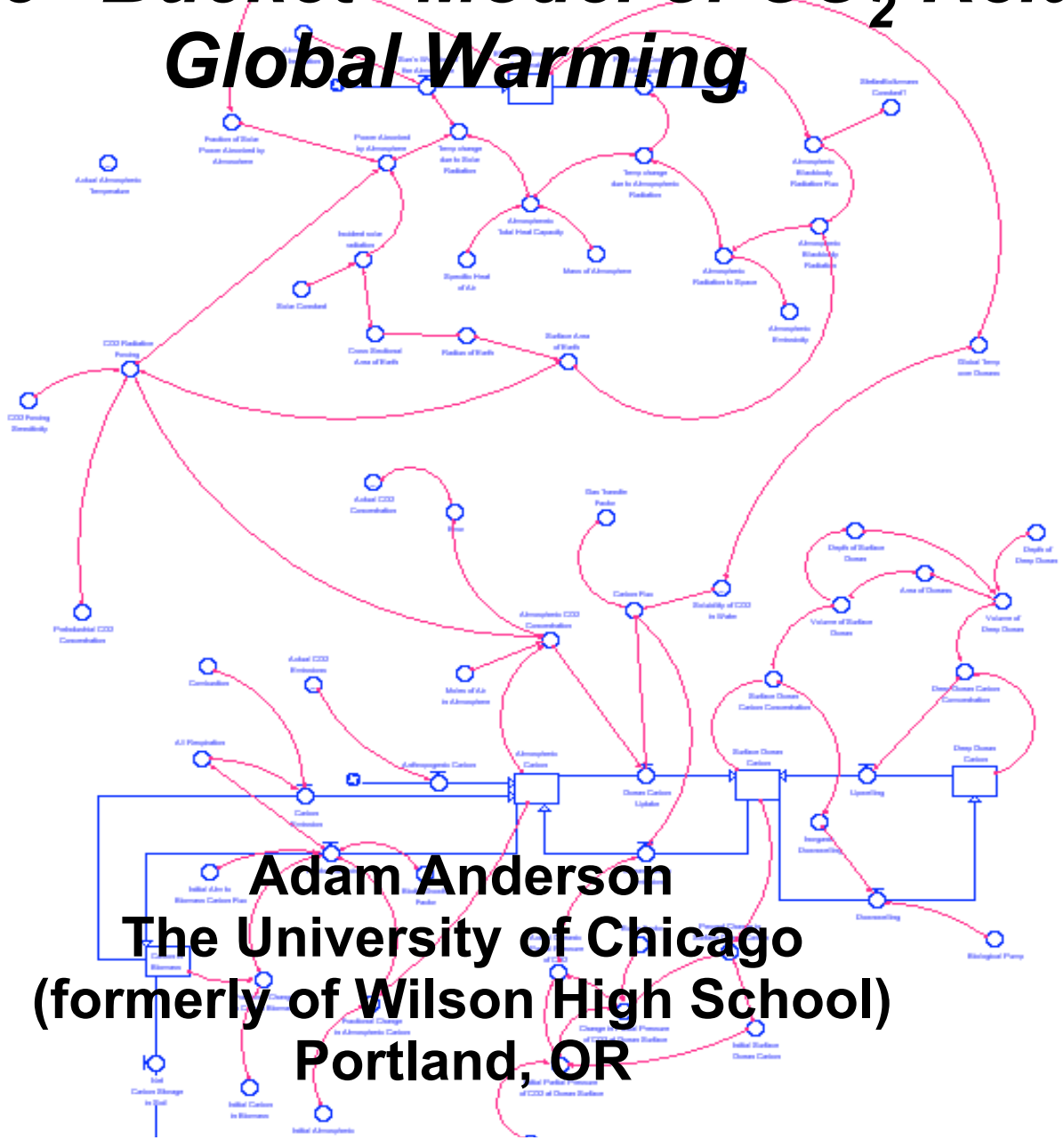
A Simple "Bucket" Model of CO_2-Related Global Warming



Adam Anderson
The University of Chicago
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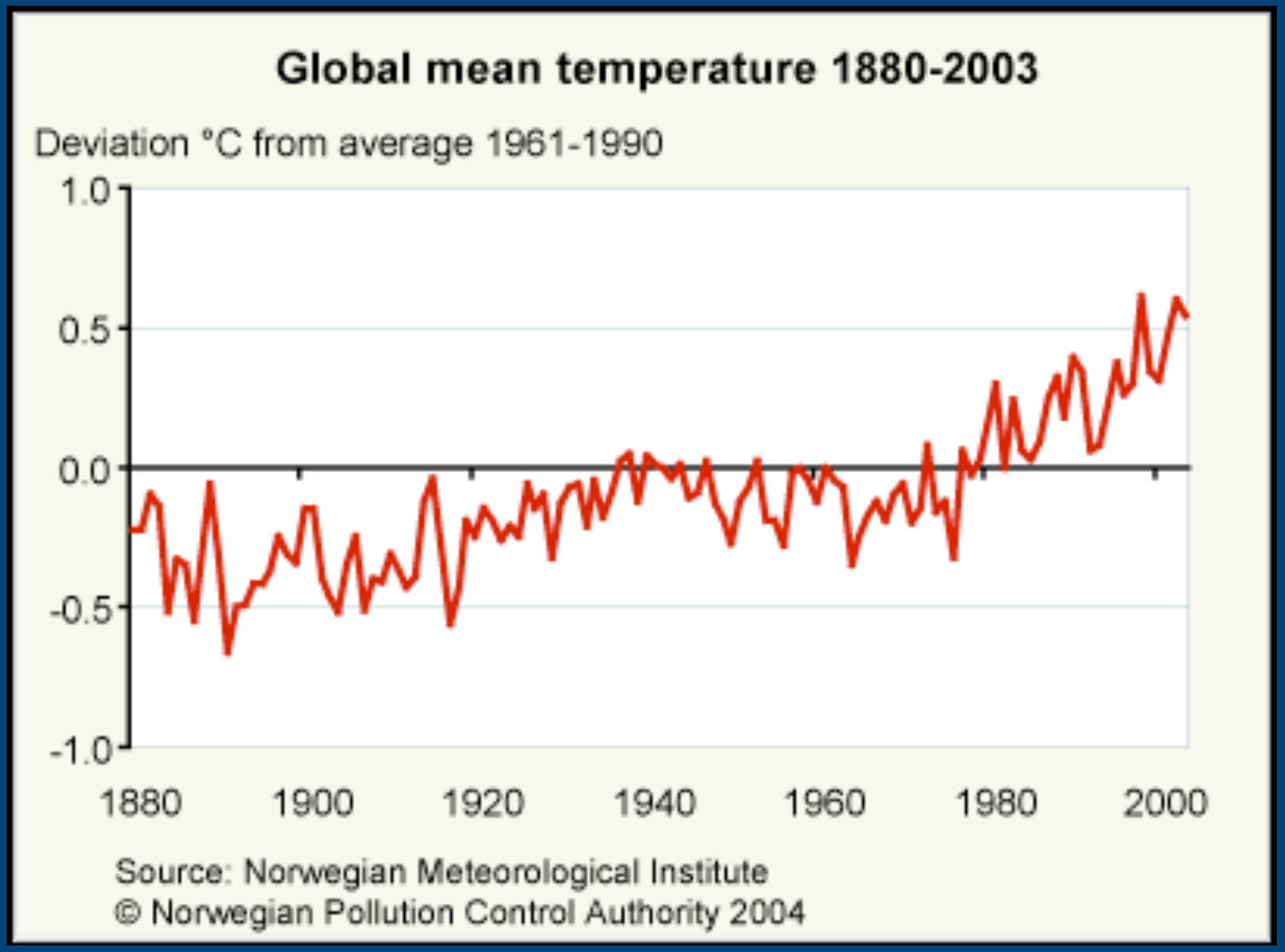
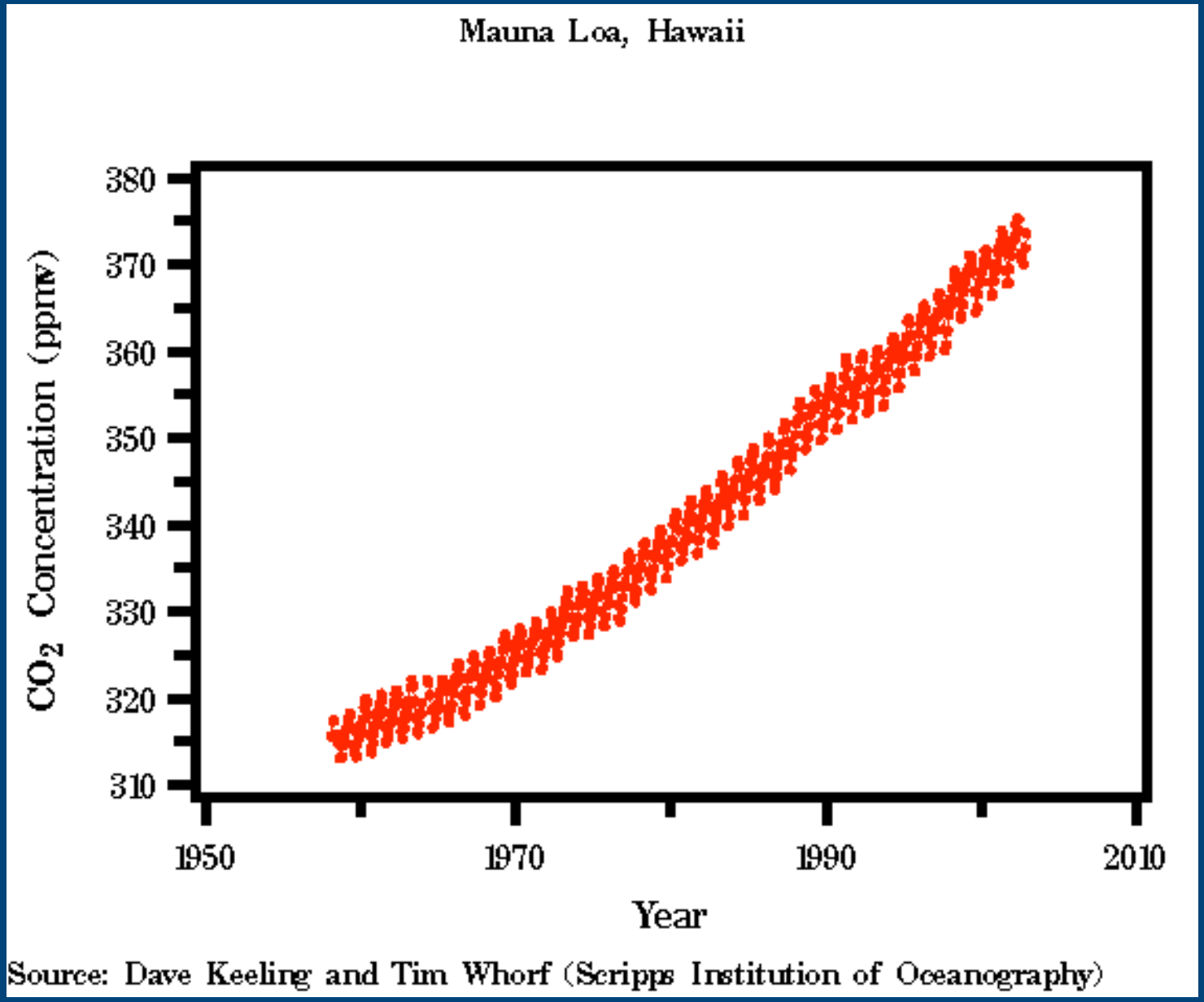
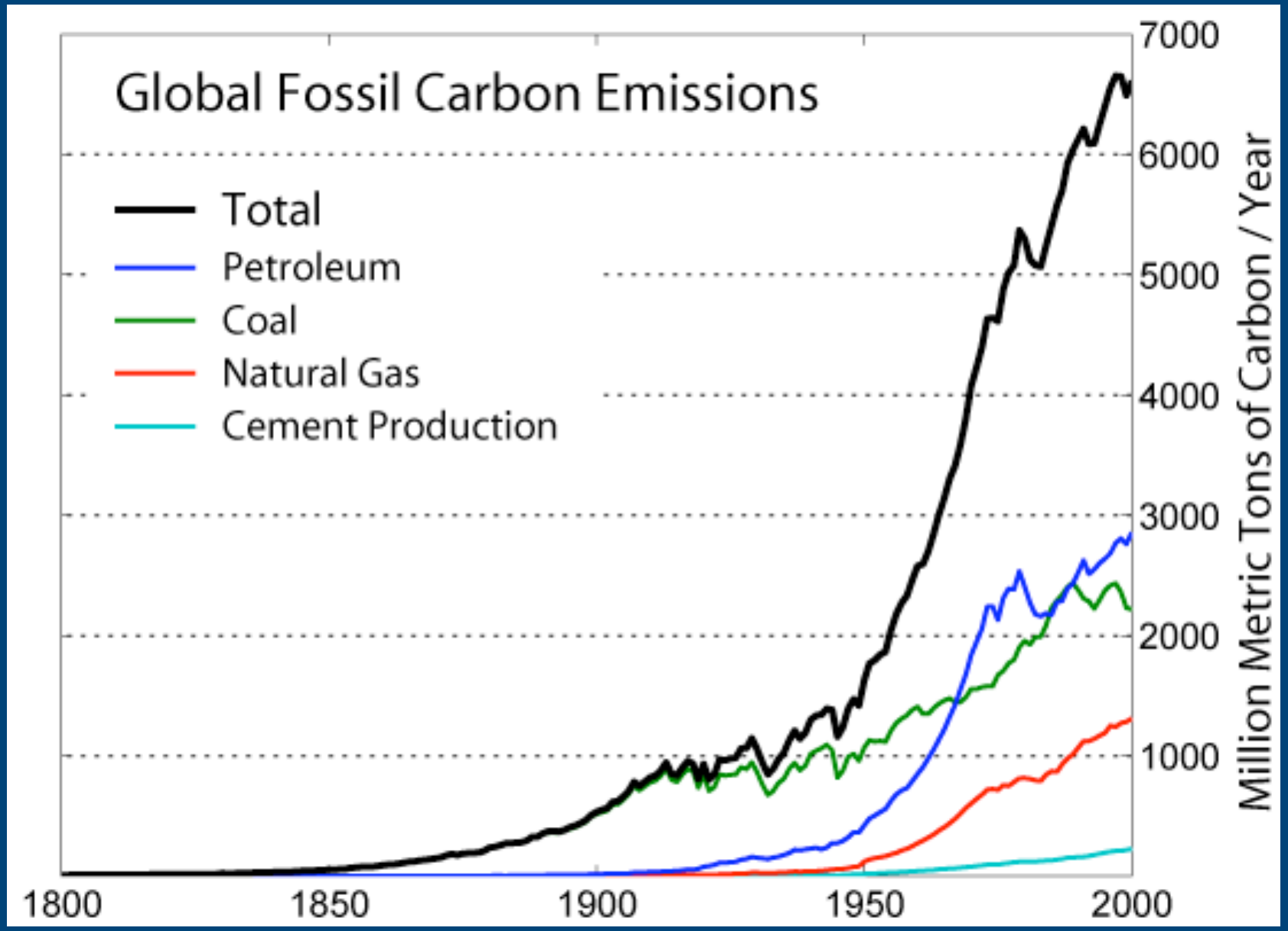

Global mean temperature 1880-2003
Deviation °C from average 1961-1990
1.0
0.5
0.0
-0.5
-1.0
1880
1900
1920
1940
1960
1980
2000
Source: Norwegian Meteorological Institute
© Norwegian Pollution Control Authority 2004

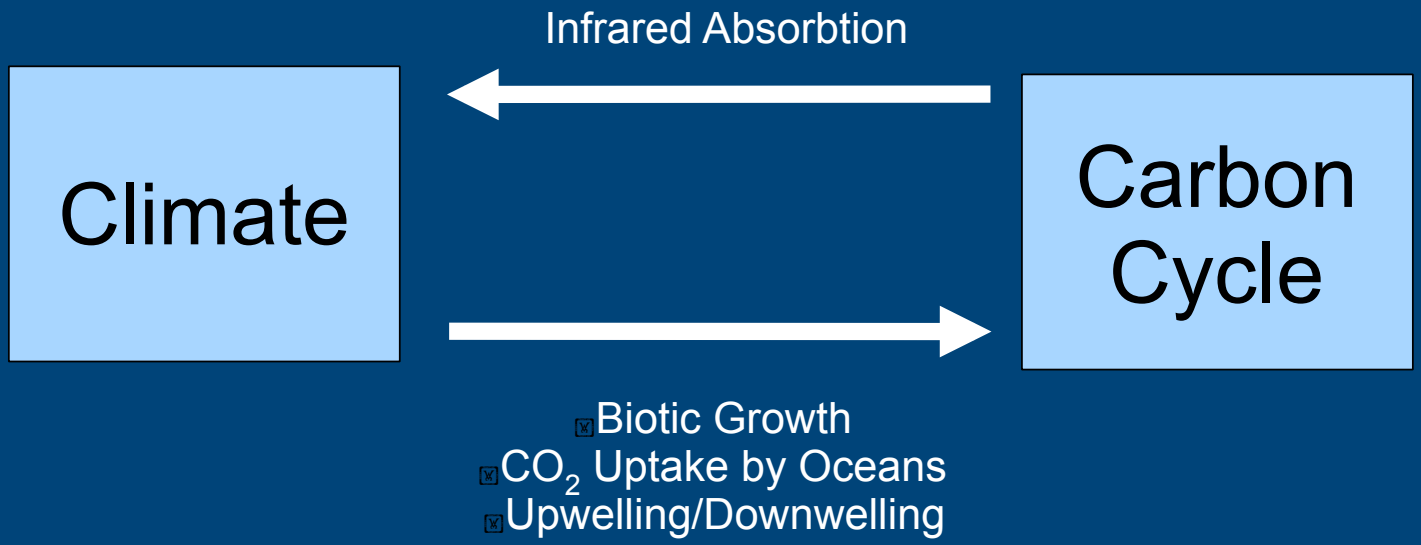

Mauna Loa, Hawaii
380
370
360
350
340
330
320
310
CO_2 Concentration (ppmv)
1950
1970
1990
2010
Year
Source: Dave Keeling and Tim Whorf (Scripps Institution of Oceanography)


Global Fossil Carbon Emissions
Total
Petroleum
Coal
Natural Gas
Cement Production
7000
6000
5000
4000
3000
2000
1000
Million Metric Tons of Carbon / Year
1800
1850
1900
1950
2000

Classes of Climate Models

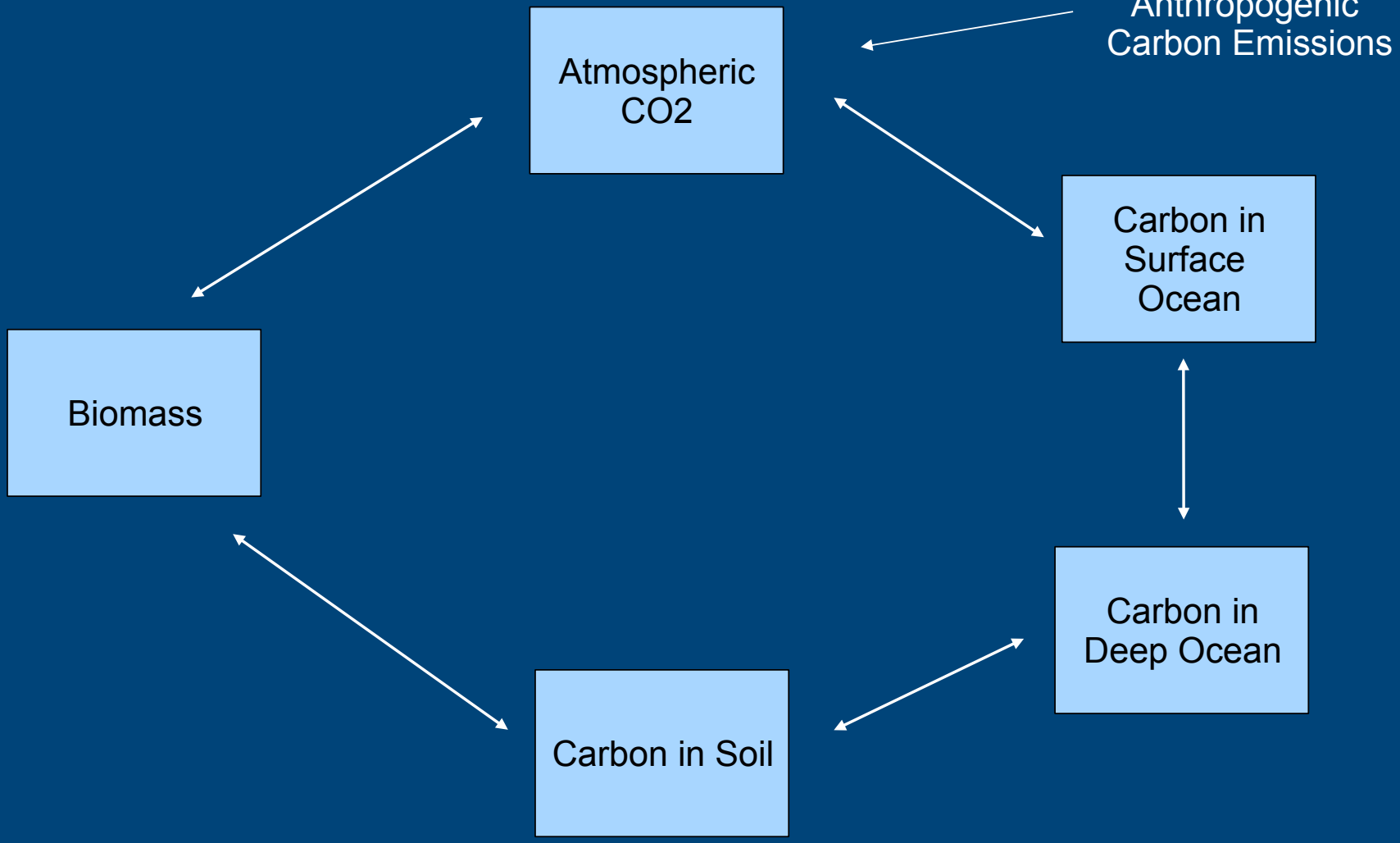
- *General circulation models:*
  - Divide earth into cells that are modeled with numerically simulated matter and energy transport
  - Computationally intensive
  - Most sophisticated
- "*Bucket" Models:*
  - Parsimonious
  - Reveals the conceptual structure of the climate system
  - Still generates useful predictions

The Model

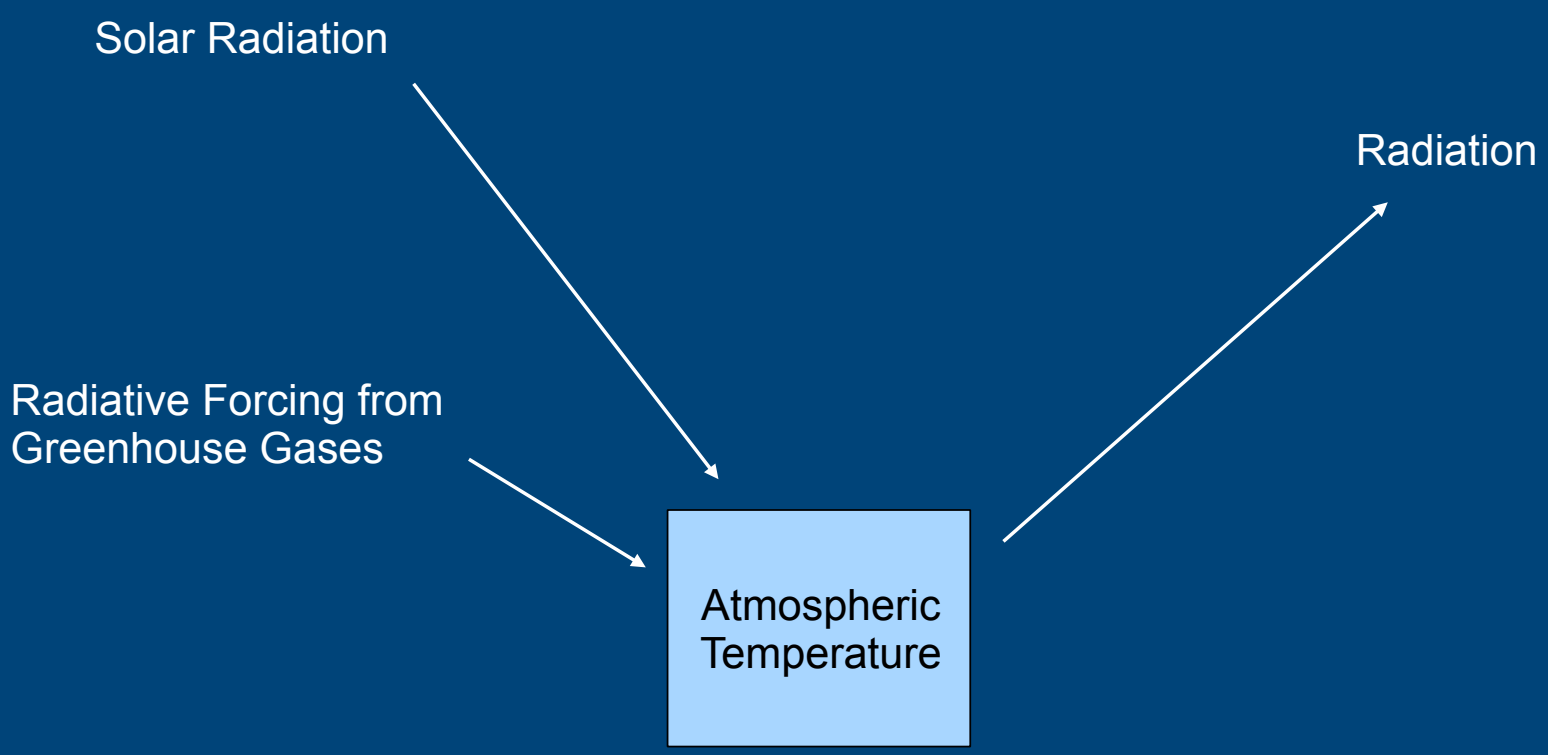


- Biotic Growth
- CO_2 Uptake by Oceans
- Upwelling/Downwelling

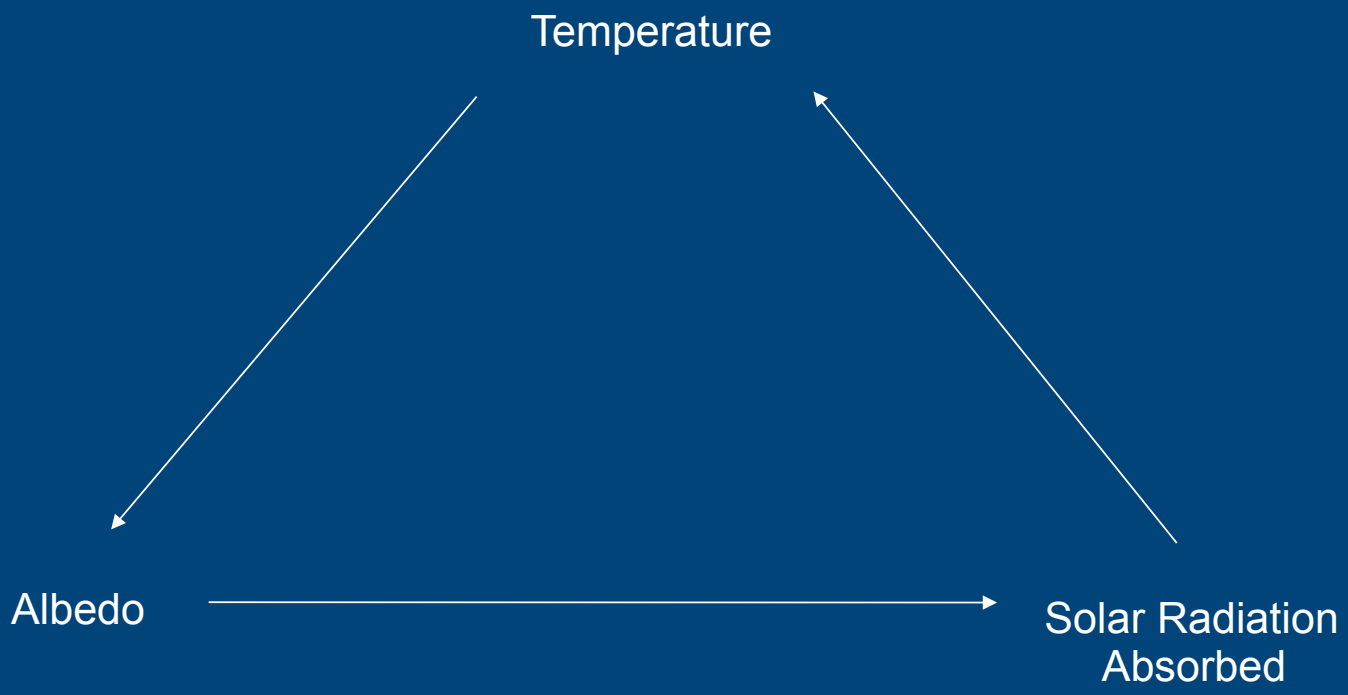
The Carbon Cycle



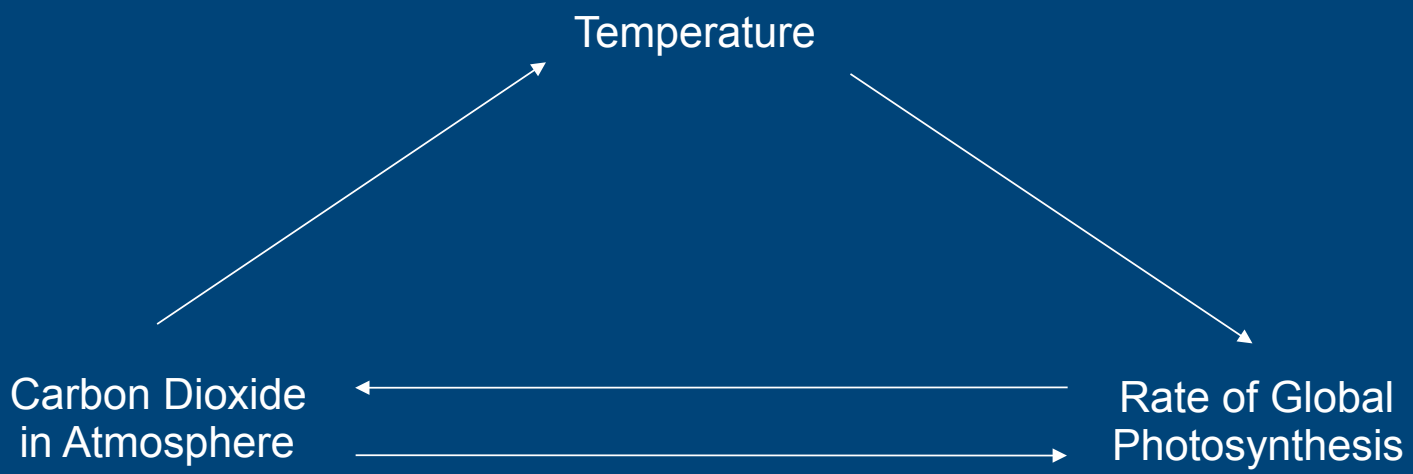
Climate


Solar Radiation
Radiation
Radiative Forcing from
Greenhouse Gases
Atmospheric
Temperature

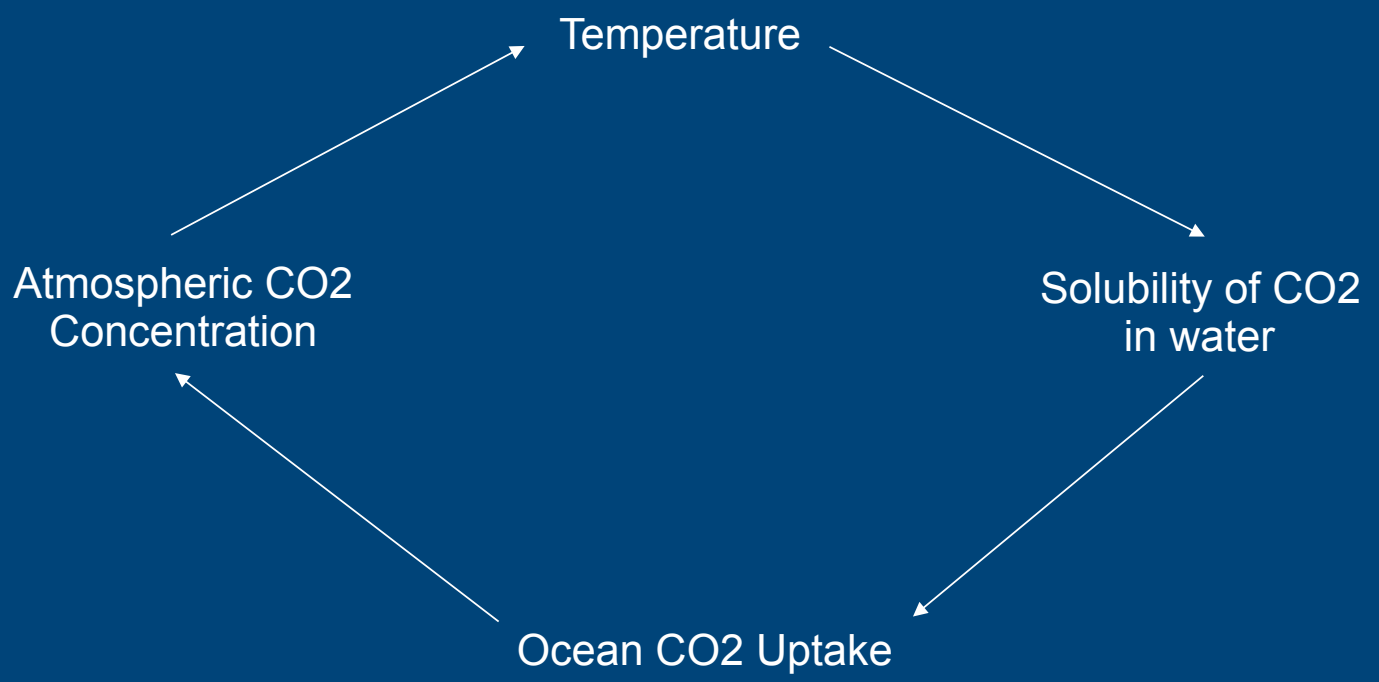
Ice-Albedo Feedback



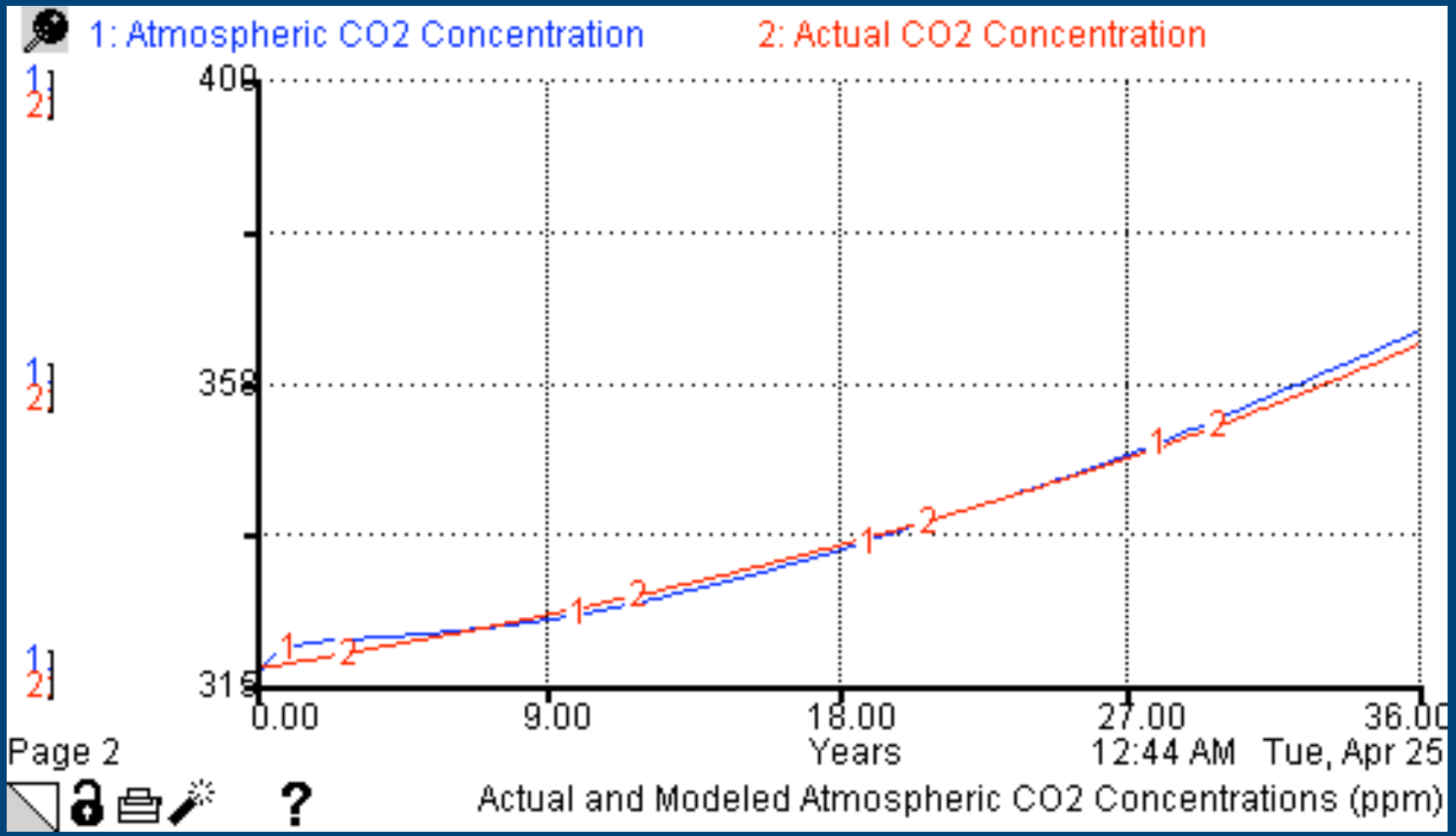
Biotic Growth Feedback



Solubility Feedback

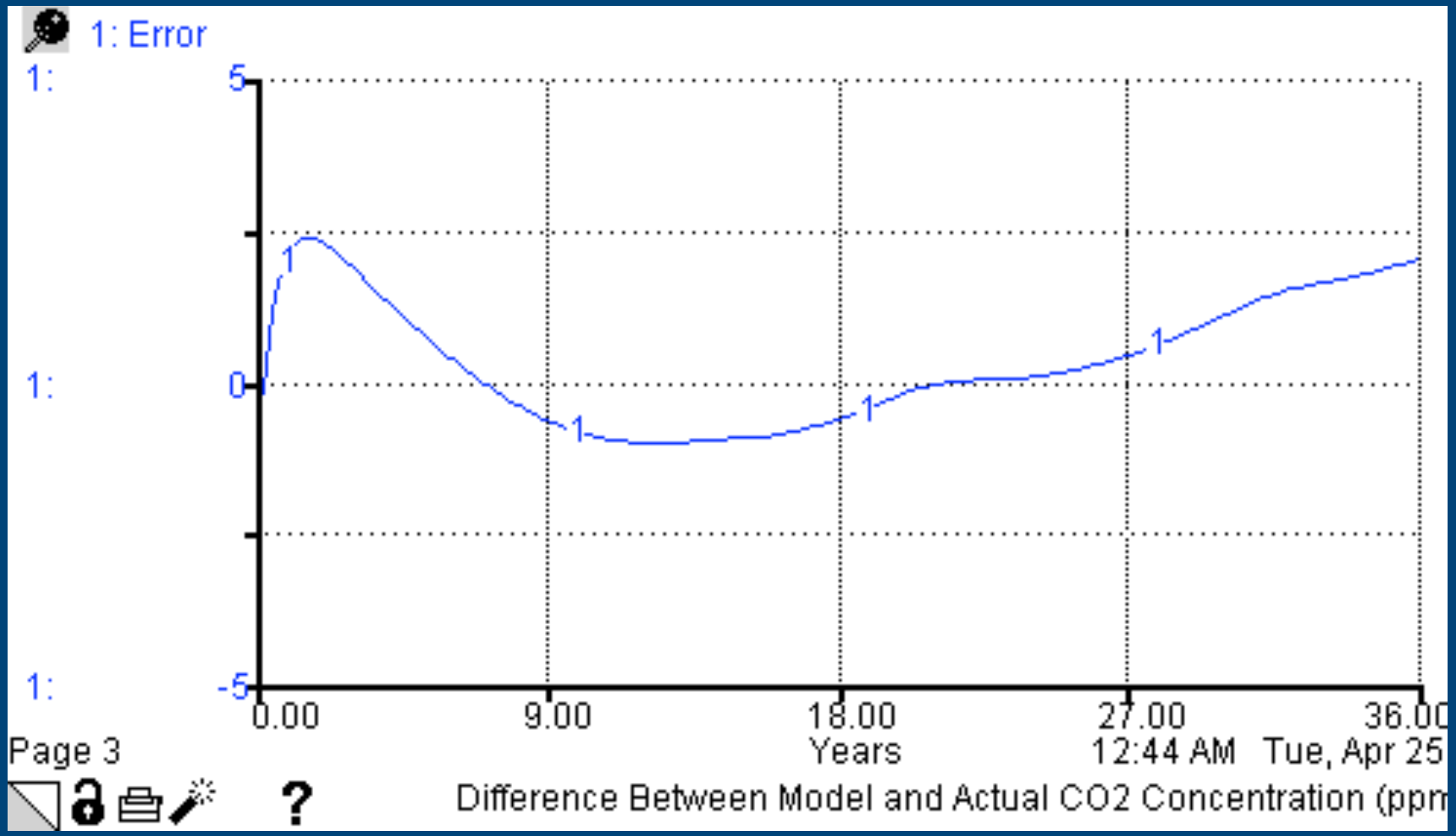


Validation



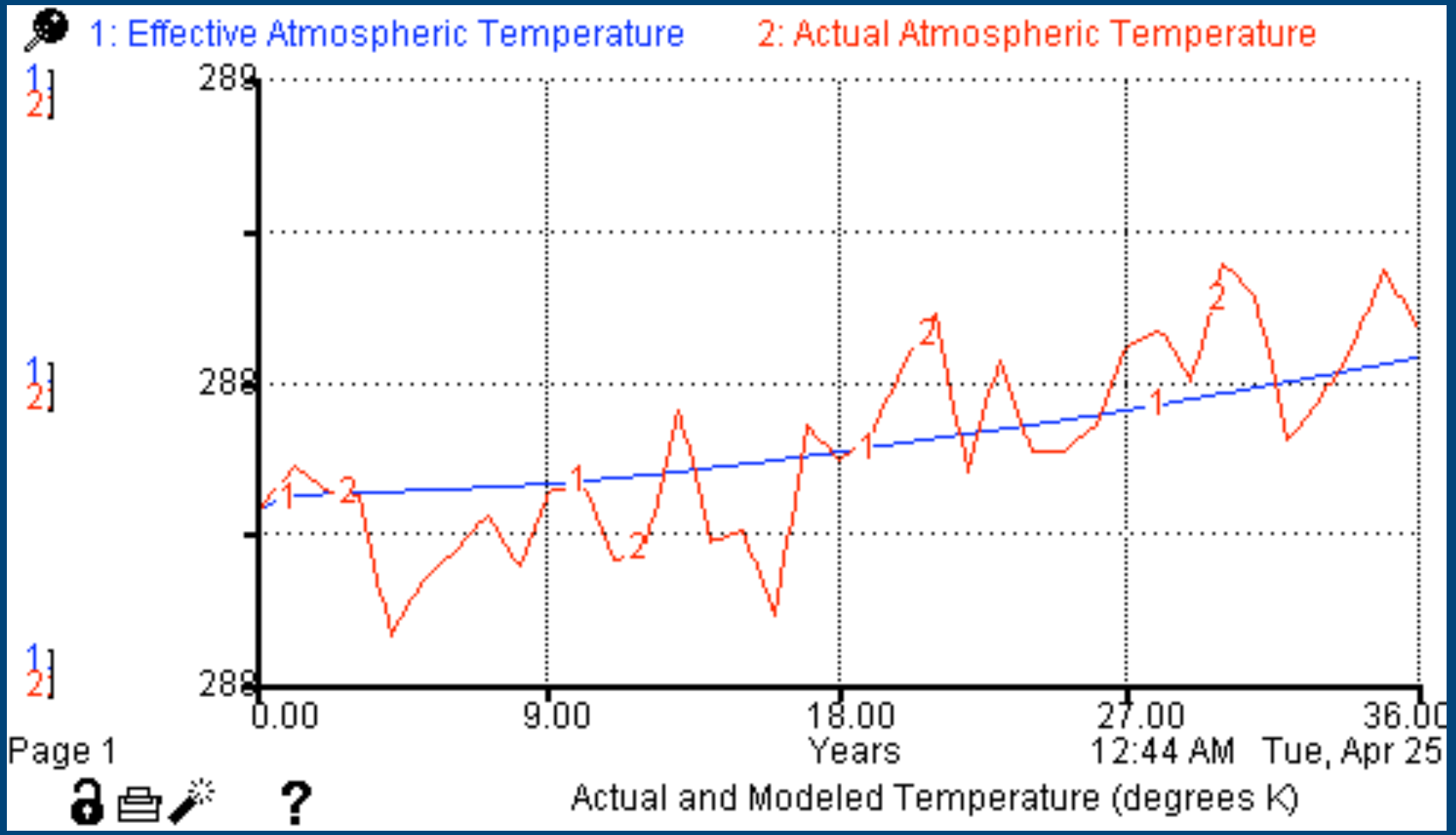
Comparison of CO2 concentration from Mauna Loa Observatory over 1960-1996 with model

Validation



Difference between actual and modeled CO2 concentrations during 1960-1996

Validation

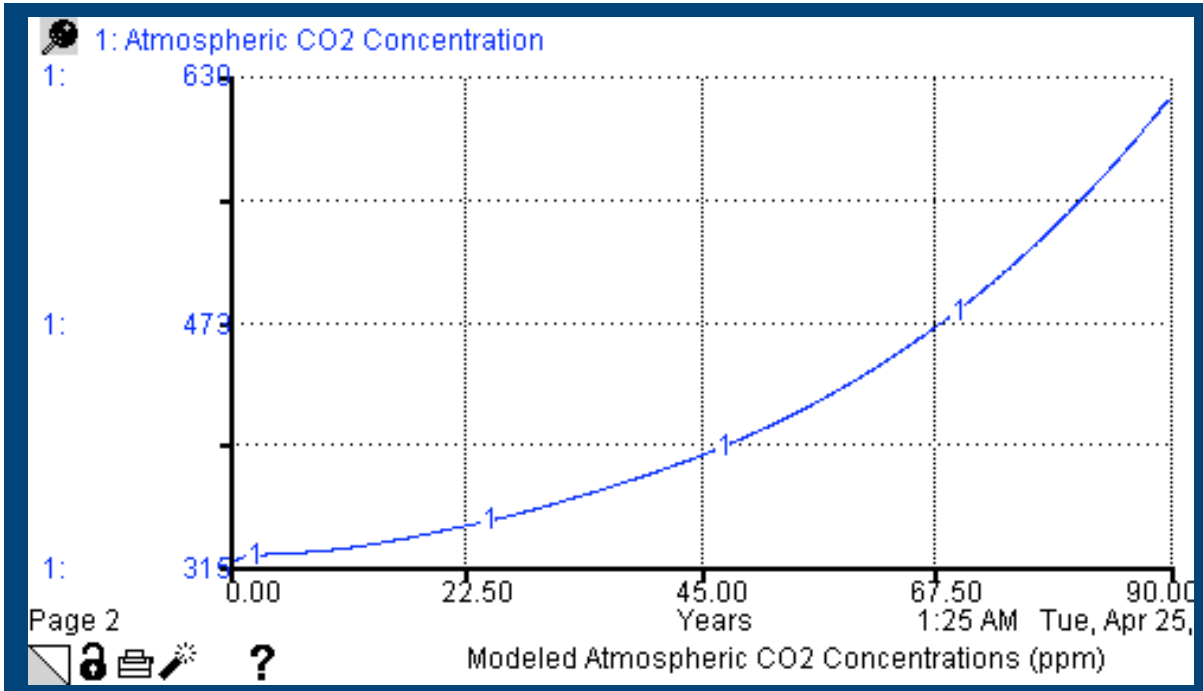


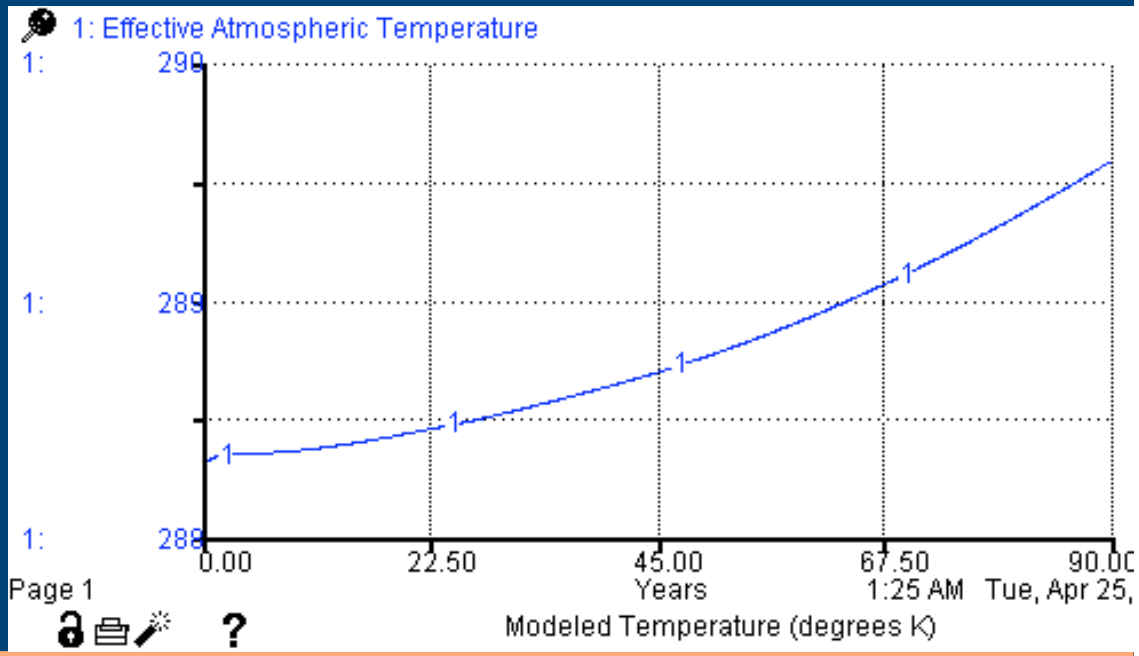
Comparison of annual global mean temperature over 1960-1996 with model

Continuing Current Behavior

An exponential regression of global emissions data from 1960 to 2002 indicates that anthropogenic carbon emissions grew at an annual rate of ***2.25%***.

Continuing this trend would increase atmospheric CO2 concentration to ***616 ppm***, and atmospheric temperature by ***1.0 degree C*** by 2050.

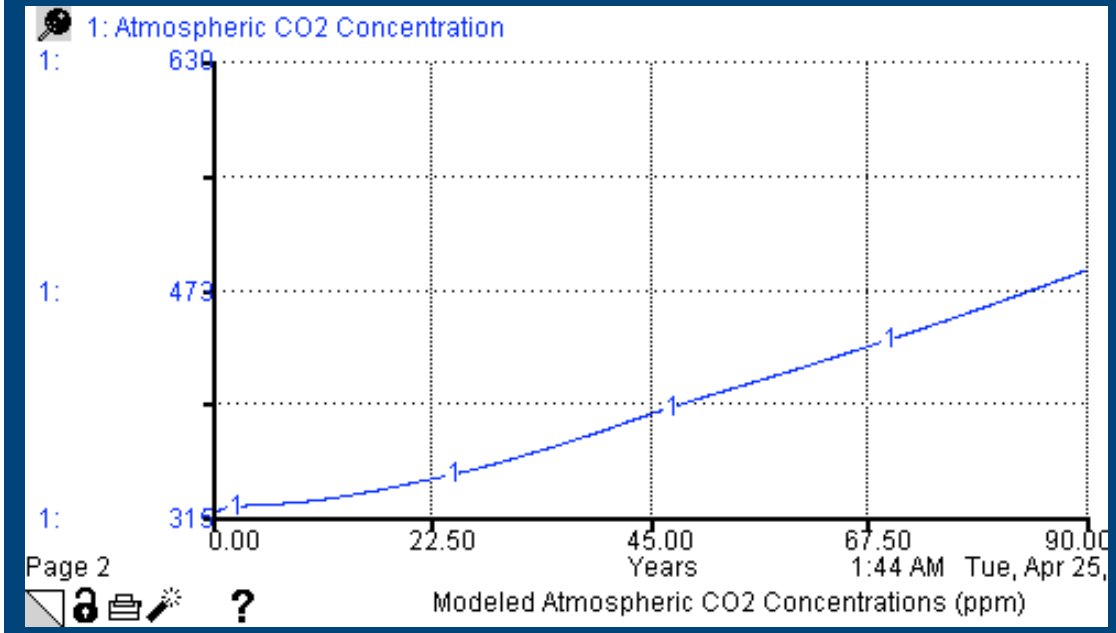

1: Atmospheric CO2 Concentration
1: 630
1: 473
1: 315
0.00
22.50
45.00
67.50
90.00
Years
Page 2
1:25 AM Tue, Apr 25,
Modeled Atmospheric CO2 Concentrations (ppm)

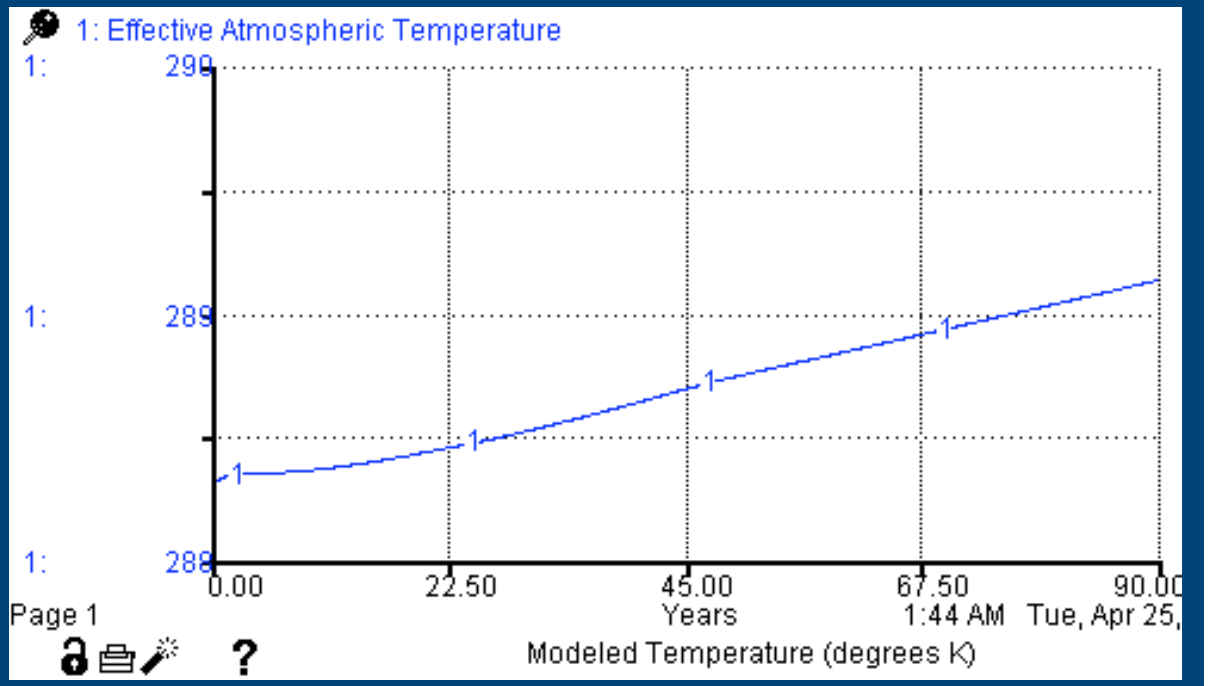

1: Effective Atmospheric Temperature
1: 290
1: 289
1: 288
0.00
22.50
45.00
67.50
90.00
Years
Page 1
1:25 AM Tue, Apr 25,
Modeled Temperature (degrees K)

Kyoto Protocol

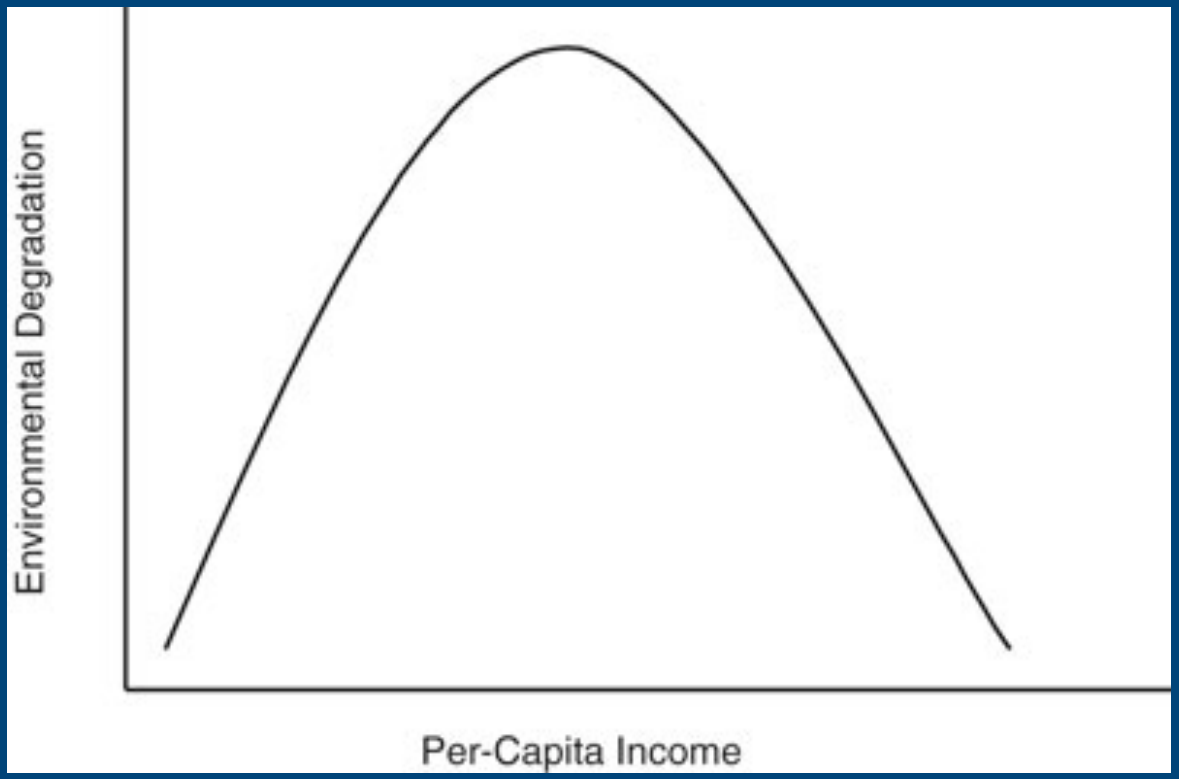
The Kyoto Protocol calls for industrialized nations to reduce their CO2 emissions by 5.2% of 1990 levels.

If we assume that this occurs by roughly 2012, and emissions are constant thereafter, then the global CO2 concentration still increases to ***485 ppm***, and global mean temperature increases to ***0.48 degrees C*** by 2050.

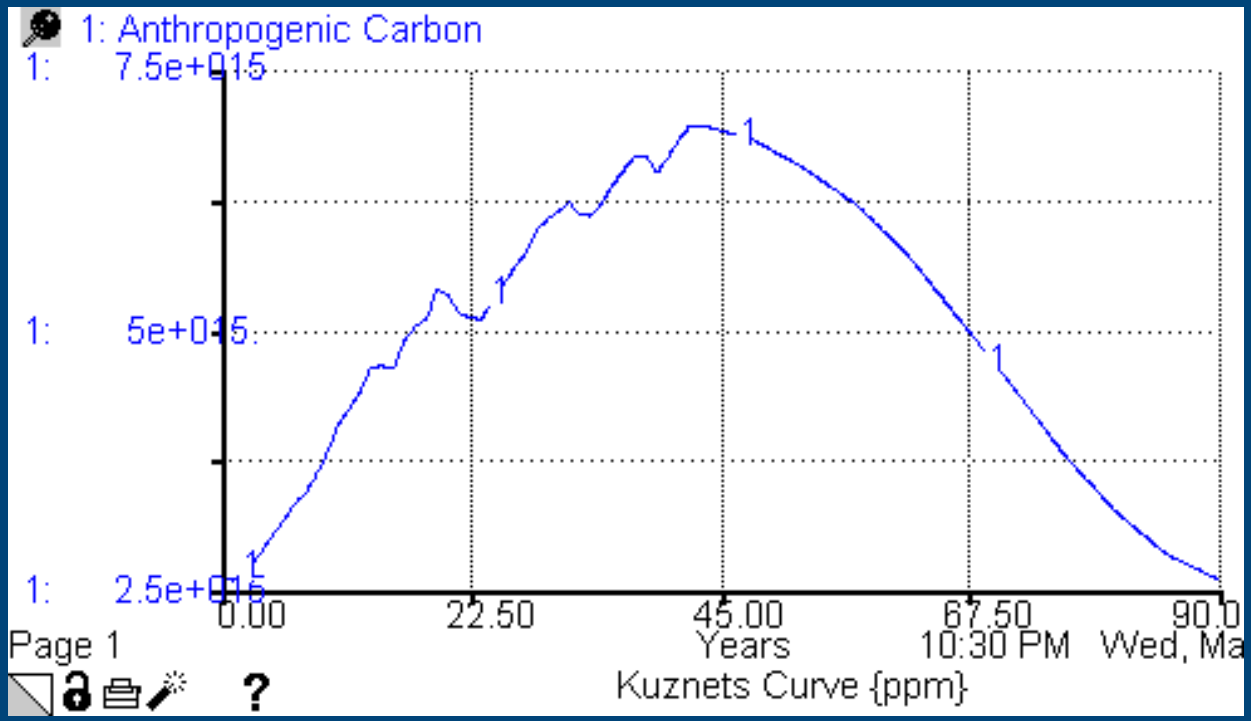

1: Atmospheric CO2 Concentration
1: 630
1: 473
1: 315
0.00
22.50
45.00
67.50
90.00
Years
Page 2
1:44 AM Tue, Apr 25,
Modeled Atmospheric CO2 Concentrations (ppm)


1: Effective Atmospheric Temperature
1: 290
1: 289
1: 288
0.00
22.50
45.00
67.50
90.00
Years
Page 1
1:44 AM Tue, Apr 25,
Modeled Temperature (degrees K)

The Environmental Kuznets Curve

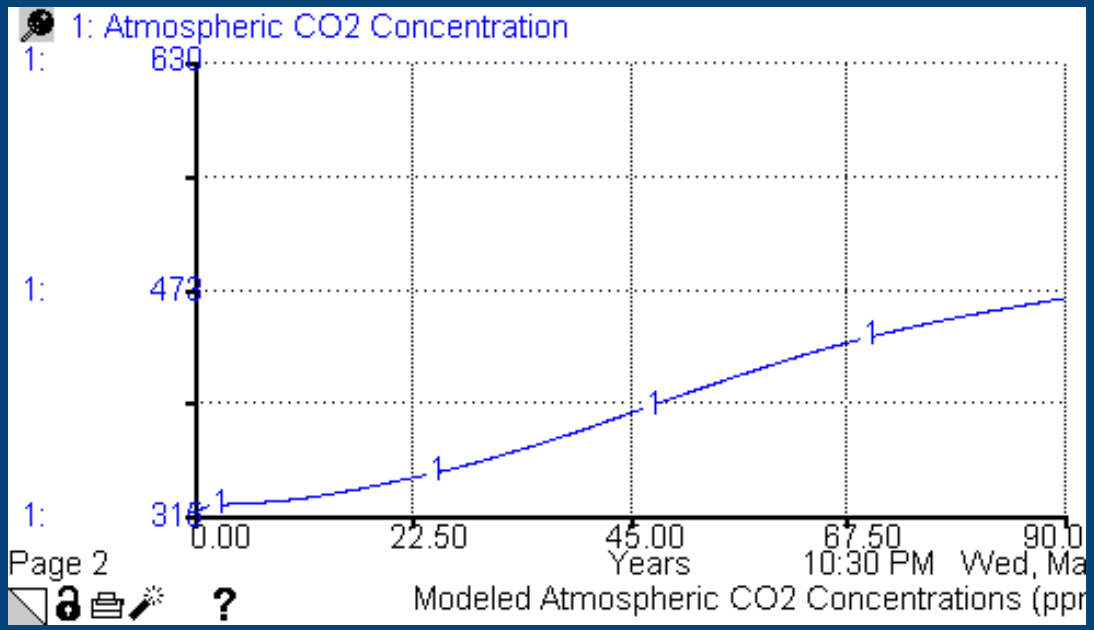


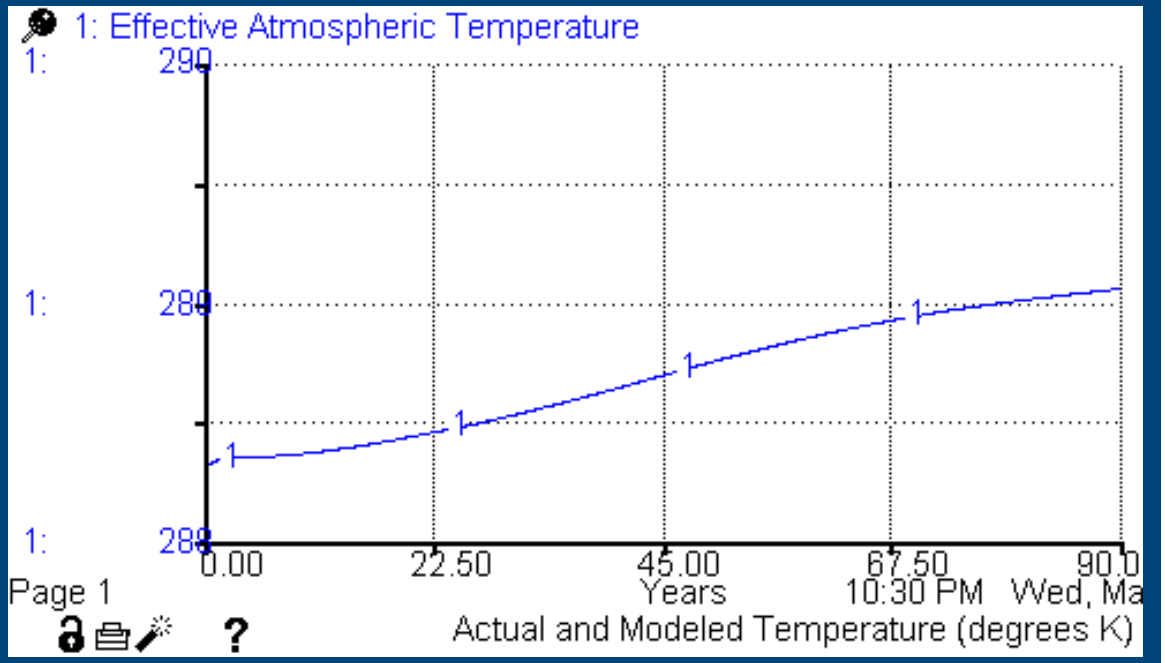
A Best Case Kuznets Curve



Kuznets Curve

Even with the most ideal environmental Kuznets curve, the global CO2 concentration still increases to ***465 ppm***, and global mean temperature increases to ***0.44 degrees C*** by 2050.


1: Atmospheric CO2 Concentration
1: 630
1: 473
1: 315
0.00
22.50
45.00
67.50
90.0
Years
Page 2
10:30 PM Wed, Ma
Modeled Atmospheric CO2 Concentrations (ppr


1: Effective Atmospheric Temperature
1: 290
1: 280
1: 288
0.00
22.50
45.00
67.50
90.0
Years
Page 1
10:30 PM Wed, Ma
Actual and Modeled Temperature (degrees K)

Acknowledgements

Special thanks to Diana Fisher for teaching me systems dynamics and many, many other topics in mathematics, science, and programming.