</table>

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.
Can we introduce quantitative analysis to all these somewhat qualitative information?
World Population (World Bank Data - 2013)

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\[
P = \frac{C}{t_o - t}
\]

\[C = 200 \times 10^9 \text{ people – yr}\]

\[t_o = 2025 \text{ yr}\]
World Population

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

- Then: \( \frac{dP}{dt} = \frac{P^2}{C} \)

- 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
World Population

• Kapitza (1996):
  \[ \frac{dP}{dt} = \frac{P^2}{C} \quad \Rightarrow \quad P = \frac{C}{t_o - t} \]

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

• Where:
  \[ \tau = \text{human life time factor} \approx 45\,\text{yrs} \]
  \[ t_1 = 1995 \]
  \[ C = 1.63 \times 10^{11} \, \text{people} - \text{yr} \]
World Population

- Solution - Kapitza (1996):

\[
P = K^2 \arccot \left( \frac{t_1 - t}{\tau} \right)
\]

\[
K^2 = \frac{C}{\tau}
\]

\[
\tau = \text{human life time factor} \approx 45 \text{ yrs}
\]

\[
t_1 = 1995
\]

\[
C = 1.63 \times 10^{11} \text{ people - yr}
\]
World Population

\[ P_{\text{max}} = \pi K^2 = 11.36 \text{ billion} \]

\[ P_{\text{max}} = \pi K^2 = 13.51 \text{ billion} \]

\[ \tau = \text{human life time factor} \approx 45 \text{ yrs} \]

\[ t_1 = 1995 \]

\[ C = 1.63 \times 10^{11} \text{ people - yr} \]

\[ \tau = \text{human life time factor} \approx 60 \text{ yrs} \]

\[ t_1 = 2030 \]

\[ C = 2.53 \times 10^{11} \text{ people - yr} \]

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Missing Information?

\[ P_{\text{max}} = \pi K^2 = 11.36 \text{ billion} \quad \quad \quad \quad \quad \quad \quad \quad P_{\text{max}} = \pi K^2 = 13.51 \text{ billion} \]

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

Environmental Systems or Human Growth capacity?

or

Sustainable Carrying Capacity?
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 –

\[
\frac{dP}{dt} = rP^2 \left( 1 - \frac{P}{K(q)} \right) \\
K(q) = \frac{P_c}{1 - \exp \left( -\alpha \frac{q}{q_c} \right)}
\]
World Population

• Akaev and Sadovnichii (2010)

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

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

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

\[P_c = 7.0\] Billion, stationary population size.

\[r, K, \gamma\] 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:

<table>
<thead>
<tr>
<th>Case</th>
<th>( r )</th>
<th>( \gamma )</th>
<th>( \kappa )</th>
<th>( \tau_1 ) (yrs)</th>
<th>( \tau_2 ) (yrs)</th>
<th>( \tau_3 ) (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>0.05</td>
<td>0.4</td>
<td>1.31</td>
<td>20-25-50</td>
<td>10-30-100</td>
<td>25-100</td>
</tr>
<tr>
<td>Case 2</td>
<td>0.07</td>
<td>0.85</td>
<td>0.51</td>
<td>20-25-50</td>
<td>10-30-100</td>
<td>25-100</td>
</tr>
<tr>
<td>Case 3</td>
<td>0.07</td>
<td>0.85</td>
<td>0.51</td>
<td>20-25-50</td>
<td>10-30-100</td>
<td>25-50-100</td>
</tr>
<tr>
<td>Case 4</td>
<td>0.07</td>
<td>0.85</td>
<td>0.51</td>
<td>20-50</td>
<td>10-75-100</td>
<td>25-100</td>
</tr>
</tbody>
</table>
World Population:

\[
\frac{dP}{dt} = rP^2(t - \tau_1) \left[1 - \frac{P(t)}{K(P, \tau_2, \tau_3)}\right]
\]
Akaev & Sodovnichii (2010)

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

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

\[
r = f_1(t); \quad \gamma = f_2(t); \quad \kappa = f_3(t); \quad P_o(t)
\]

External Stress?

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New Model with Climate Change term

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

\[ K(P, \tau_2, \tau_3) = P_c + \gamma (P(t - \tau_2) - P_o) \exp(-\kappa (P(t - \tau_3) - P_o)) \]
New Model: Temp Data

\[
\frac{dP}{dt} = rP_0^2 (t - \tau_1) \left[ 1 - \frac{P(t)}{K(P, \tau_2, \tau_3)} \right] - \frac{P(t - \tau_3)}{(P_c + P(t - \tau_3))} \left( \frac{\beta T(t - \tau_3)}{T_o} \right)^2
\]
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)
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.
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 $\sim 1^\circ$ 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...
Thank You

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Climate Change and Human Population Dynamics

Mustafa M. Aral