Response to Climate Change: Adaptation and Mitigation Requires A Robust Economy*

By
John M. Armentrout[1]

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[1]Consultant, Cascade Stratigraphics Inc., Damascus, OR. (jarmenrock@msn.com)

Abstract

Climate change and global warming are issues of great concern to humankind. The geologic record documents a cyclic pattern of warm versus cool climates throughout Earth's history. Recent observations and data collections demonstrate a significant pattern of ocean and atmospheric warming. Controversy exists as to how much of this change is part of natural cycles and how much is contributed from anthropogenic greenhouse gas and aerosols. How these patterns of climate change impact society requires careful evaluation of data and predictive models for future climates. Our response must include both adaptation to change and mitigation of consequences. Adaptation is adjustment to our environment, such as retreat from the present shoreline as sea level rises or changes in planting schedules or areas as rainfall patterns shift. Mitigation involves efforts to modify or negate the consequences of environmental change, including constructing and strengthening levees to control higher river discharge into an ocean with rising sea level. Many professional organizations representing members active in energy and resource industries have a role in our understanding both climate change and global warming. These organizations exist to advance the science and profession of energy-related geosciences worldwide, through assembly and distribution of the best science related to the discovery and production of oil, natural gas, coal and other forms of energy. This is a shared responsibility with other energy-resource related societies. The necessary development of new technologies and the maintenance of the existing energy-supply infrastructure require investment capital from a robust global economy. Energy for that global economy will be supplied by fossil fuels for the foreseeable future.

AAPG Annual Meeting, San Antonio, April 2008

Climate Change Science

What do the data interpretations suggest?

John M. Armentrout
Geologist
Damascus, Oregon

Armentrout, 4/16/2008

Climate science is intriguing and a challenge ----

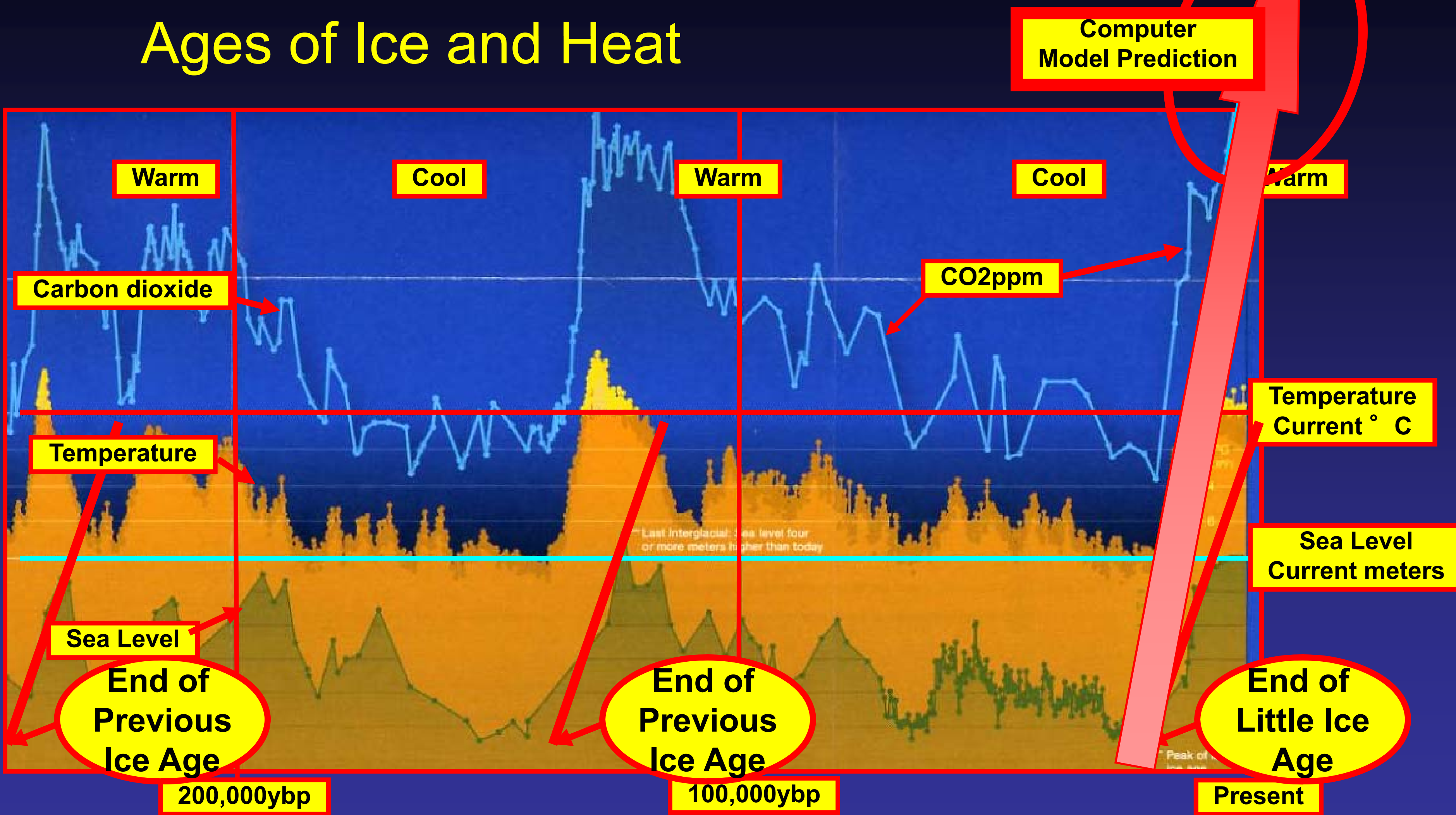
and how it impacts our future is a critical issue!

My Family

Armentrout, 4/16/2008

Climate has a History

Ages of Ice and Heat



A Cyclic Pattern

Bourne, National Geographic, August 2007 (chart)

Subjects

Atmospheric Pollution with Green House Gases

(CO_2; N_2O; SF_6; PFC; HFC; H_2O)

Global Warming of the atmosphere and oceans

Consequences:

- Glacial and Permafrost Melt – land disruption.
- Sea Level Rise – displacing populations.
- Increased Storm Intensity – megafloods.
- Rainfall Pattern Change – crop failure and famine.
- Others

Climate Change Science

Critical Questions:

- Is global warming a natural cycle or human-caused?
- Is the rate of climate change accelerated by humankind?
- Can humankind modify climate change?

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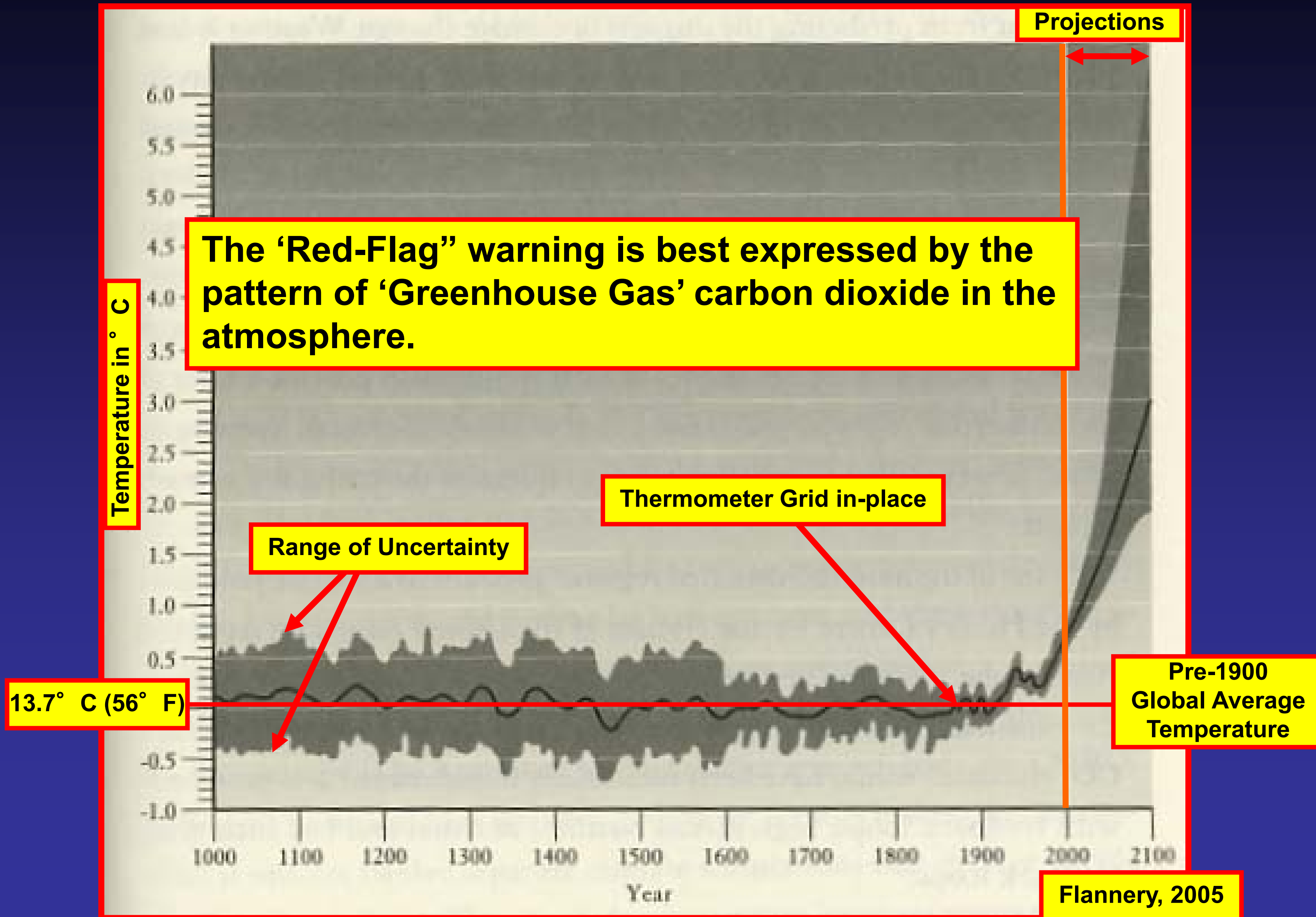
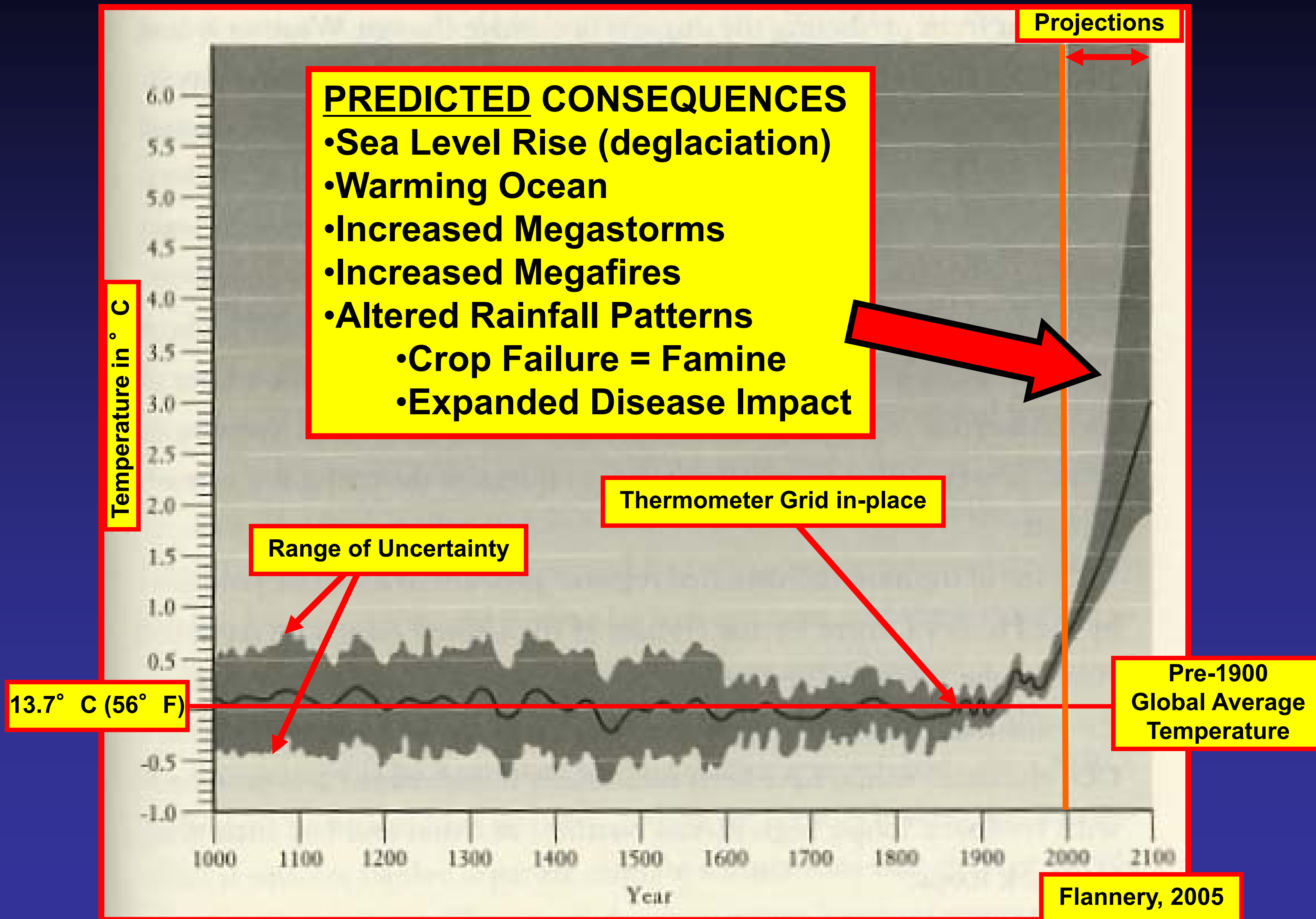
The “Hockey Stick” Curve

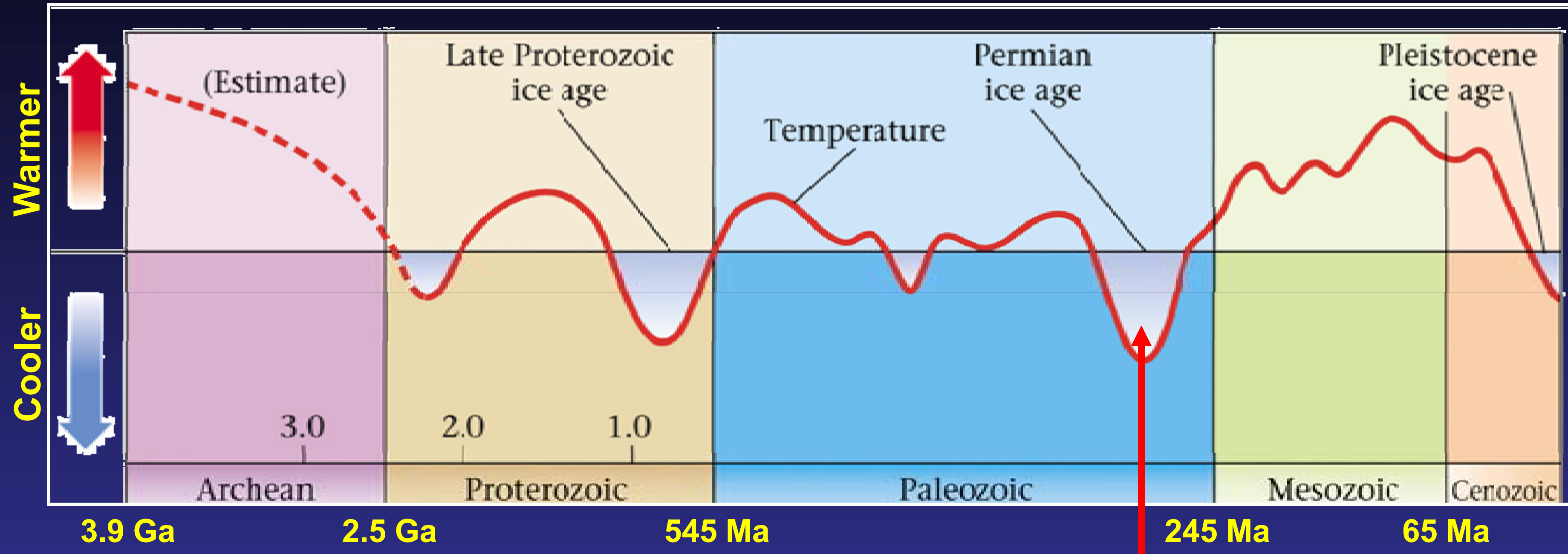


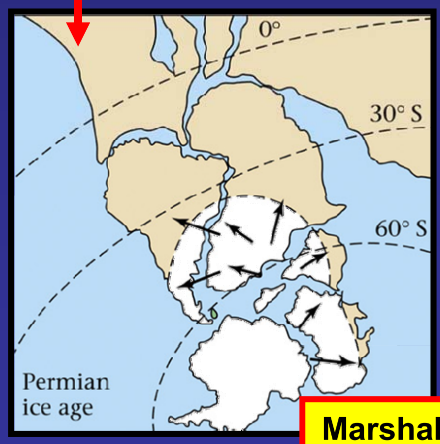
"Hockey Stick" Curve = Accelerated Global Warming



Armentrout, 4/16/2008

A Geological Perspective on Climate Change





Marshak, 2004

Geologist's think in Deep-Time (Ma-Ga)

Politician's think in Election Cycles
(2 yrs., 4 yrs., 6yrs., 8yrs.)

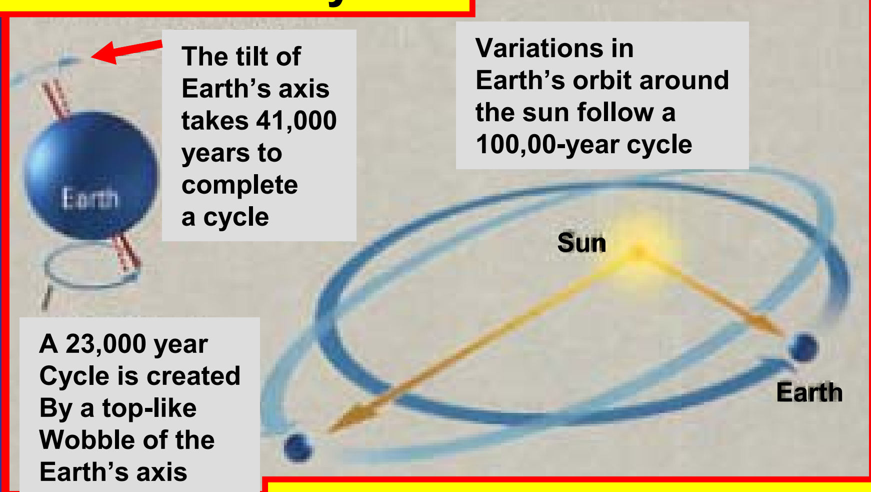
For many folks it's the next meal

Armentrout, 4/16/2008

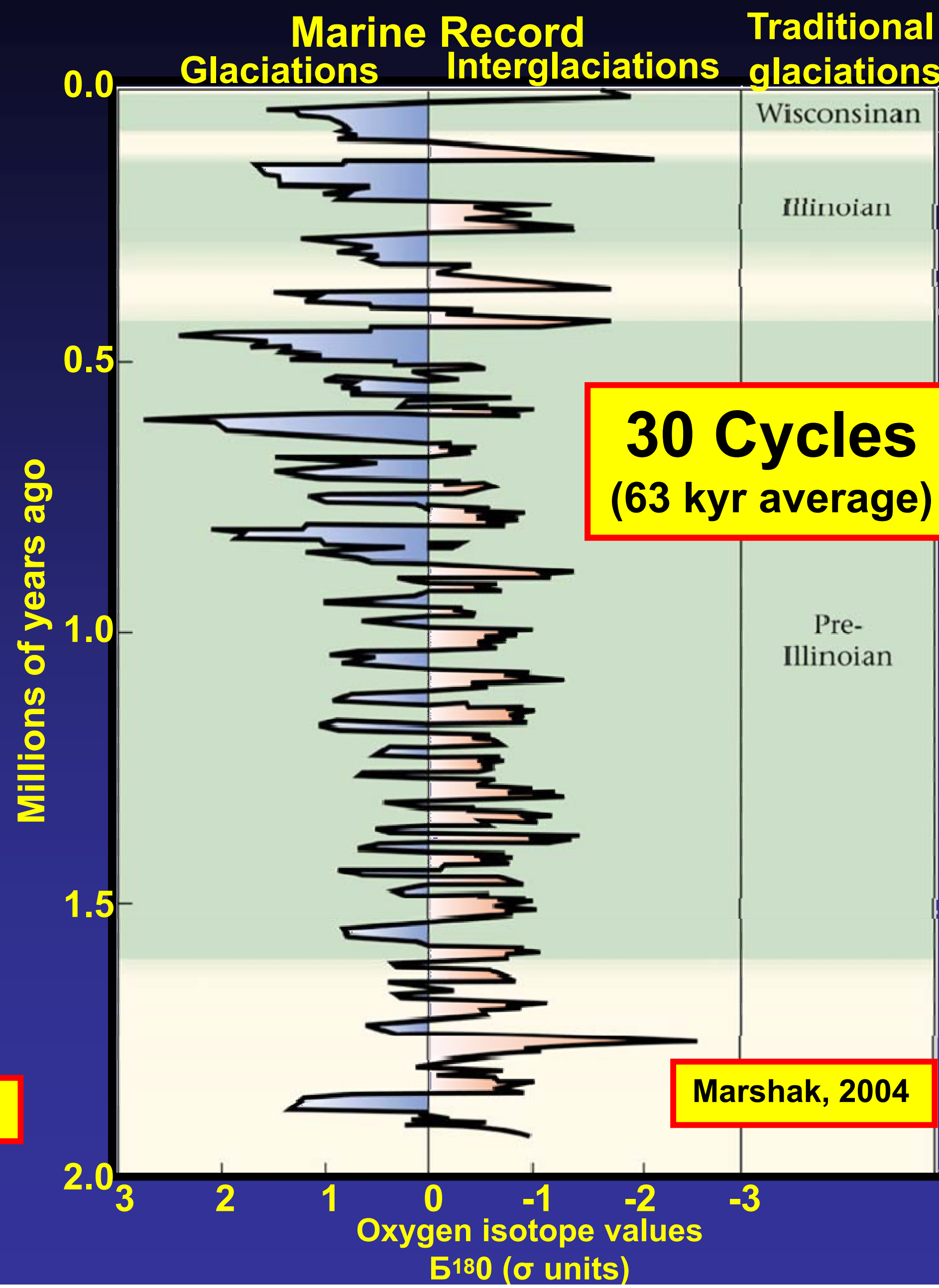
Pleistocene Ice Ages

Dominant 'drivers' are changes in solar energy input due to orbital and spin motions of Earth.

Milankovitch cycles



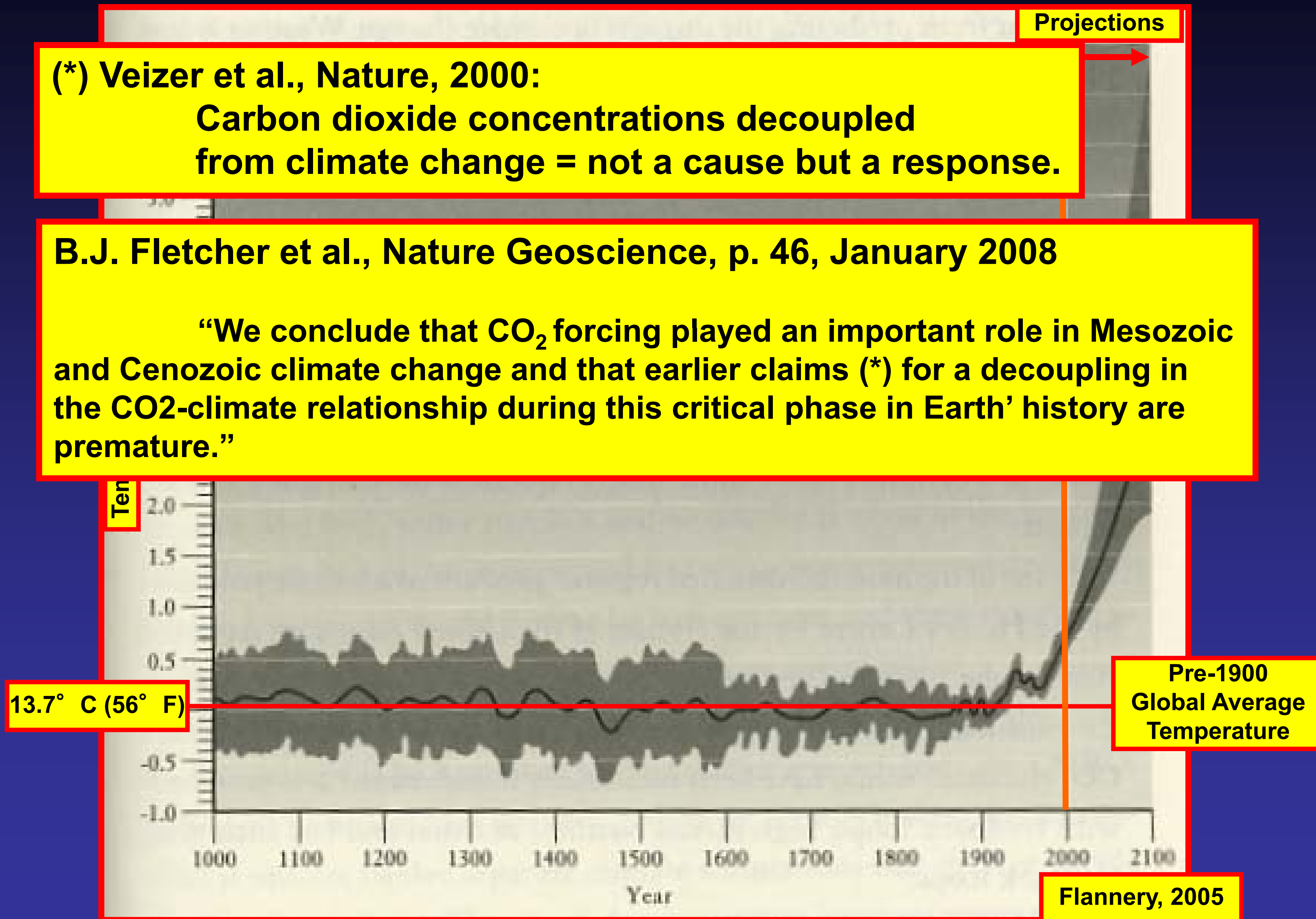
Suplee, National Geographic, May 1998



30 Cycles
(63 kyr average)

Marshak, 2004

? Is Carbon Dioxide the Driver of or Response from Warming?



(*) Veizer et al., Nature, 2000:
Carbon dioxide concentrations decoupled from climate change = not a cause but a response.

B.J. Fletcher et al., Nature Geoscience, p. 46, January 2008

"We conclude that CO_2 forcing played an important role in Mesozoic and Cenozoic climate change and that earlier claims (*) for a decoupling in the CO2-climate relationship during this critical phase in Earth' history are premature."

Melting of Glaciers

"Ice is on the run in its mountain and polar strongholds. As the ice sheets on Greenland and Antarctica shrink in the <u>next few centuries</u>, seas could rise 20 feet."

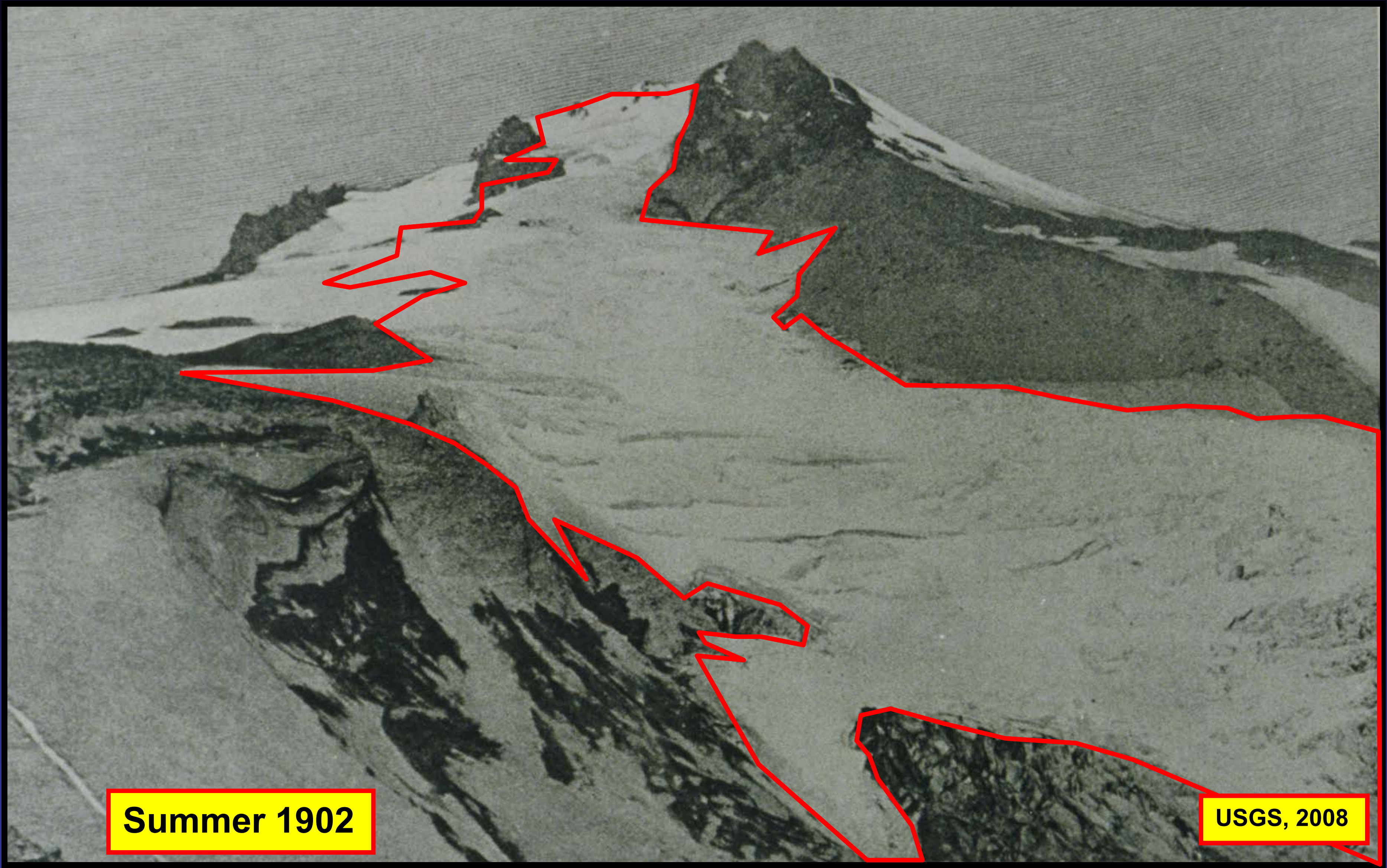
Appenzeller, Nat. Geog. 2007

Note the data is from 1977 to 2005. This reflects satellite data = not a very long history for climate patterns.

Appenzeller, National Geographic, June 2007

Armentrout, 4/16/2008

Melting of Glaciers: White River Glacier: Mt. Hood, Oregon



Armentrout, 4/16/2008

Melting of Glaciers: White River Glacier: Mt. Hood, Oregon

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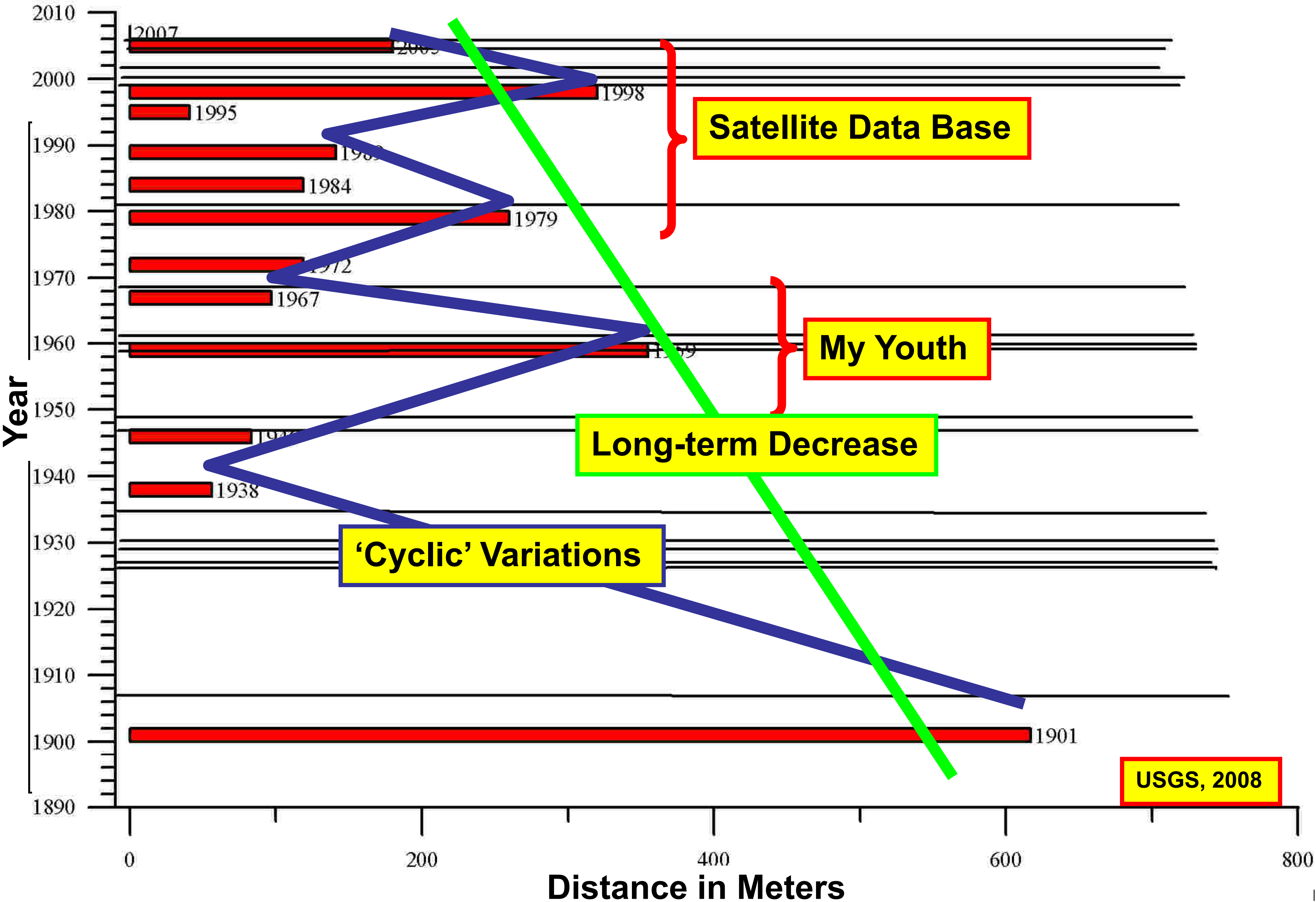
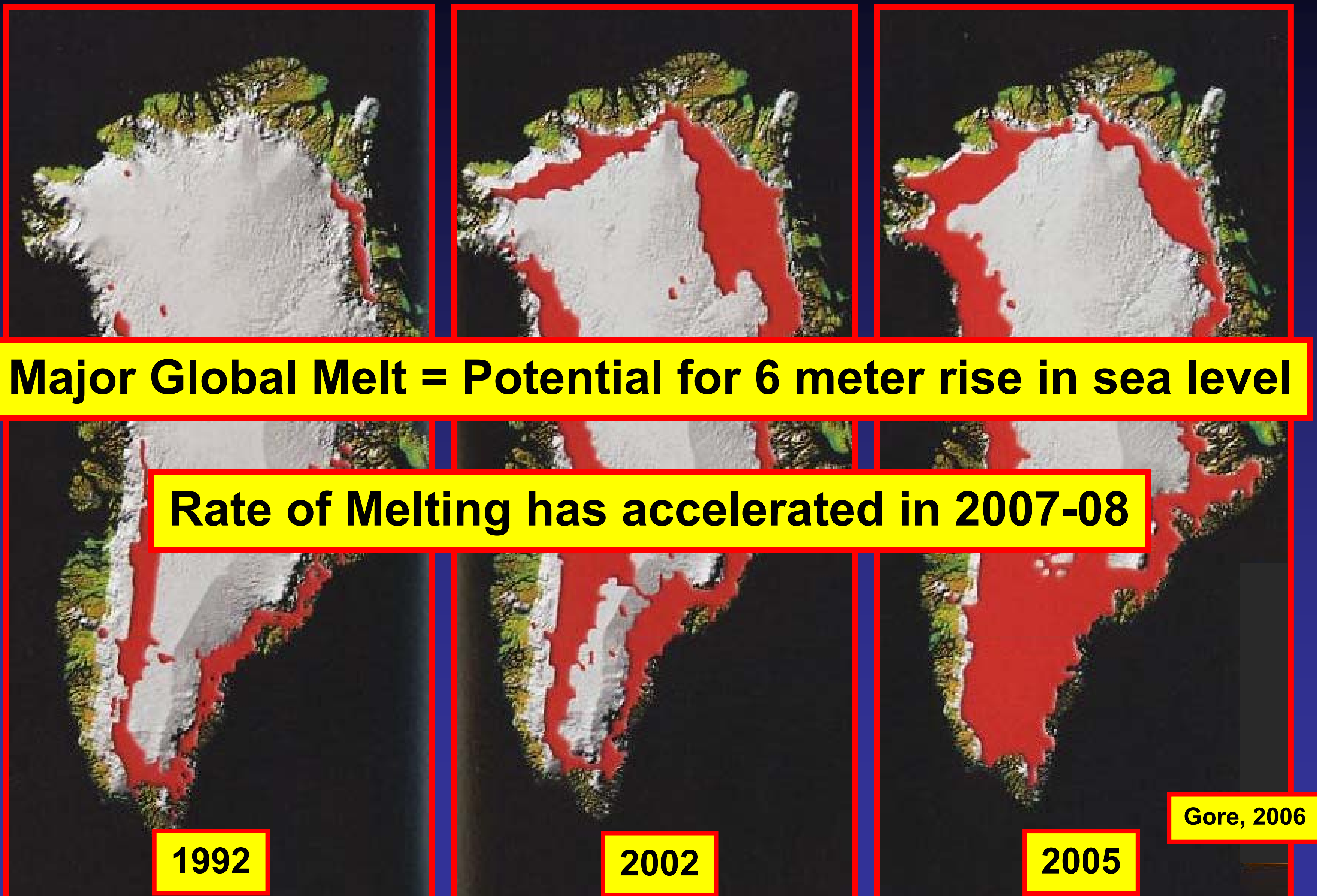


Armentrout, 4/16/2008

Melting of Glaciers: Greenland Ice Cap Melting



Major Global Melt = Potential for 6 meter rise in sea level

Rate of Melting has accelerated in 2007-08

Rates of Sea Level Rise

- 2.6mm/yr — Recent rate of rise
- 3.5mm/yr — Modeled future rate
- 11mm/yr — Last deglaciation (max) (14-7 kyr)
- 11-20mm/yr — Previous deglaciation (130-118 kyr)

Overpeck et al., Science, 2006:

Years to reach different magnitudes of sea level rise:

	Rate of Rise	Years-1.0m	Years-5.8m	Years-6.1m
Probable	2.6mm/yr	384	2230	2346
	3.5mm/yr	285	1657	1743
Possible	11mm/yr	90	527	555
	20mm/yr	50	290	305
Extreme	44mm/yr	23	132	139

Compiled by Armentrout, 2007

Armentrout, 4/16/2008

Louisiana in 2100 – with a one meter rise in sea level

"We have to recognize that Global Warming is part of our future, Sea Level Rise is part of our future."

Ivor Van Heerden, Louisiana State University (quoted in Bourne, 2007)

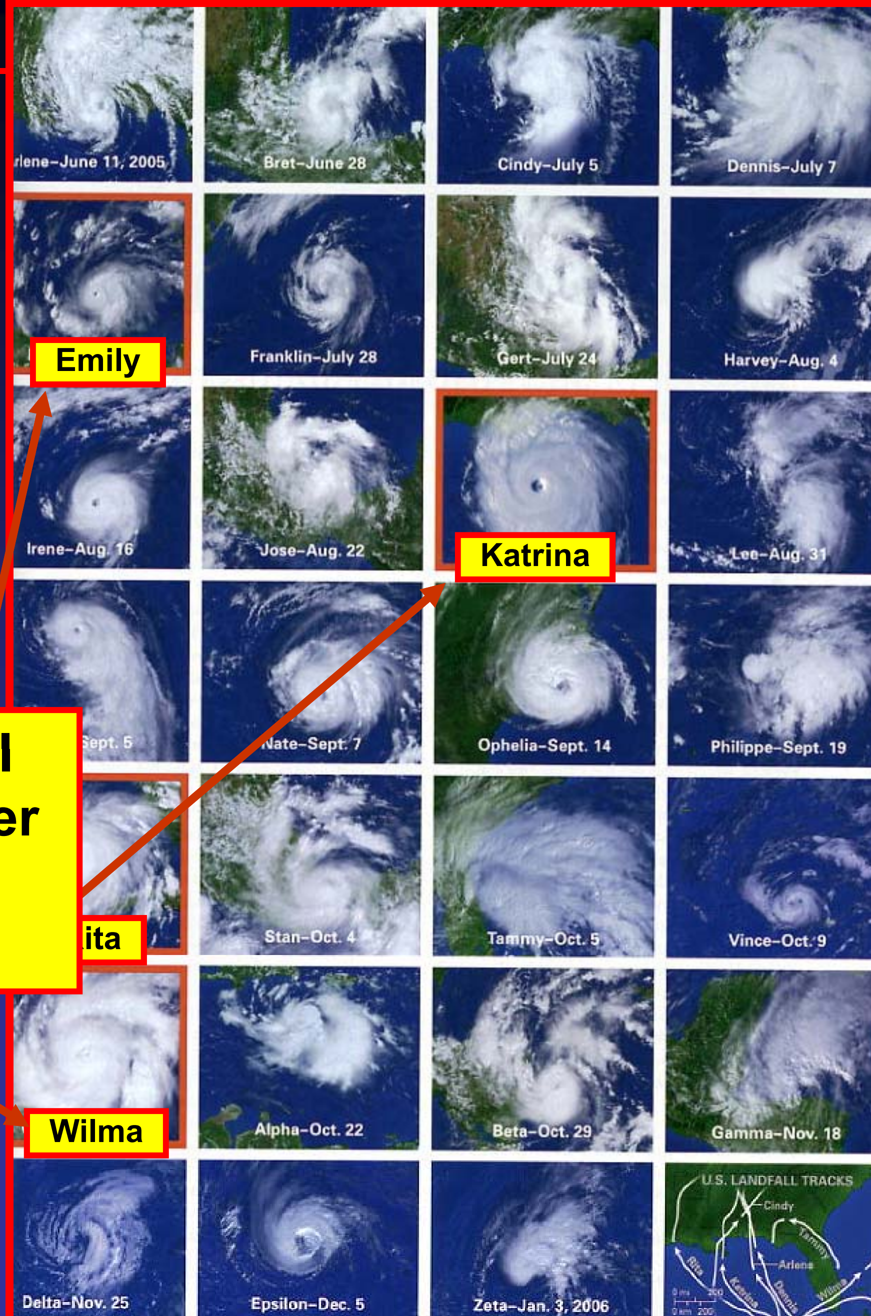
Bourne, National Geographic, August 2007

2005 Hurricanes

27 Atlantic Hurricanes:
7 made landfall in US
4 were category 5

Never had 15 hurricanes been spotted in one season, including four Category 5 storms.

"We're 11 years into the cycle. I can't tell you if it will last another ten years, or thirty."
Gerry Ball, NOAA meteorologist



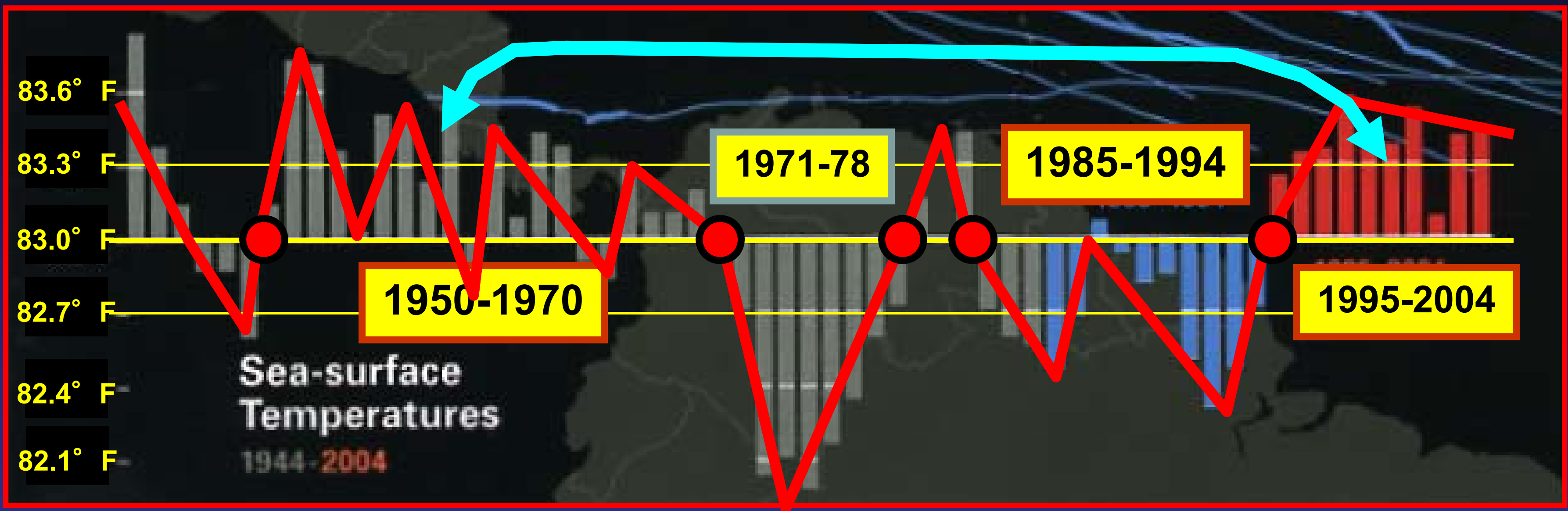
Category 5 Hurricanes

Hayden, National Geographic, August 2006

Armentrout, 4/16/2008

Sea Surface Temperature Cycles 1944-2004

Compare the current temperatures with the 1950-1970 'cycle'

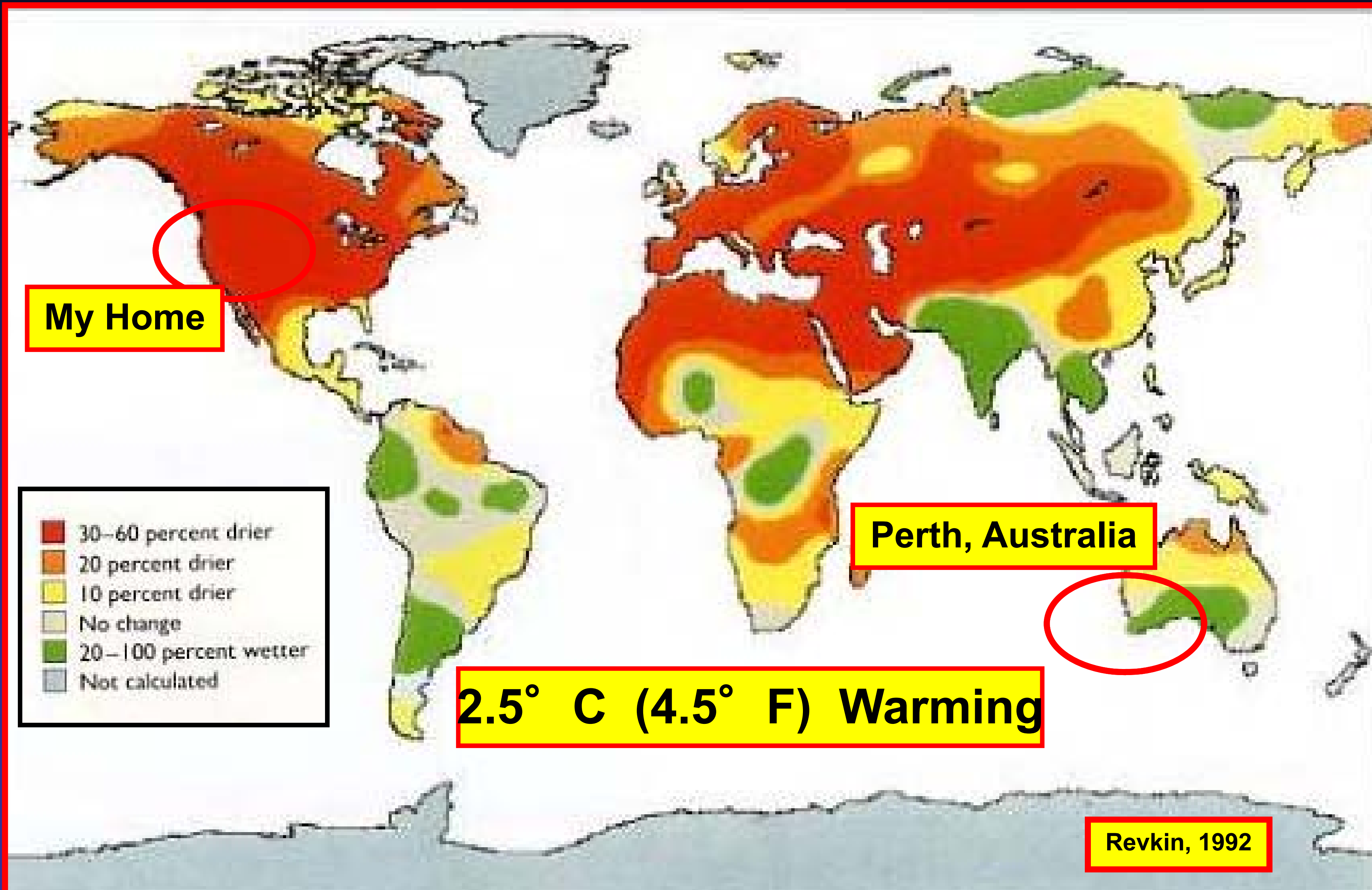


"Frequency of major hurricanes rises and falls on a multidecadal time frame … that scientists are still trying to understand"

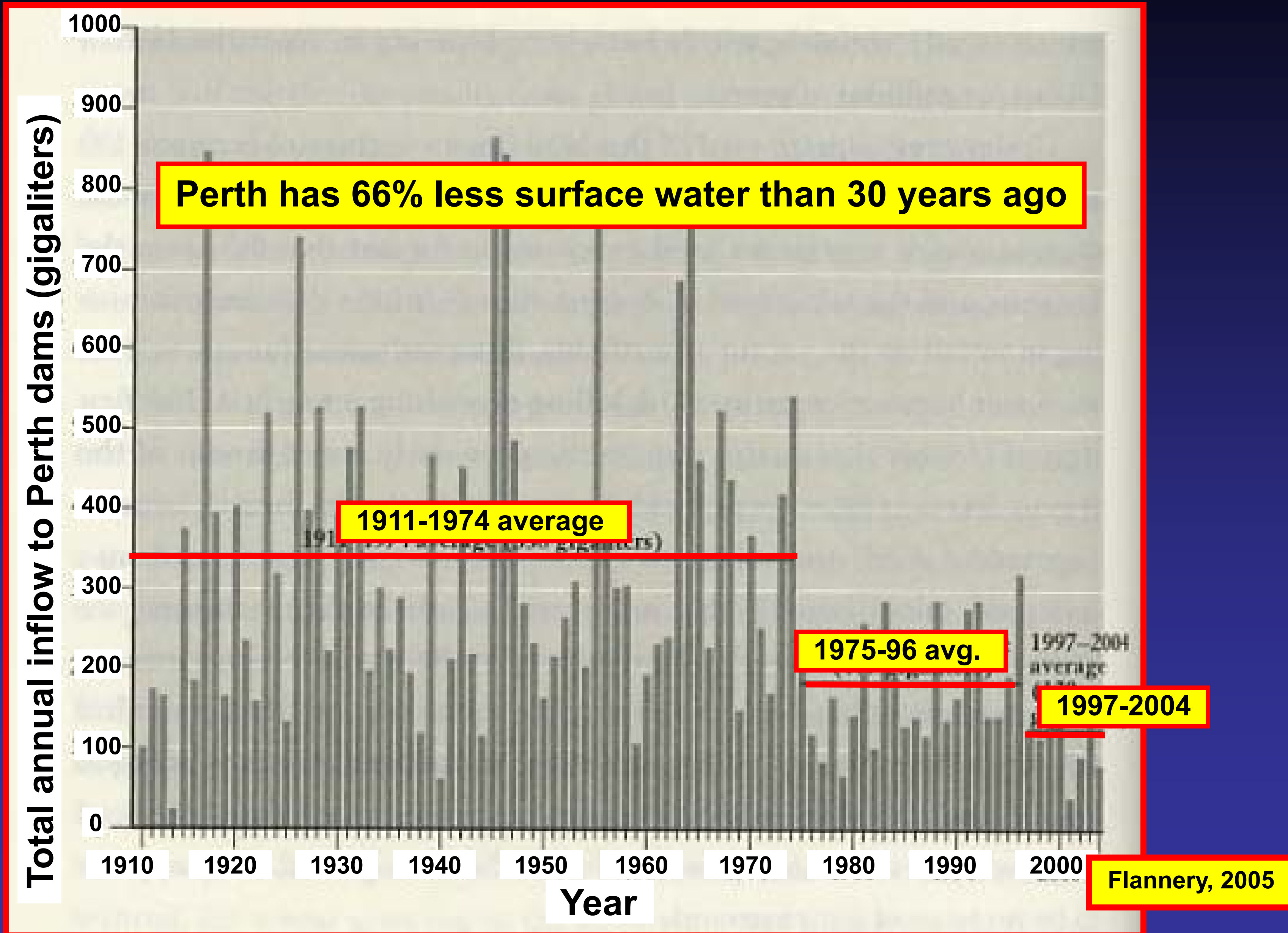
? A Cyclic Pattern ?

Carroll, National Geographic, August 2005

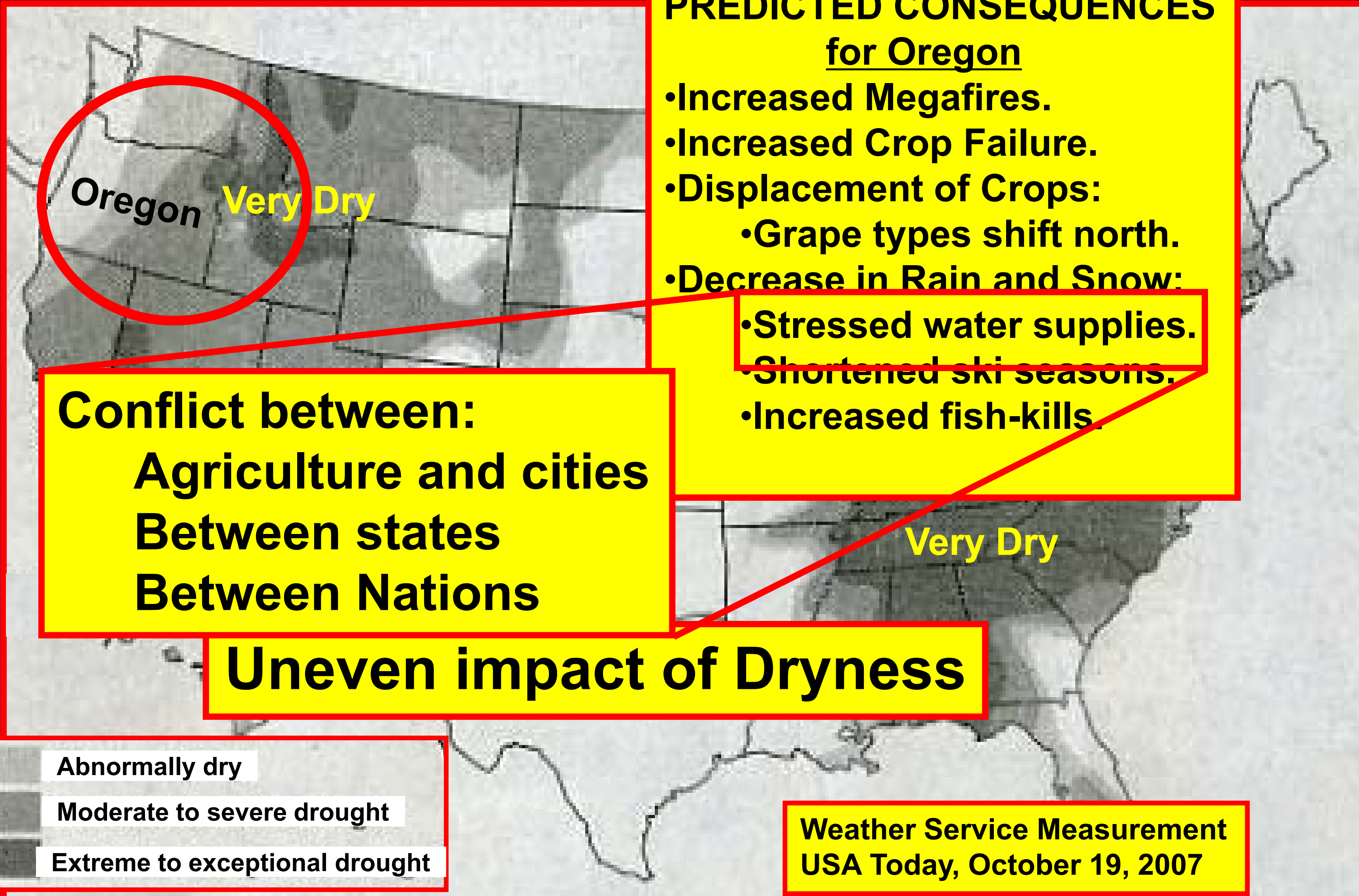
Rainfall Patterns: Computer Prediction with Warming



Rainfall Patterns: Perth's Catchment Basin



Rainfall Patterns: USA Dryness Conditions 2007



PREDICTED CONSEQUENCES for Oregon

- Increased Megafires.
- Increased Crop Failure.
- Displacement of Crops:
  - Grape types shift north.
- Decrease in Rain and Snow:
  - Stressed water supplies.
  - Shortened ski seasons.
  - Increased fish-kills.

Conflict between:

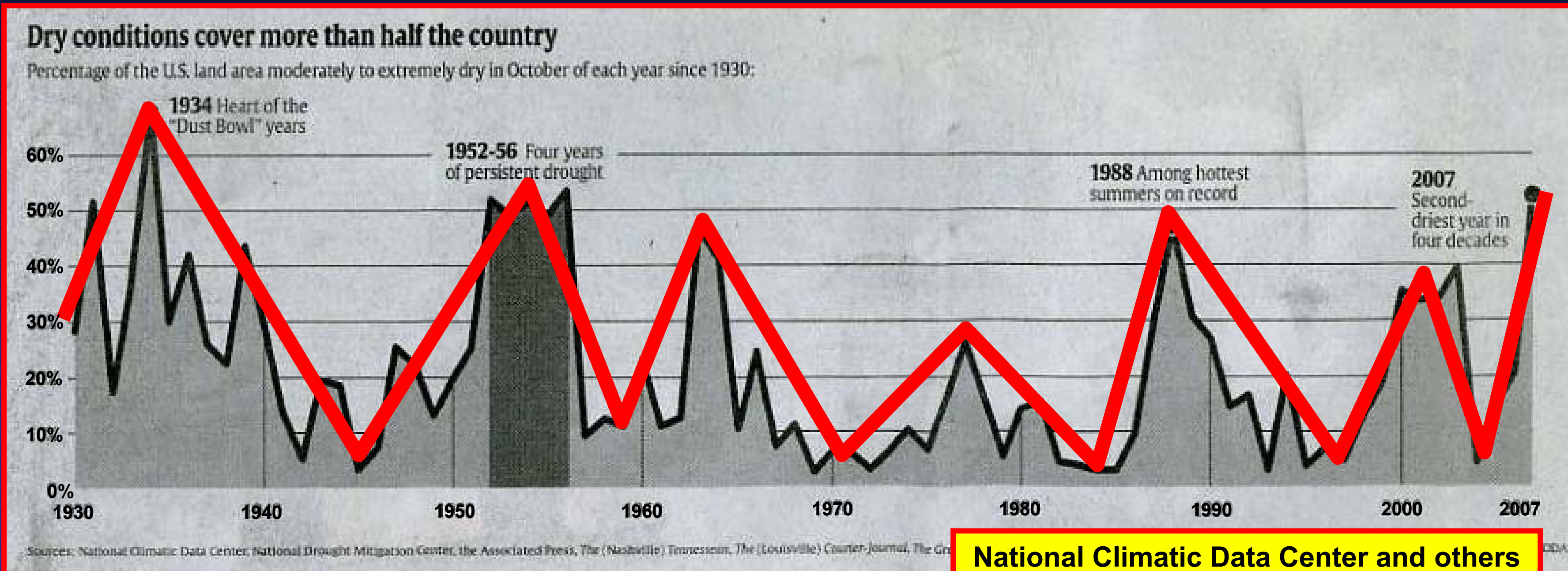
- **Agriculture and cities**
- **Between states**
- **Between Nations**

Uneven impact of Dryness

Weather Service Measurement
USA Today, October 19, 2007

USA Rainfall Pattern 1930 to 2007

Percentage of USA area moderately to extremely dry in October of each year



National Climatic Data Center and others

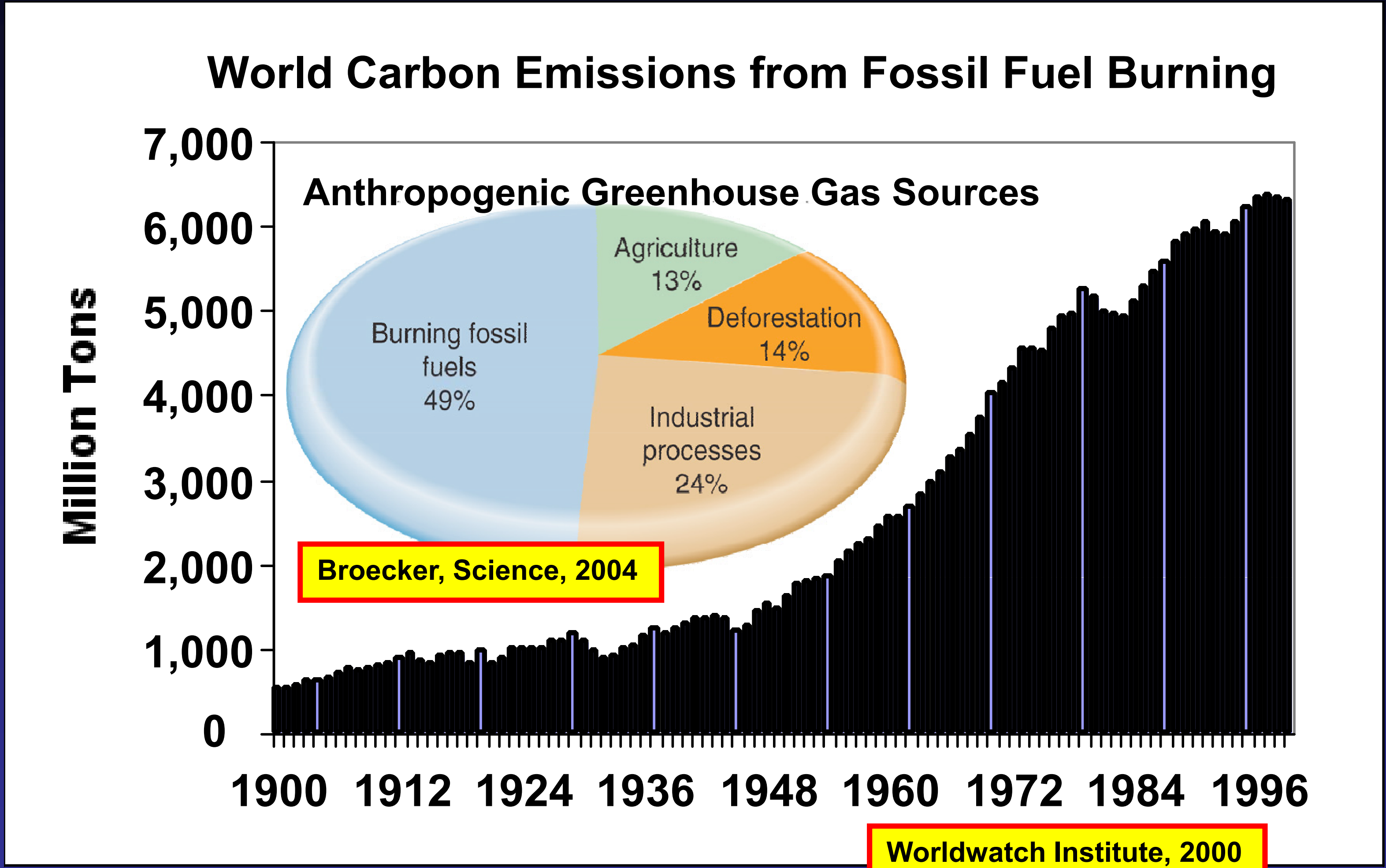
? A Cyclic Pattern ?

? La Nina – El Nino ?

USA Today, October 19, 2007

Armentrout, 4/16/2008

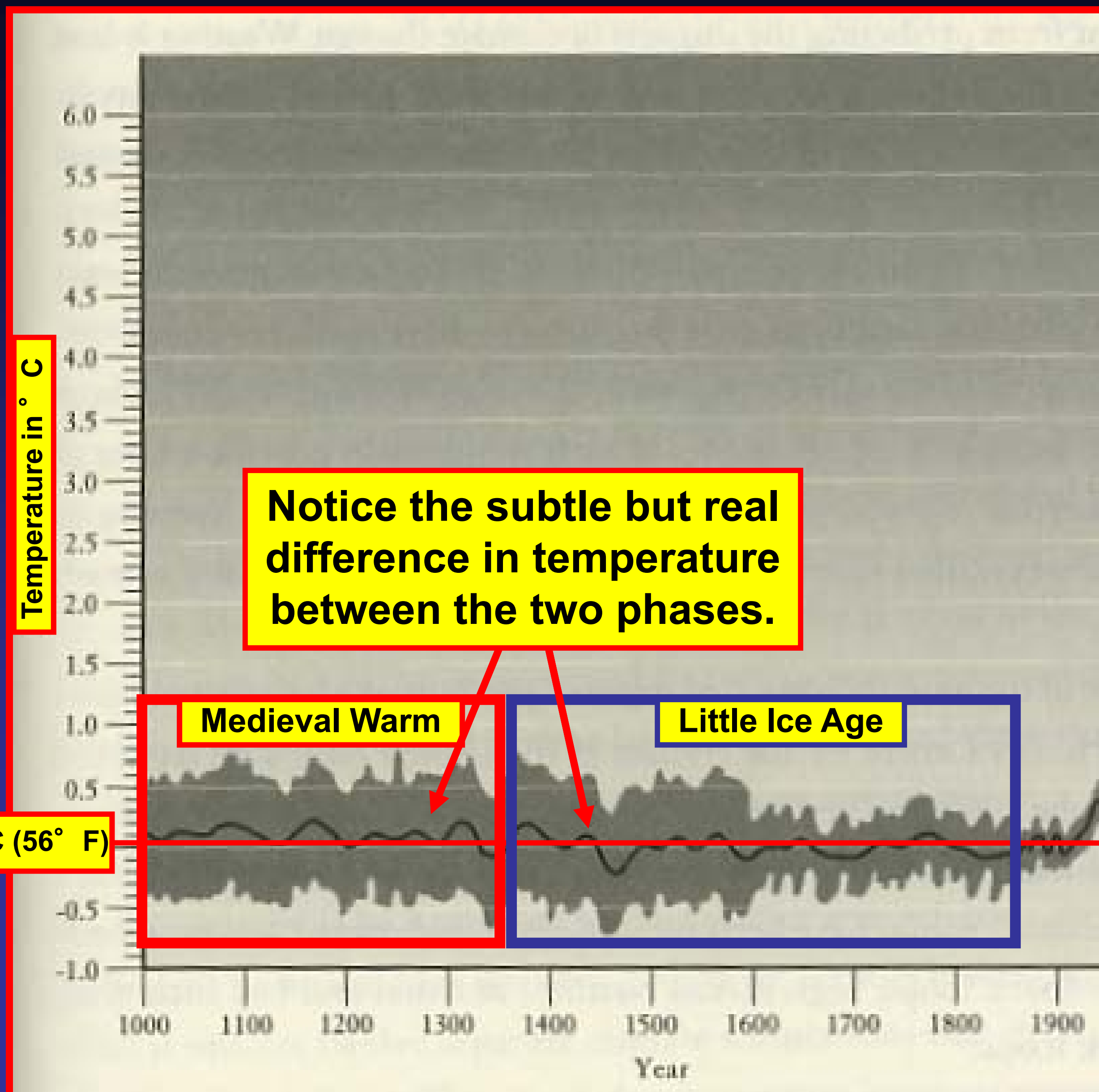
Gigatons of Carbon Emissions Each Year



Worldwatch Institute, 2000

~4000 Gigatons of carbon added to atmosphere from 1960 to 2000 can easily account for measured increase in atmospheric carbon dioxide.

A History of Climate Change



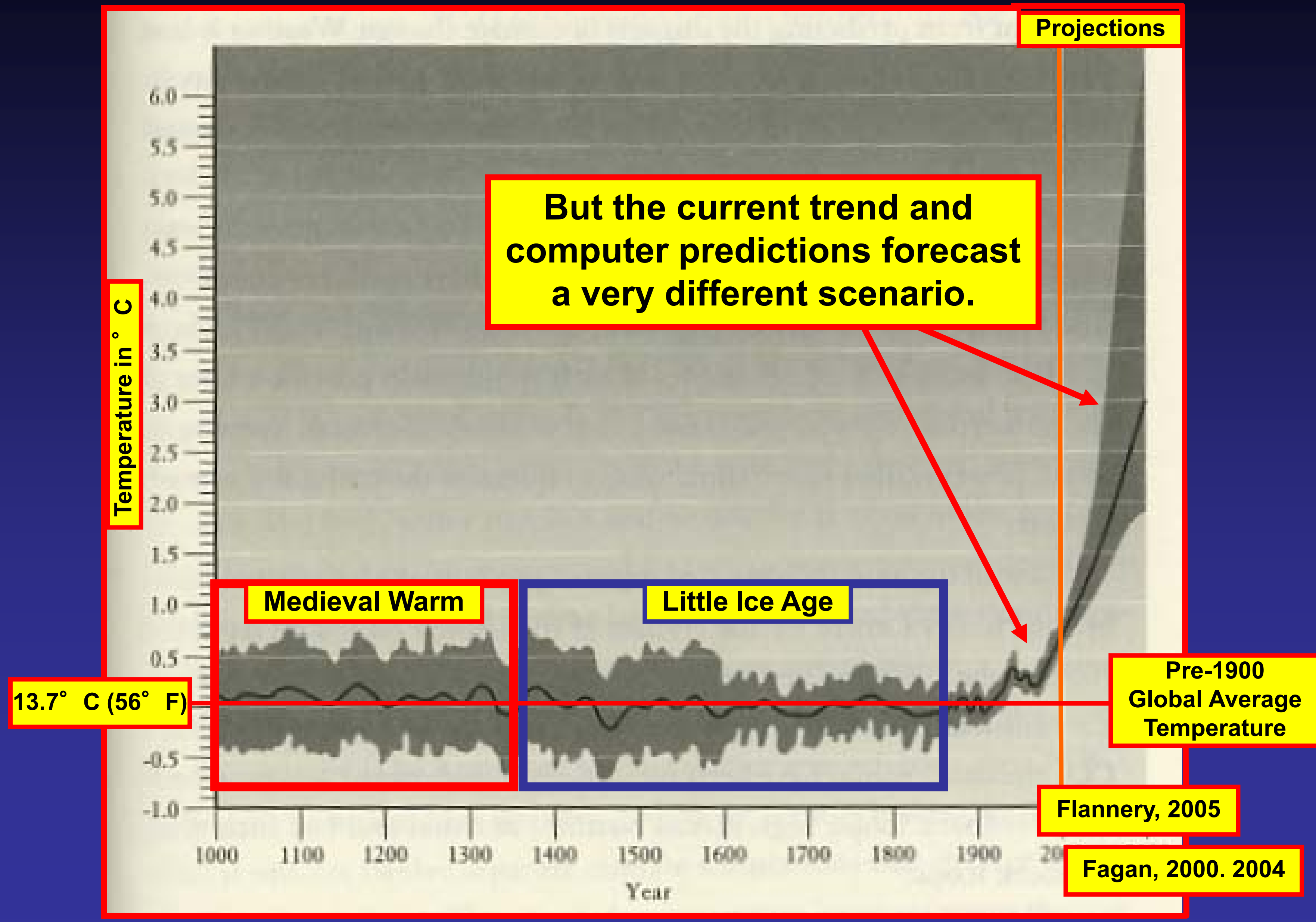
13.7° C (56° F)

Pre-1900 Global Average Temperature

Flannery, 2005

Fagan, 2000. 2004

A History of Climate Change



One man's opinion (Armentrout):

Is global warming a natural cycle or human-caused?

Much of the currant climate change is part of a natural cycle, but the consequences still impact humankind significantly. We must plan for adaptation and mitigation. With an increasing population we are increasingly vulnerable to any climate change.

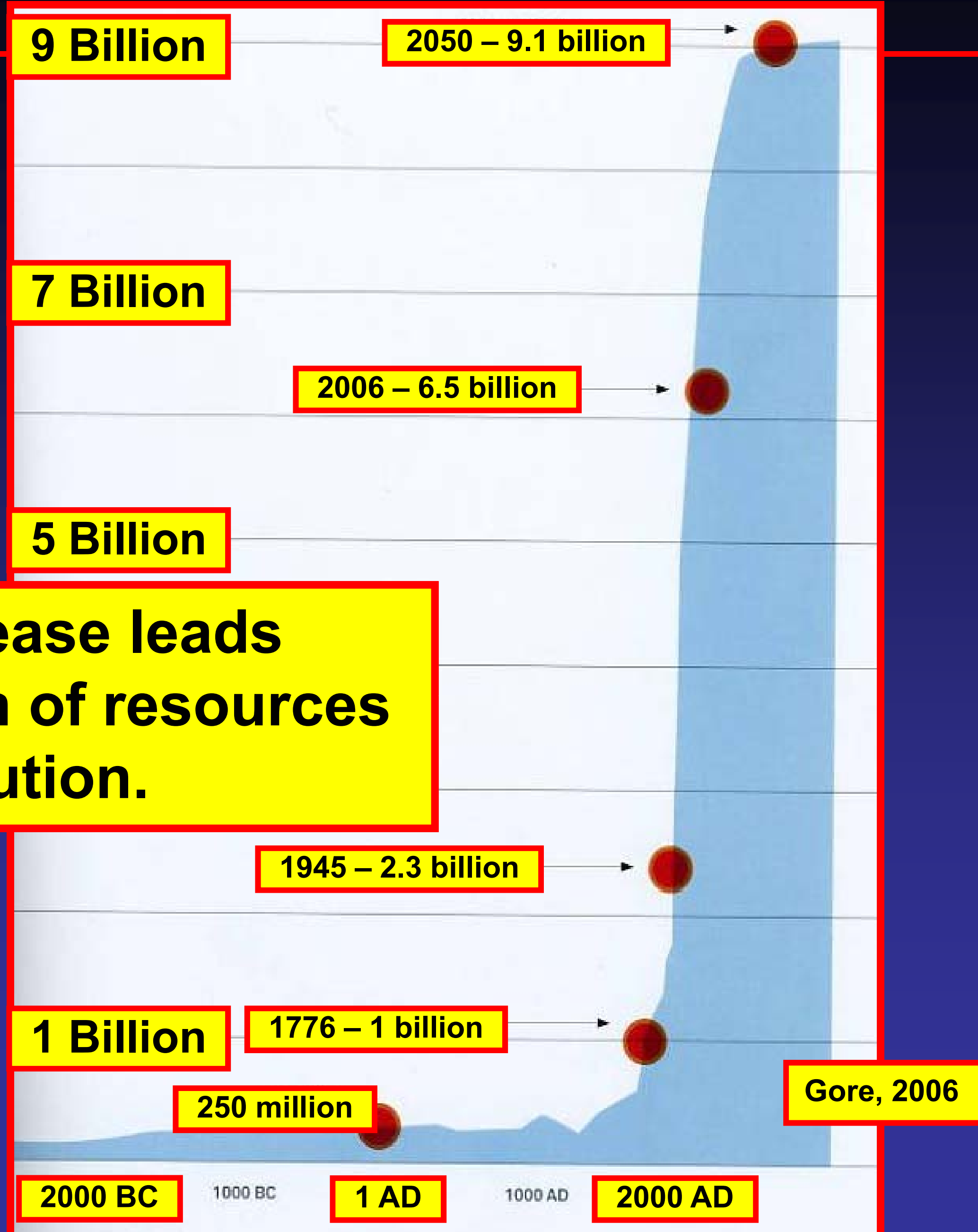
Is the rate of climate change accelerated by humankind?

Scientific evidence strongly points toward accelerated climate change. Can the natural ecosystems and human populations adapt fast enough to avoid catastrophes?

Population

The Earth can support approximately 3.1 Billion people with a sustainable environment and economy.

Grant, 2005



Global population increase leads to greater consumption of resources and generation of pollution.

How do we respond?

- Any cultural response/change requires time and money
- The world's economy is energy dependent
- Funds for change require a robust economy
- The currently cost effective energy is from fossil fuel
- We have a 40 year supply of fossil fuels
- Fossil fuels produce large volumes of CO_2

See Nathan S. Lewis, Engineering & Science, No. 2, 2007

- Thus the Earth will get warmer and sea level will rise during the time we seek a sustainable and 'greener' energy supply.
- We have a choice:
  - Mitigate
  - Adapt

There are many choices

- **Mitigation = modify a condition:**
  - Greenhouse gas production and accelerated warming:
    - Reduce ‘greenhouse’ gas production
    - Capture and sequester ‘greenhouse’ gas
  - Sea level rise and coastal erosion:
    - Levee or dike the coastline and raise river levee heights
  - Rainfall pattern change:
    - Change crop types and adjust planting cycles
    - Find alternative sources of water
- **Adaptation = adjust to a condition:**
  - Greenhouse gas production and accelerated warming:
    - Get used to increased temperatures
    - Increase air conditioning (increased CO_2 production)
  - Sea level rise and coastal erosion:
    - Withdraw from the coastal plain and river valleys
  - Rainfall pattern change:
    - Change crop types and adjust planting cycle
    - Stringent restriction on water use

Decision Making – What Response to Climate Change

- Bad decisions are made in times of crisis!
- Ignoring or distorting science results in bad decisions!
- Example: Ethanol

Ethanol Realities

In 2007, the Oregon State Legislature mandated ethanol-mix gasoline throughout the state by November 2008

- Limited solution:
  - 100% USA Corn Crop can yield only 12% of US fuel supply
- Decreased Fuel efficiency:
  - 1.2 gal/ethanol-gas = 1.0 gal/gasoline
- Inflation of Food Cost:
  - Corn for ethanol drove the price of corn up ≈100% in 2 years
- Corn for ethanol has displaced food crops:
  - Grain prices up >40% in one year;
  - Deforestation in Brazil: marginal land for replacement crops
  - Food ‘riots’ due to cost of food (Haiti, Egypt)

We have a choice

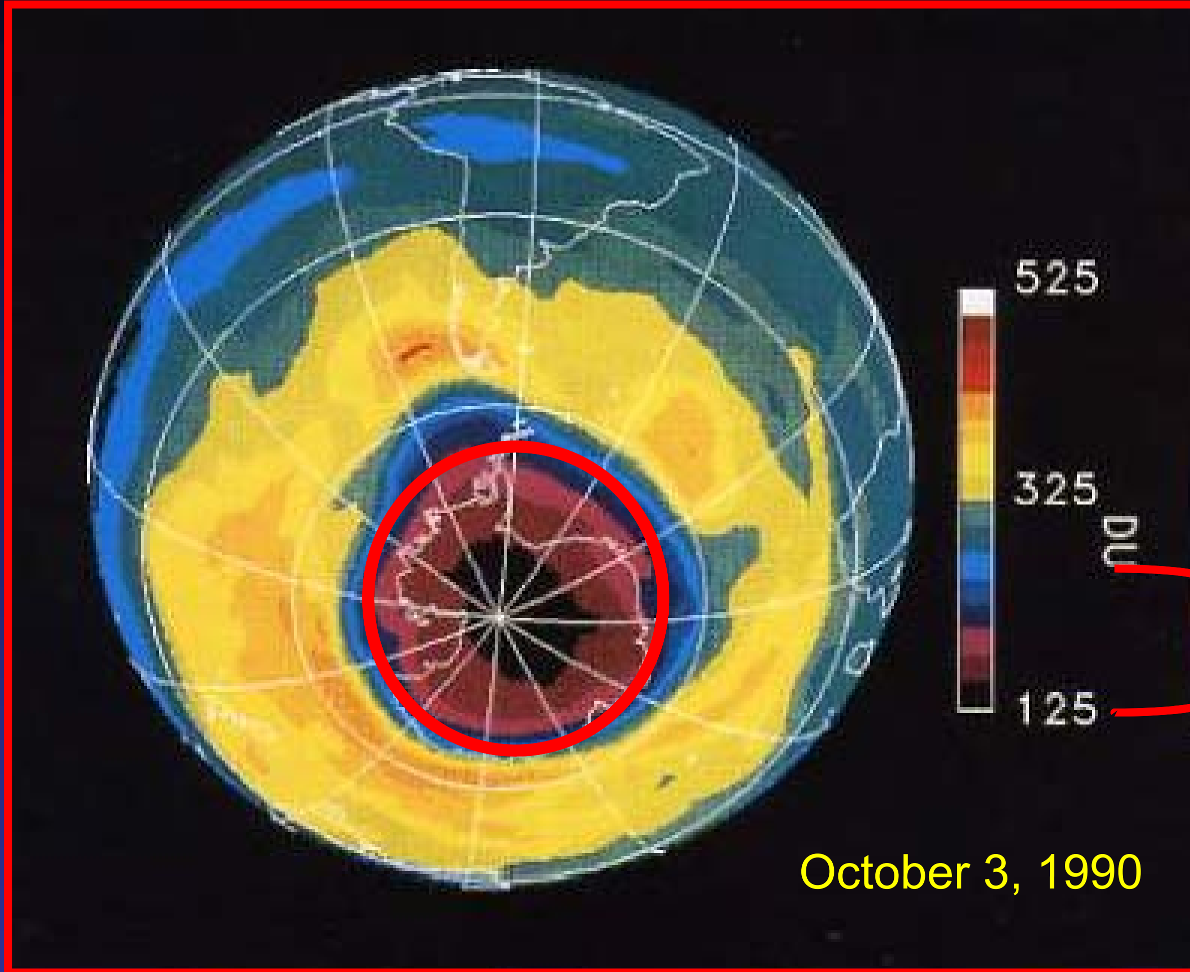
B e?

Yes, and we have: for instance --

"We have an obligation to weigh risks of inaction against the cost of action. In that regard, global warming is no different than any other problem. But global warming is novel in one respect. It brings with it the possibility of global disaster, and we have only one Earth to experiment with. Oppenheimer, Environmental Defense Fund, in Revkin, 1992

Armentrout, 4/16/2008

The Ozone Hole: A Human caused crisis!



Between 1970-1990, The Ozone Hole over the Antarctic, increased due to the atmospheric pollution of chlorofluorocarbons.

See: NASA's Ozone Hole Watch Website

Chronology of the "Ozone Hole" Issue

Does this scenario sound familiar?

- 1985 Publication of data confirming the seasonal Antarctic ozone hole.
- 1980's-90's Skeptics: Ozone depletion is not a problem:
  - "…a few credentialed scientists affiliated with influential conservative think tanks that are pushing an extreme antiregulatory agenda."
  - "…media personalities ….have picked up the cause and are amplifying the skeptics' voice far beyond the usual scientific forums."
- 1995 Nobel Prize in Chemistry awarded three scientists who discover
  ozone la
- 1996 International agreement imposing restrictions on industrial countrie
  known t

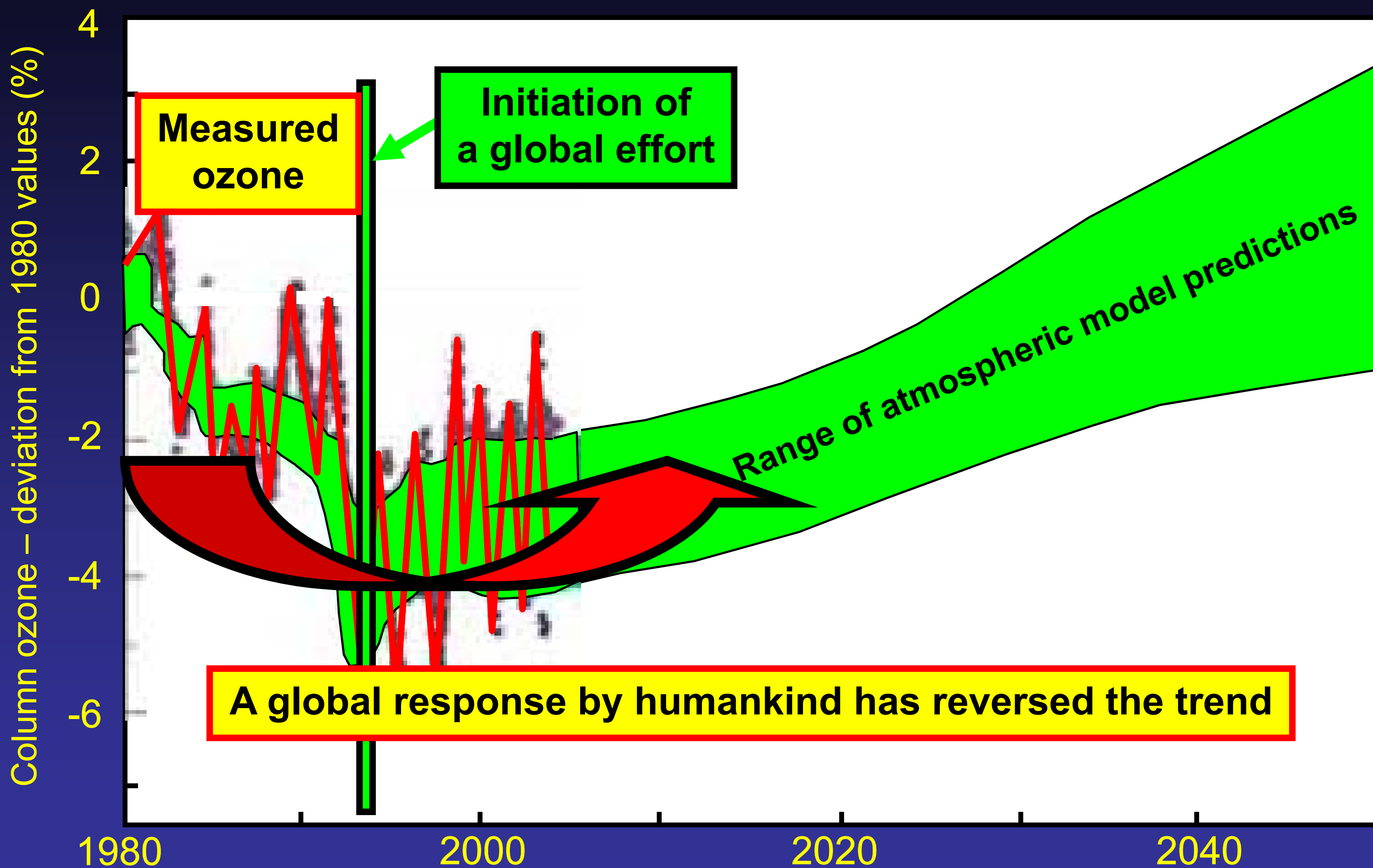
2007 IPCC and Gore – Nobel Peace Prize

200? Will there be an international effort?

Wager, Nucleus, v. 17, no.4, Union of Concerned Scientists, 1995-96

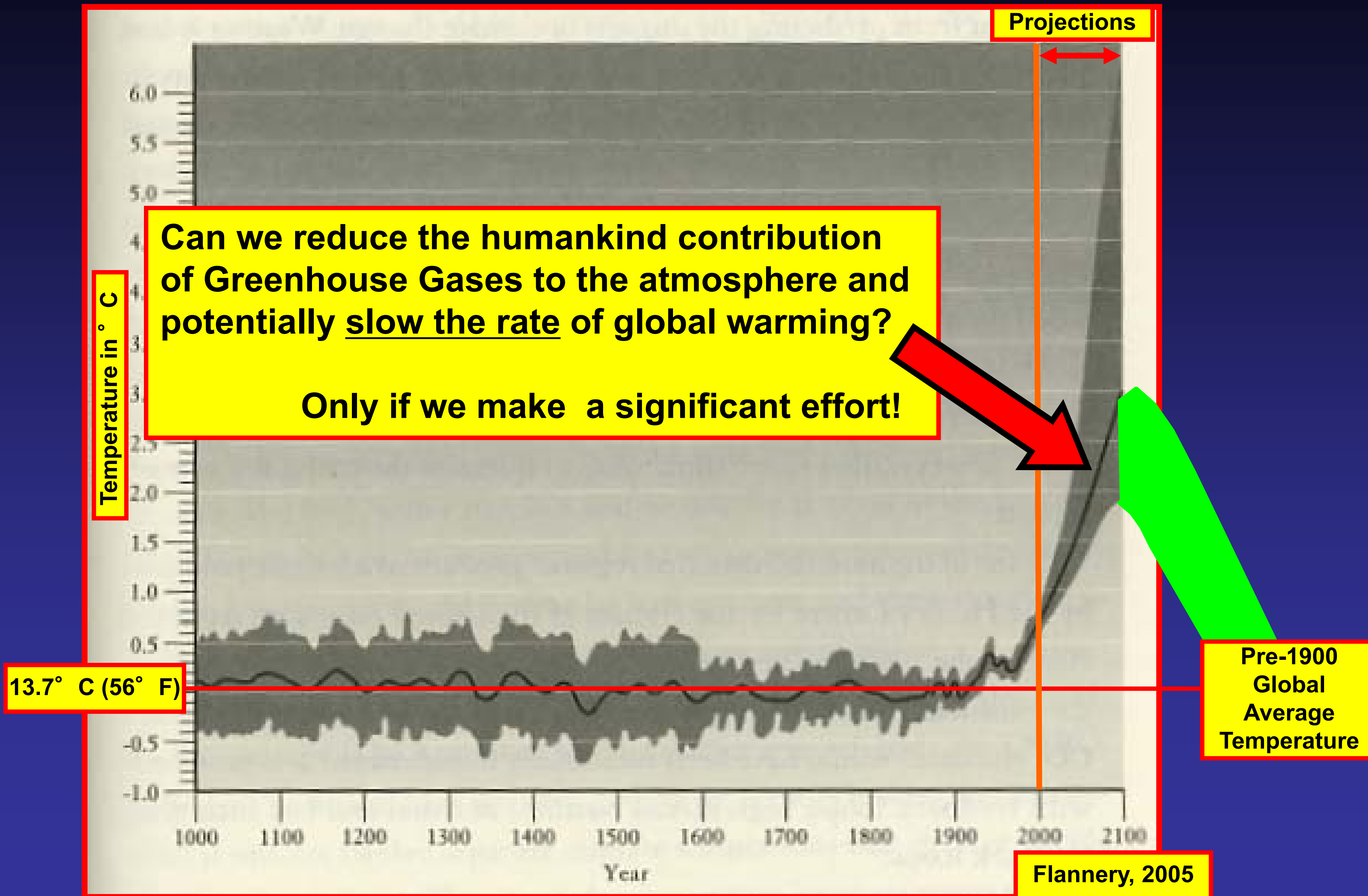
Armentrout, 4/16/2008

We can make a difference!



IPCC, 2005

The “Hockey Stick” Curve



Can we reduce the humankind contribution of Greenhouse Gases to the atmosphere and potentially slow the rate of global warming?

Only if we make a significant effort!

Climate Change Science Forum

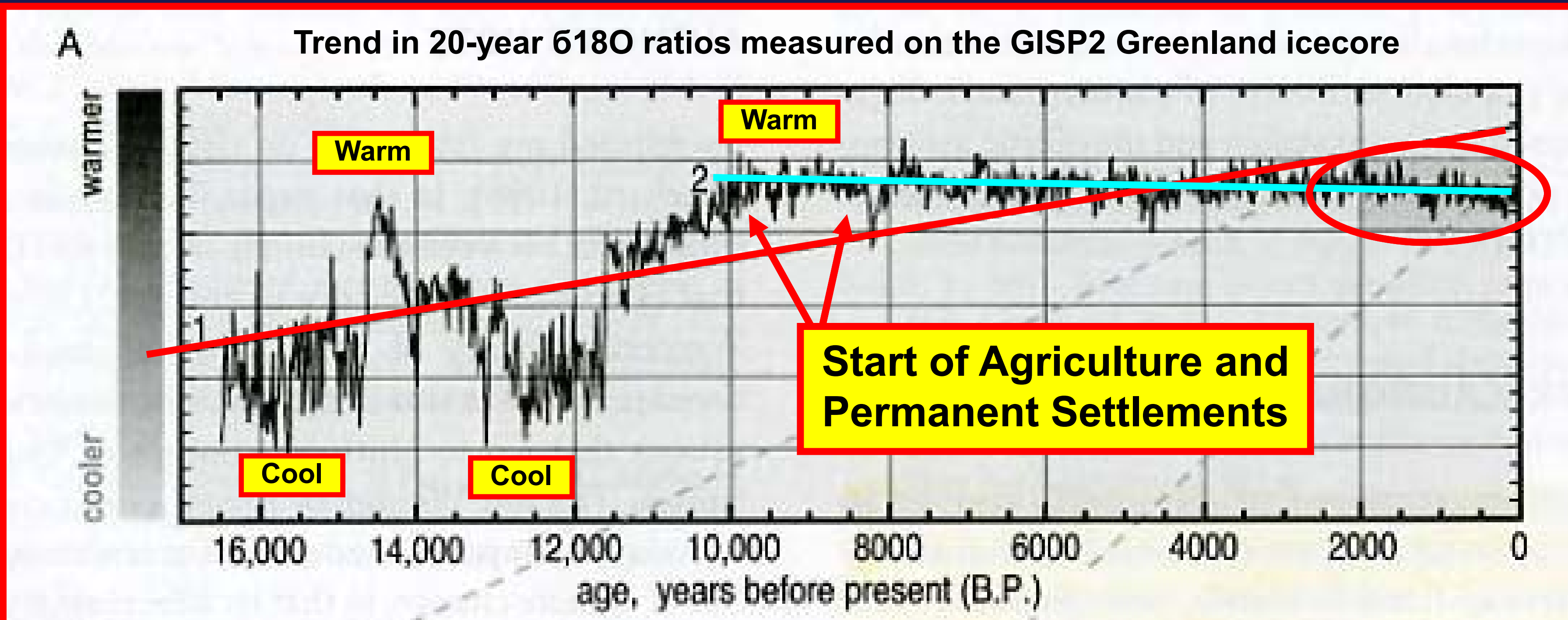
Wednesday, 8:00AM to 11:30 AM – Convention Center Rm. 217 B-C

- Gerald North, Atmospheric Sciences, Texas A&M University:
  - Temperature Reconstruction of Last 2000 Yrs.: Data and Interpretations
- Kurt Cuffey, Geography, University of California Berkeley:
  - Evidence for Changing Climate Recorded in Ice Sheets and Glaciers
- Judith Lean, Space Science Division, US Naval Research Lab.:
  - Sun Variability and Possible Links Between Variability and Climate
- Thomas Peterson, Climate Analysis Branch, NOAA:
  - Modern Temperature Observations: The Data and Interpretations
- Eric Barron, Jackson School Geosciences, Univ. Texas at Austin:
  - Role of Carbon Dioxide in climate change during Earth History?

Trends in Temperature: GISP2 Greenland Ice Core

A caution in evaluating data:

Climate changes over time can be argued as either warming or cooling by choosing the interval of time over which the observation is made.

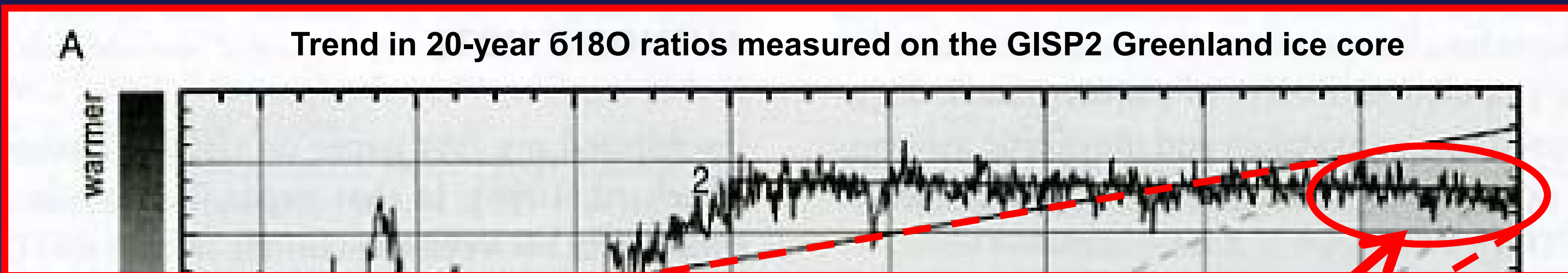


Davis and Bohling, 2001

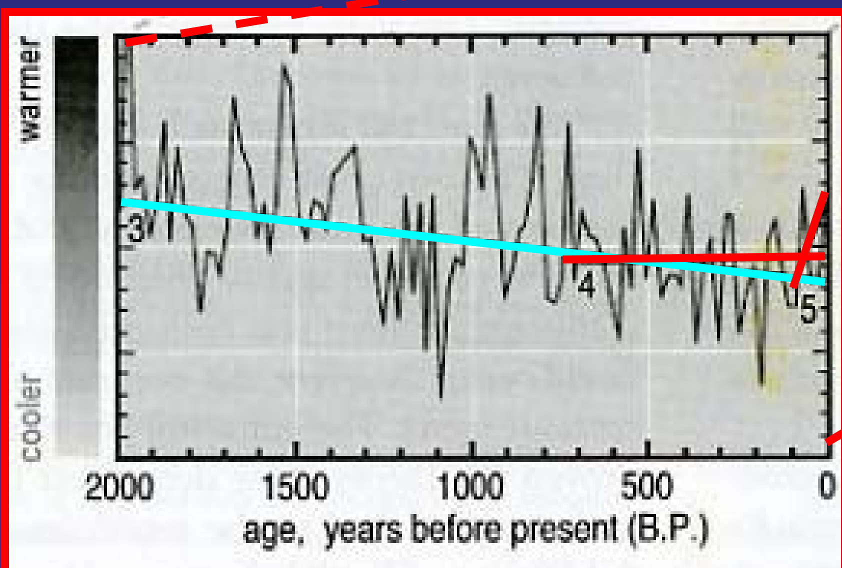
1. **Warming since before 16,000 yr B.P.**
2. **Cooling since 10,000 yr B.P.**

Trends in temperature: Greenland Ice Core

Climate changes over time can be argued as either warming or cooling by choosing the interval of time over which the observation is made.



Details of past 2000 years



3. Cooling since 2,000 yr B.P., especially 700 yr. BP to now.

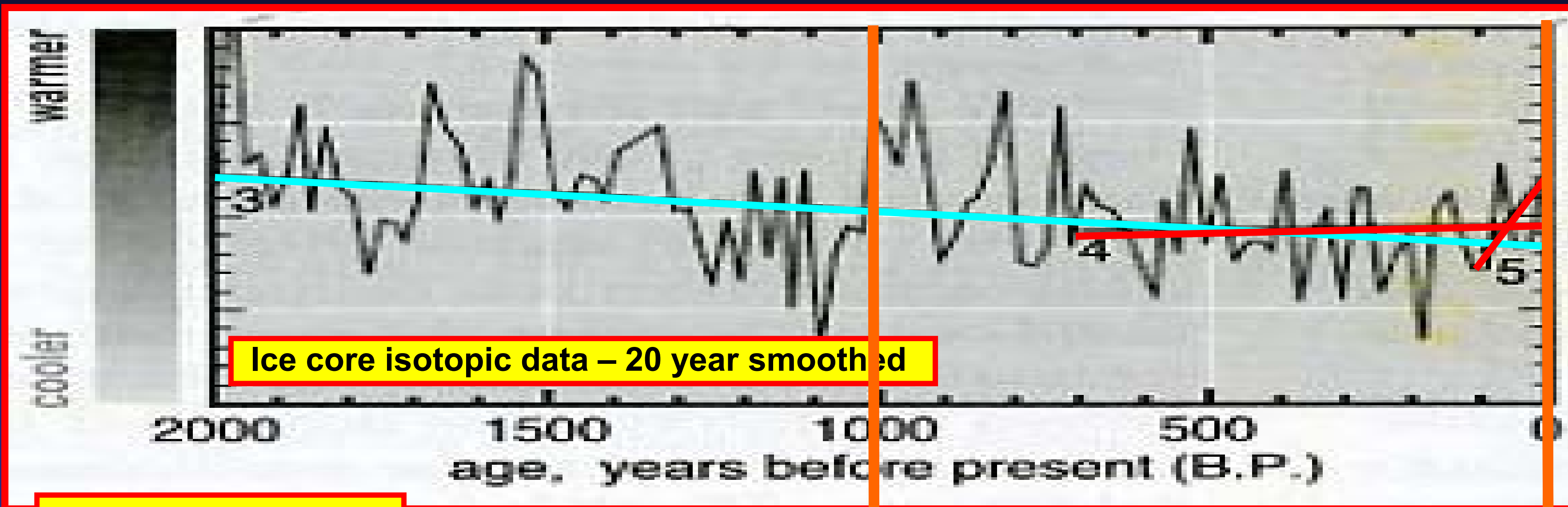
4. Slight warming since start of Little Ice Age 700 yr B.P.

5. Dramatic warming since start of Industrial Revolution, 150 yr B.P.

Davis and Bohling, 2001

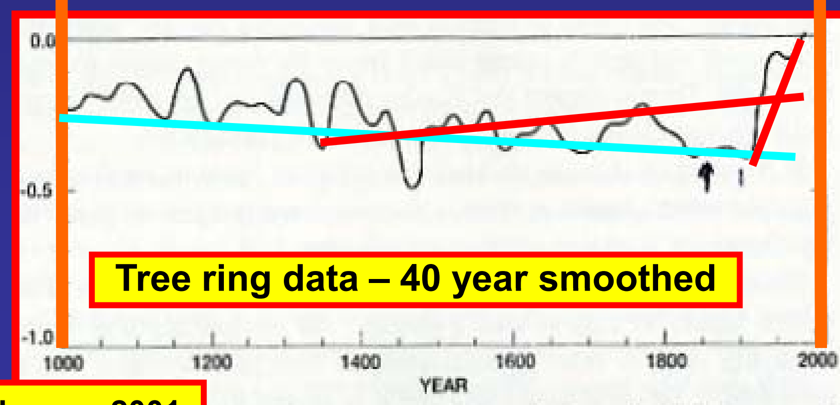
Comparison of 'proxy' temperature curves

Both Northern Hemisphere



Davis and Bohling, 2001

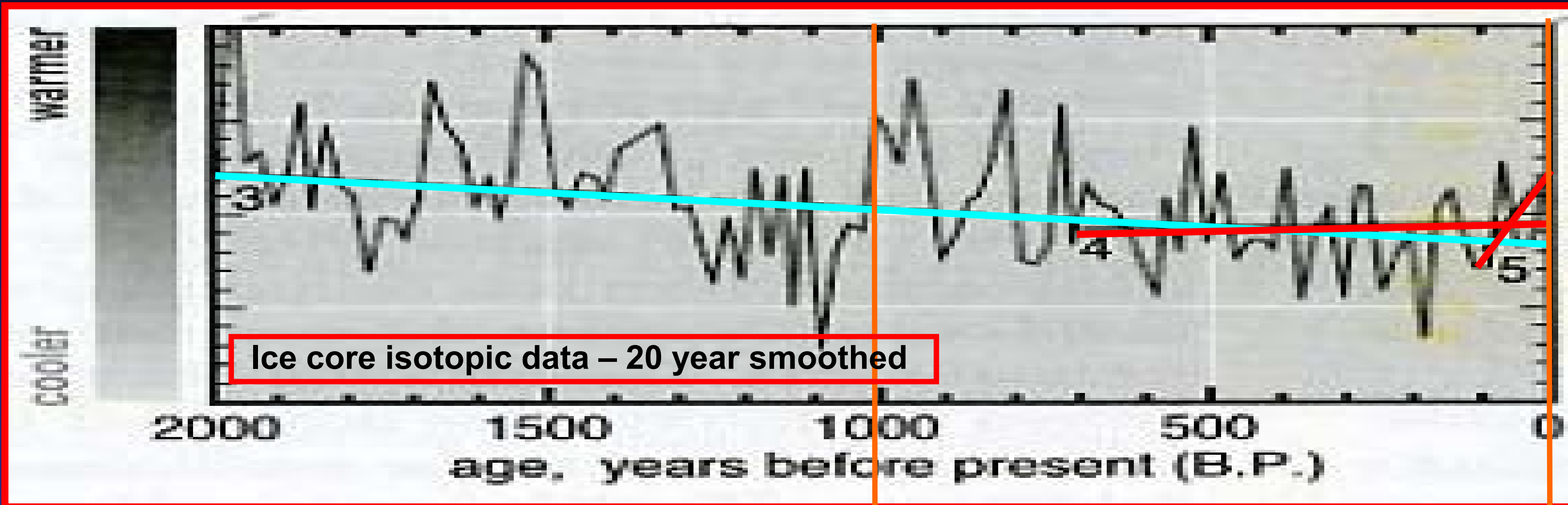
Different data sets: Similar trends



IPCC Climate Change, 2001

Comparison of ‘proxy’ temperature curves

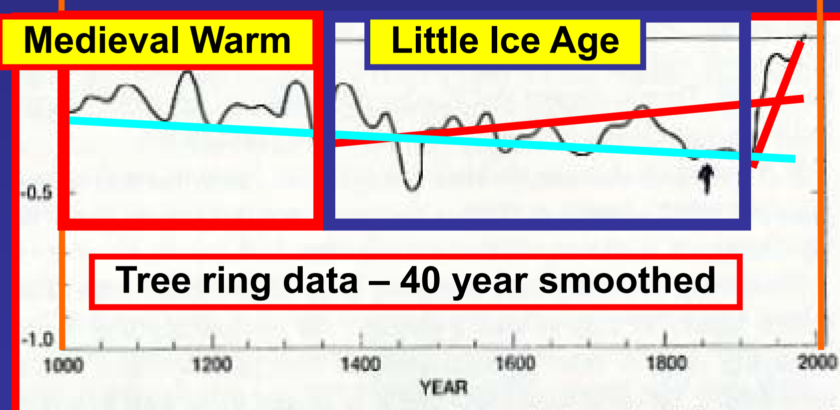
Both Northern Hemisphere



Davis and Bohling, 2001
In an AAPG Volume

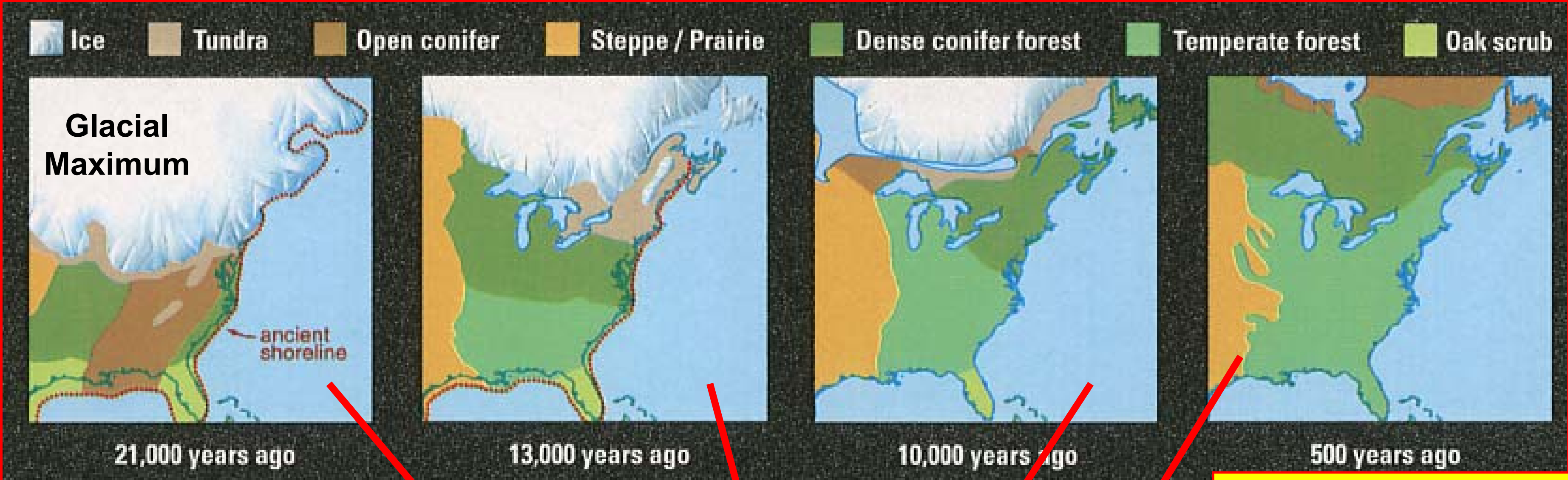
? A Cyclic Pattern ?

IPCC Climate Change, 2001



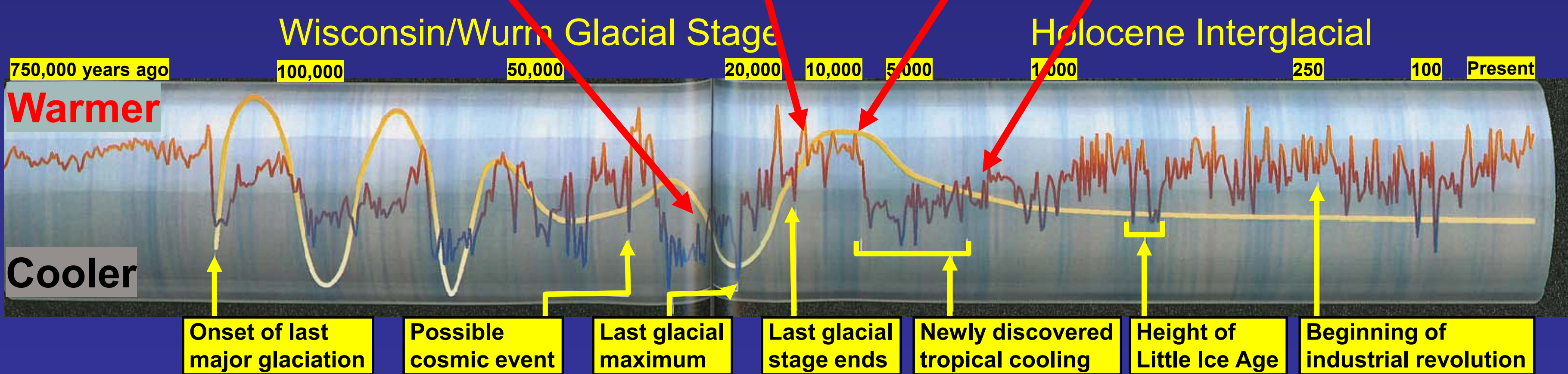
Armentrout, 4/16/2008

750,000 Years of Temperature History



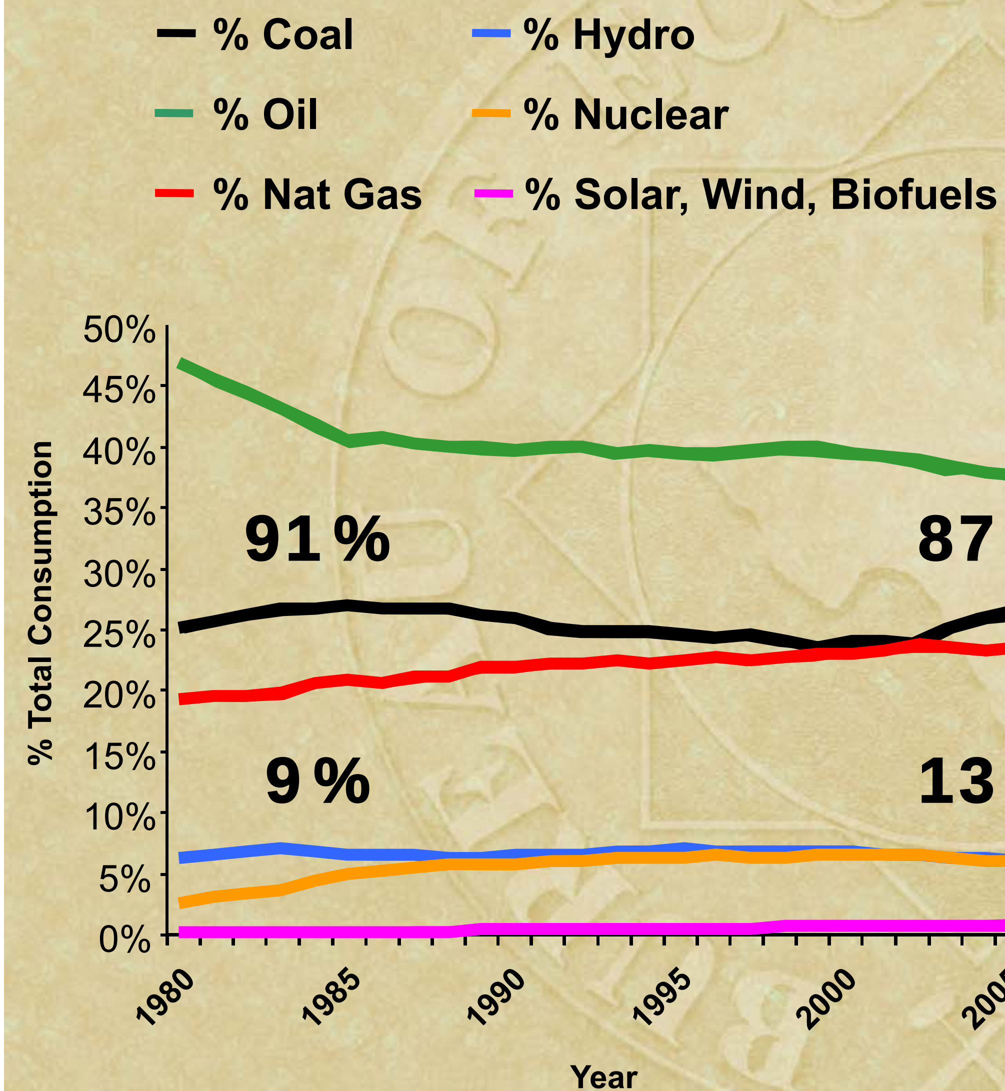
J. Adams, in Suplee, 1998

Temperature from oxygen isotopes extracted from Tibetan Ice Core



L.G. Thompson, in Suplee, 1998

Future Global Energy Trends



Requirements for Success

Environment and Access

IGCC and Sequestration

Access and LNG Terminals

Land Use and Environment

Permits and Waste Storage

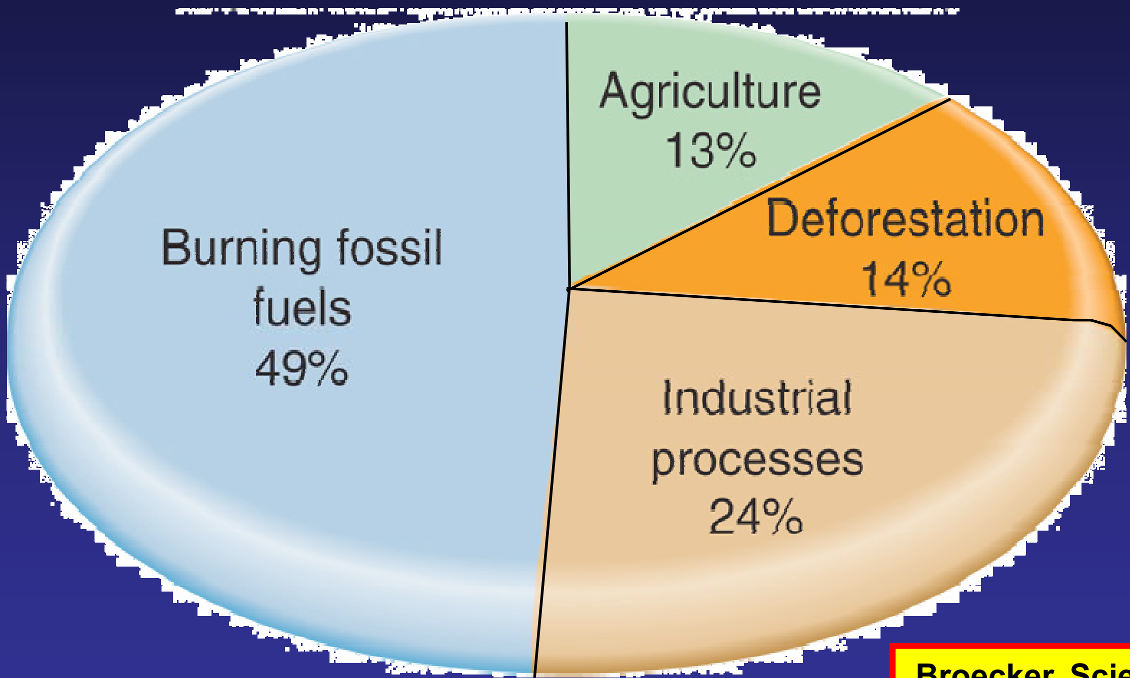
Storage & Trans, Soil & Water

Historical Data: EIA October 2007
Forecasts: Tinker, 2008

Scott Tinker, Texas Bureau, April 2008

Where can we make a difference?

Anthropogenic Greenhouse Gas Sources



Broecker, Science, 2004

We can not stop natural climate change but ….
we can reduce humankind's contribution to the accelerated rate of atmospheric pollution.