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

By

John M. Armentrout1

Search and Discovery Article #70046 (2008)
Posted October 22, 2008

*Adapted from oral presentation at AAPG Annual Convention, San Antonio, TX, April 20-23, 2008

1Consultant, 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.
Climate Change Science

What do the data interpretations suggest?

John M. Armentrout
Geologist
Damascus, Oregon
Climate science is intriguing and a challenge ----

and how it impacts our future is a critical issue!

My Family
Climate has a History
Ages of Ice and Heat

A Cyclic Pattern

Bourne, National Geographic, August 2007 (chart)
Atmospheric Pollution with Green House Gases
(\text{CO}_2; \text{N}_2\text{O}; \text{SF}_6; \text{PFC}; \text{HFC}; \text{H}_2\text{O})

\textit{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
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?
The “Hockey Stick” Curve

The ‘Red-Flag” warning is best expressed by the pattern of ‘Greenhouse Gas’ carbon dioxide in the atmosphere.

13.7° C (56° F)

Pre-1900 Global Average Temperature

Flannery, 2005

Range of Uncertainty

Temperature in °C

Thermometer Grid in-place

Projections

Armentrout, 4/16/2008
“Hockey Stick” Curve = Accelerated Global Warming

PREDICTED CONSEQUENCES
• Sea Level Rise (deglaciation)
• Warming Ocean
• Increased Megastorms
• Increased Megafires
• Altered Rainfall Patterns
  • Crop Failure = Famine
  • Expanded Disease Impact

Pre-1900 Global Average Temperature
Flannery, 2005

Range of Uncertainty
Thermometer Grid in-place

13.7° C (56° F)

Armentrout, 4/16/2008
A Geological Perspective on Climate Change

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

Marshak, 2004
Pleistocene Ice Ages

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

Milankovitch cycles

The tilt of Earth’s axis takes 41,000 years to complete a cycle.

A 23,000 year Cycle is created by a top-like Wobble of the Earth’s axis.

Variations in Earth’s orbit around the sun follow a 100,000-year cycle.

Oxygen isotope values $^{18}$O ($\sigma$ units)

Marine Record Interglaciations

Glaciations

Traditional glaciations

Wisconsinan

Illinoian

Pre-Illinoian

0.0

1.0

2.0

Millions of years ago

30 Cycles

(63 kyr average)

Marshak, 2004

Suplee, National Geographic, May 1998
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 CO₂ 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.”
“Ice is on the run in its mountain and polar strongholds. As the ice sheets on Greenland and Antarctica shrink in the next few centuries, 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.
Melting of Glaciers: White River Glacier: Mt. Hood, Oregon

Summer 1902

USGS, 2008
Melting of Glaciers: White River Glacier: Mt. Hood, Oregon

September 2007

USGS, 2008
Melting of Glaciers: White River Glacier: Mt. Hood, Oregon

Satellite Data Base

My Youth

Long-term Decrease

‘Cyclic’ Variations

USGS, 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

1992 2002 2005

Gore, 2006
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:

<table>
<thead>
<tr>
<th>Rate of Rise</th>
<th>Years-1.0m</th>
<th>Years-5.8m</th>
<th>Years-6.1m</th>
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<tr>
<td>2.6mm/yr</td>
<td>384</td>
<td>2230</td>
<td>2346</td>
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<tr>
<td>3.5mm/yr</td>
<td>285</td>
<td>1657</td>
<td>1743</td>
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<tr>
<td>11mm/yr</td>
<td>90</td>
<td>527</td>
<td>555</td>
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<td><strong>Possible</strong></td>
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<tr>
<td>11mm/yr</td>
<td><strong>90</strong></td>
<td>527</td>
<td>555</td>
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<tr>
<td>20mm/yr</td>
<td>50</td>
<td>290</td>
<td>305</td>
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<tr>
<td>44mm/yr</td>
<td>23</td>
<td>132</td>
<td>139</td>
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</tbody>
</table>

Compiled by Armentrout, 2007
“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)
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

Hayden, National Geographic, August 2006
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

My Home

Perth, Australia

2.5° C (4.5° F) Warming

Revkin, 1992
Rainfall Patterns: Perth’s Catchment Basin

Perth has 66% less surface water than 30 years ago

1911-1974 average

1975-96 avg.

1997-2004

Flannery, 2005
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

Dry conditions cover more than half the country

Percentage of the U.S. land area moderately to extremely dry in October of each year since 1930:

- 1934: Heart of the "Dust Bowl" years
- 1952-56: Four years of persistent drought
- 1988: Among hottest summers on record
- 2007: Second-driest year in four decades

Sources: National Climatic Data Center, National Drought Mitigation Center, the Associated Press, The (Nashville) Tennessean, The (Louisville) Courier-Journal, The Cleveland Plain Dealer

? A Cyclic Pattern ?
? La Nina – El Nino ?

USA Today, October 19, 2007
~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

Notice the subtle but real difference in temperature between the two phases.

Temperature in °C

Medieval Warm

Little Ice Age

Pre-1900 Global Average Temperature

13.7° C (56° F)

Flannery, 2005

A History of Climate Change

But the current trend and computer predictions forecast a very different scenario.

Pre-1900 Global Average Temperature

Medieval Warm

Little Ice Age

13.7°C (56°F)

Flannery, 2005

Fagan, 2000, 2004
One man’s opinion (Armentrout):

Is global warming a natural cycle or human-caused?

Much of the current 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?
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.

Gore, 2006
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 CO₂

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 CO₂ 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
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

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
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 discovered substances that can destroy the ozone layer.
- **1996** International agreement imposing restrictions on industrial countries to stop producing the three human-made chemicals known to destroy the ozone layer.
- **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
We can make a difference!

A global response by humankind has reversed the trend

Initiation of a global effort

Measured ozone

Range of atmospheric model predictions

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!

13.7°C (56°F)

Flannery, 2005
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.

Trend in 20-year δ18O ratios measured on the GISP2 Greenland icecore

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

Start of Agriculture and Permanent Settlements

Davis and Bohling, 2001
Climate changes over time can be argued as either warming or cooling by choosing the interval of time over which the observation is made.

Trend in 20-year δ18O ratios measured on the GISP2 Greenland ice core

Details of past 2000 years

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

- Ice core isotopic data – 20 year smoothed
  
  Davis and Bohling, 2001

- Tree ring data – 40 year smoothed
  
  IPCC Climate Change, 2001

Different data sets: Similar trends
Comparison of ‘proxy’ temperature curves

Both Northern Hemisphere

Ice core isotopic data – 20 year smoothed

Davis and Bohling, 2001
In an AAPG Volume

? A Cyclic Pattern ?

Medieval Warm
Little Ice Age

Tree ring data – 40 year smoothed

IPCC Climate Change, 2001
750,000 Years of Temperature History

Glacial Maximum

Temperature from oxygen isotopes extracted from Tibetan Ice Core

J. Adams, in Suplee, 1998

L.G. Thompson, in Suplee, 1998

Onset of last major glaciation
Possible cosmic event
Last glacial maximum
Last glacial stage ends
Newly discovered tropical cooling
Height of Little Ice Age
Beginning of industrial revolution

Wisconsin/Wurm Glacial Stage
Holocene Interglacial
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

Scott Tinker, Texas Bureau, April 2008

Historical Data: EIA October 2007
Forecasts: Tinker, 2008
Where can we make a difference?

Anthropogenic Greenhouse Gas Sources

- Burning fossil fuels: 49%
- Agriculture: 13%
- Deforestation: 14%
- Industrial processes: 24%

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

Broecker, Science, 2004