

## Global Warming: Fact or Fiction?

Ken Crawford and Gary McManus  
Office of the State Climatologist  
Oklahoma Climatological Survey



Presentation to Seniors in Chemical Engineering  
The University of Oklahoma  
April 15, 2008

### The Aim of This Presentation

- To summarize the physics of radiative transfer as it pertains to potential global warming
- To summarize what is known about global climate change while remaining 'practically relevant'
- To share our understanding of the regional impacts of a warming climate — with an emphasis on public water supplies
- To refute some myths about human-induced global warming



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### Climate Change & Global Warming: Extreme Viewpoints

- Senator James Inhofe (R, Oklahoma), Chair, Senate Environmental and Public Works Comm., in a speech to the US Senate on January 4, 2005 — "I called the threat of catastrophic global warming the 'greatest hoax ever perpetrated on the American people'."
- British Prime Minister Tony Blair in a speech on September 14, 2004 — "I want to concentrate on what I believe to be the world's greatest environmental challenge: climate change."



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## Tunes Are Changing...

U.S. Secretary of State Condoleezza Rice, September 2007 – “It is our responsibility as global leaders to forge a new international consensus on how to solve climate change...If we stay on our present path, we face an unacceptable choice: either we sacrifice global economic growth to secure the health of our planet or we sacrifice the health of our planet to continue with fossil-fuelled growth.”



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## Anthropogenic climate change is not a new theory...



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## It is the confirmation of a prediction:

- In the late 1890s, Svante Arrhenius theorized about a warming climate due to the burning of coal.
- In 1938, Guy Stewart Callendar asserted that warming of the 19<sup>th</sup> century forward was due to a rise in CO<sub>2</sub>.
- “By the year 2000, the increase in atmospheric CO<sub>2</sub> ... may be sufficient to produce measurable and perhaps marked change in climate...” — National Medal of Science winner Roger Revelle and the U.S. President’s Scientific Advisory Committee, 1965.



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## The Fundamental Physics

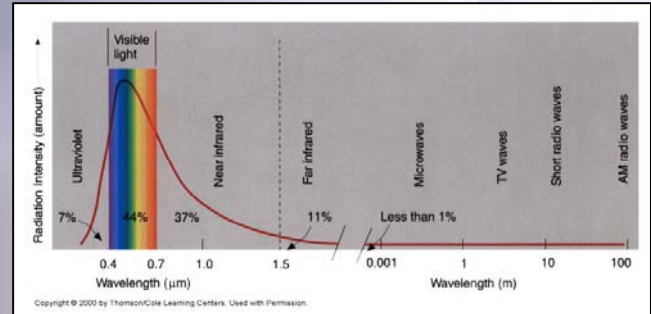


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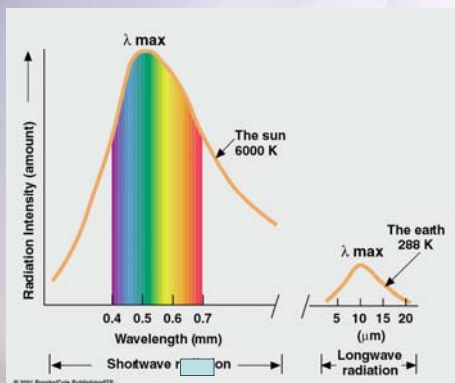
## Properties of Radiation

- The hot sun radiates at shorter wavelengths that carry more energy (i.e., intensity varies inversely with  $\lambda$ ).
- A small fraction of this energy is absorbed by the cooler earth and is re-radiated at longer wavelengths (as predicted by Wein's Law).
- Solar radiation has peak intensities in the shorter wavelengths. This radiation is very intense in the region we know as the visible portion of the spectrum.
- In pictorial form....

## The Sun's Electromagnetic Spectrum



## Radiation From The Sun Versus Earth



## Balancing Act

- If objects only absorb or emit radiation, they would become very hot or very cold.
  - ✧ Objects do both - absorb and emit
- Kirchoff's Law tells us:
  - ✧ Good absorbers are good emitters
  - ✧ Poor absorbers are poor emitters
  - ✧ The atmosphere has both properties
  - ✧ As a result, the earth converts sunlight to longwave radiation and/or to heat energy to drive atmospheric motions.

## Earth's Energy Budget: Part I

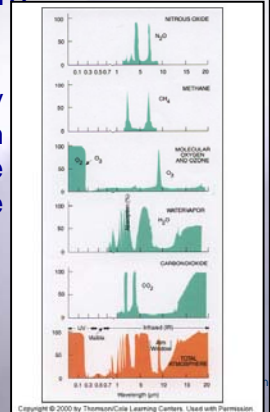
- Absorption and re-emission of radiation at the earth's surface is only one part of an intricate web of heat transfer in the earth's planetary domain.
- Equally important are **selective absorption and emission of radiation** from molecules in the atmosphere. If the earth did not have an atmosphere, **surface temperatures would be too cold to sustain life**. If too many gases which absorb and emit infrared radiation were present in the atmosphere, surface temperatures would be too hot to sustain life.



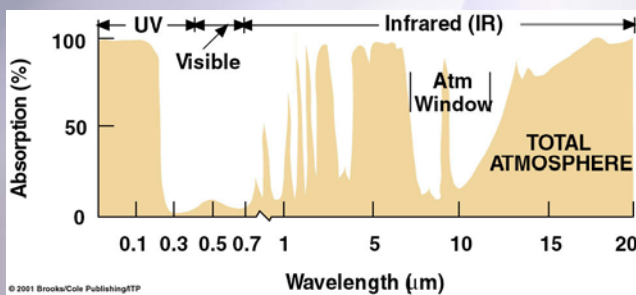
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## Absorption of Radiation by Gases in the Atmosphere

Conceptually, this is a very important slide. It deals with 'selective absorbers'. Note the atmospheric window and the greenhouse effect.



## Selective Absorbers



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## Outgoing Terrestrial Radiation

- The earth's surface, atmosphere, and clouds emit radiation in the infrared band and near-infrared band.
- Outgoing infrared (IR) radiation from the earth's surface (also called terrestrial radiation) is selectively absorbed by certain molecules, particularly water vapor and carbon dioxide.
- Gases which absorb IR radiation are termed collectively as "greenhouse gases", producing the 'atmospheric greenhouse effect'.



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## Outgoing Terrestrial Radiation

- Infrared radiation from greenhouse gases in the atmosphere is emitted in all directions, including back to the earth's surface. It is this re-emission to the earth's surface that maintains a higher temperature on our planet than would be possible without the atmosphere.



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## Global Energy Balance

- If we consider the atmosphere alone, we find that the atmosphere experiences net radiative cooling.
- If earth had no atmosphere, the globally averaged surface temperature would be  $-18\text{ }^{\circ}\text{C}$ . But, because our earth does have an atmosphere, the average surface temperature actually is  $15\text{ }^{\circ}\text{C}$ .



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## Global Energy Balance

- The atmosphere acts as a greenhouse because of gases that selectively allow solar radiation to pass through but absorb and then re-emit terrestrial radiation. The 'greenhouse gases' are selective as to which wavelengths they will absorb. For example, ozone absorbs shortwave ultraviolet radiation whereas water vapor absorbs infrared radiation more readily.
- Most of the sun's radiation that passes through the atmosphere to reach the earth is in the visible part of the spectrum.



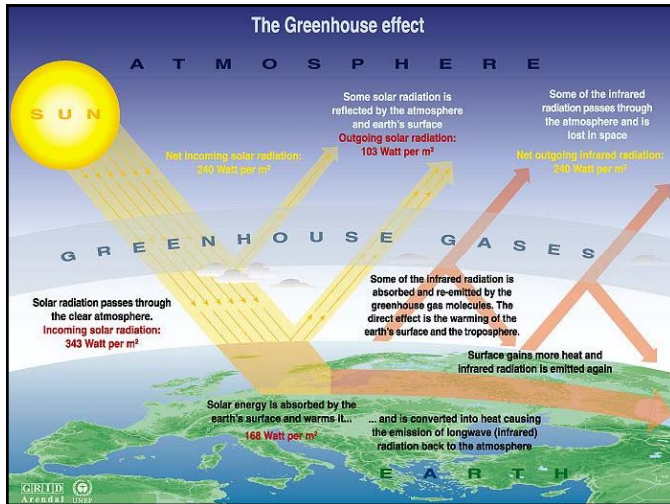
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## Global Energy Balance

- Most of the earth's radiation that escapes from the atmosphere is in the infrared band between 8 microns and 11 microns.
- This region of the spectrum is called the "atmospheric window".
- A quick view of the visible, infrared and water vapor satellite images for the day is the best illustration of these radiative processes at work.



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## The Scientific Consensus

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### IPCC: Intergovernmental Panel on Climate Change

- Established in 1988 by United Nations Environment Program and World Meteorological Organization
- Not to do research, but to synthesize and assess it
- Response to scientific predictions of the 1970s: global warming due to greenhouse gas emissions likely to become a problem
- Today: scientific experts from > 130 countries
  - Most recent report: > 800 authors & > 2500 peer reviewers
- Historically unprecedented: scale, scope, ambition
- Summary approved by consensus (including representatives of the Bush Administration) at meetings of the IPCC

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### The following represents the VAST MAJORITY of scientific expertise on global climate change

Important to remember, however:

- Projections versus observations
- Think GLOBALLY and DECADELLY
- Modeled temperature projections represent a RANGE of possible warming, dependent upon societal responses (i.e. SCENARIOS)
- Natural variability will still occur (i.e. hot years, cold years, wet and dry)
- Regional projections are still somewhat uncertain

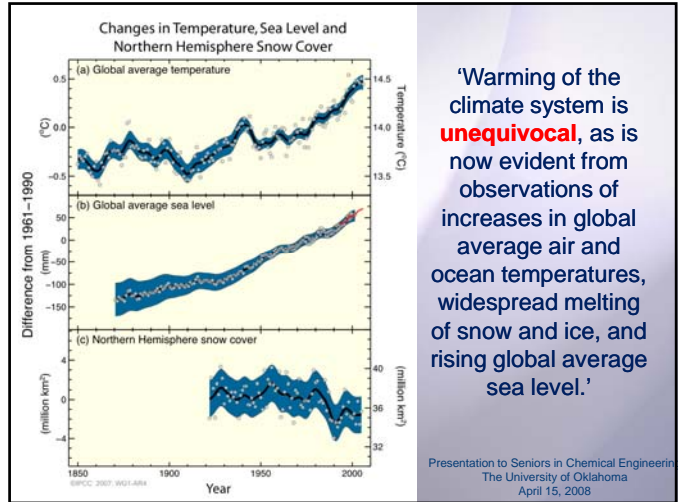
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## Observational Evidence: The Globe is Warming



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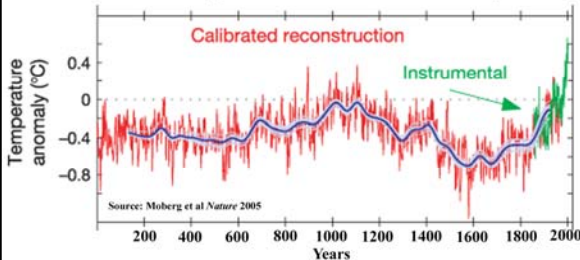


‘Warming of the climate system is **unequivocal**, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.’

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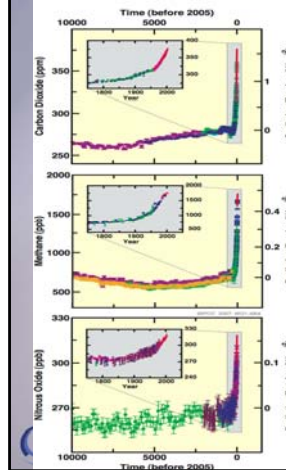
“Paleoclimate information supports the interpretation that the warmth of the last half century is unusual in at least the previous 1300 years.”

2000 Year Northern Hemisphere Reconstruction of Surface Air Temperatures



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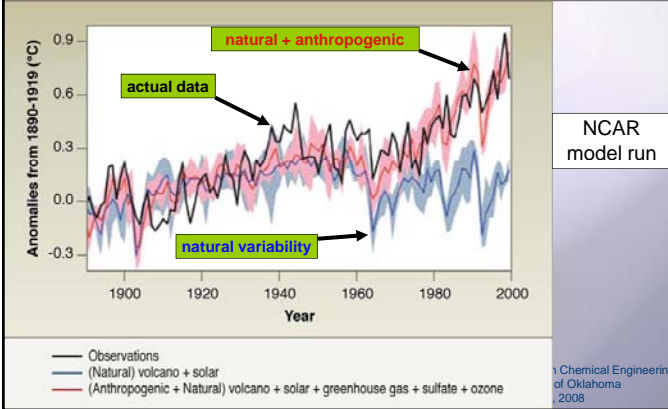
Changes in Greenhouse Gases from ice-Core and Modern Data



- ‘Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years.
- The global increases in carbon dioxide concentration are due primarily to fossil fuel use and land-use change, while those of methane and nitrous oxide are primarily due to agriculture.’

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"The observed widespread warming of the atmosphere and ocean, together with ice mass loss, support the conclusion that it is *extremely unlikely* that global climate change of the past fifty years can be explained without external forcing...."



# Projections

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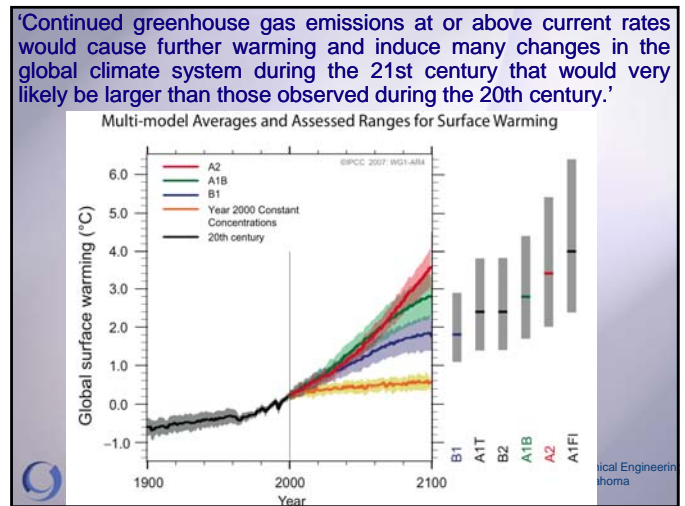
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## The IPCC Consensus

- Higher confidence now exists in projected patterns of warming than exists for other elements such as rainfall.
- It is *very likely* that hot extremes, heat waves, and heavy precipitation events (due to higher moisture content in the atmosphere) will continue to become more frequent.
- Snow cover is projected to contract and sea ice is projected to shrink in both the Arctic and Antarctic. Thus, sea levels will rise.
- Storm tracks are projected to move poleward, with resultant changes in wind, precipitation, and temperature patterns.
- Increasing atmospheric CO<sub>2</sub> concentrations will lead to increasing acidification of the ocean.
- Anthropogenic CO<sub>2</sub> emissions during the 21st century will contribute to warming & sea level rise for more than a millennium, due to the long timescales required for removal of this gas.

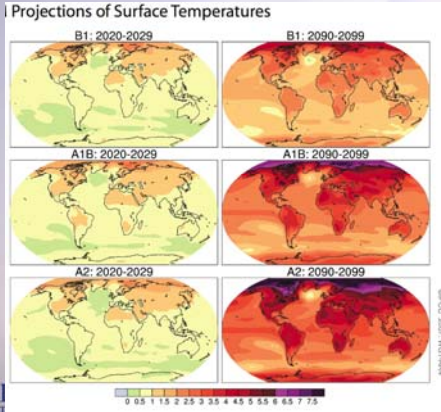
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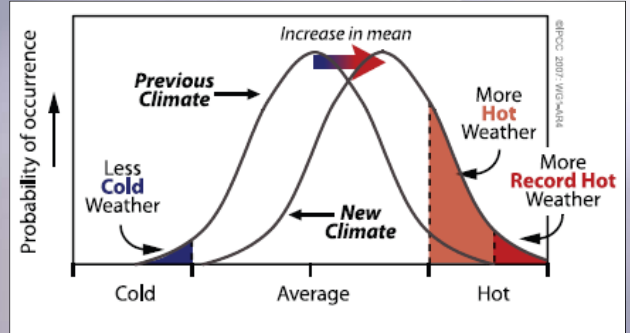
### Projected temperature changes for the early and late 21st century



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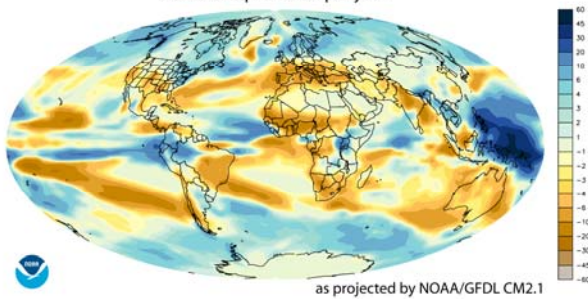
### Extreme Temperatures Will Increase



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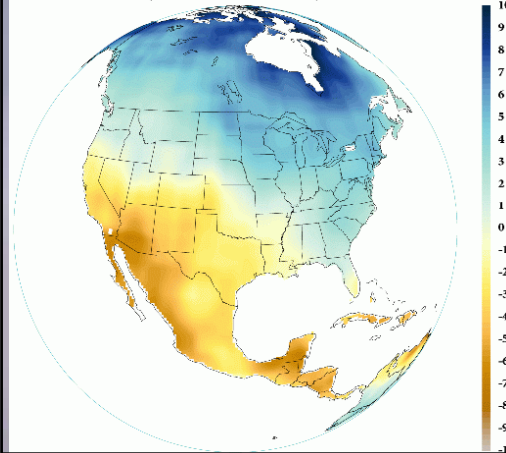
### CHANGE IN PRECIPITATION BY END OF 21st CENTURY inches of liquid water per year



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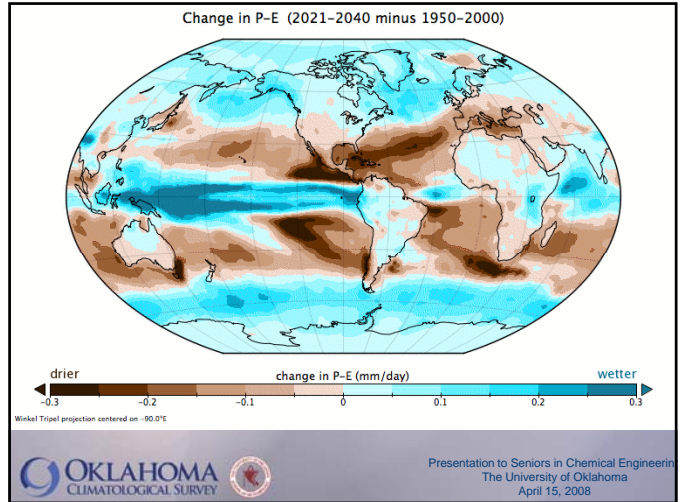
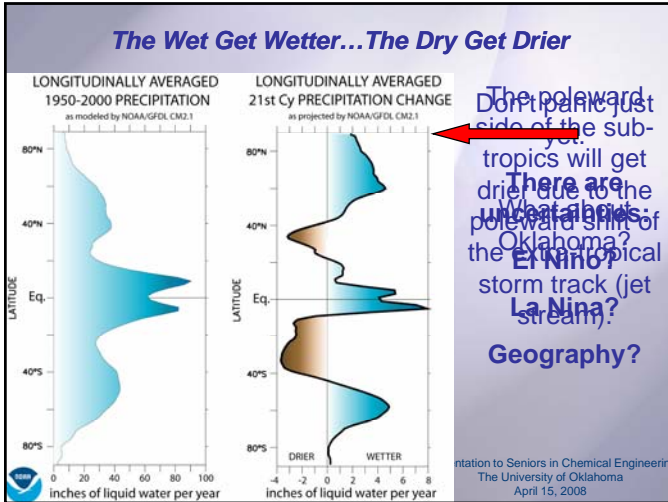


### Projected Change in Precipitation 1950-2000 to 2021-2040 (Percent of 1950-2000)



Average of 19 climate models. 2007.

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### The Continental Picture

- Annual precipitation is projected to decrease across the southwestern United States, especially during the summer.
- Warmer temperatures will cause more evaporation in summer and less soil moisture.
- As a result, drier conditions will contribute to severe episodes of extreme heat, particularly across the southwest USA.
- 'Ordinary' droughts (e.g., 2005-2006) may be transformed into a style of the '30s- and '50s.
- Warmer temperatures and drier conditions in summer will increase the risk and intensity of wildfires.
- But...climate model projections are uncertain because the impact depends on socio-economic responses to climate change.

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### Winners and Losers

“There will be winners and losers from the impacts of climate change, even within a single region, but globally the losses are expected to far outweigh the benefits.”

National Academies' Report  
“Understanding and Responding to Climate Change”

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### The Bottom Line

# “Water is the delivery mechanism of most climate change impacts”

**Kathy Jacobs**  
Executive Director  
Arizona Water Institute



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### Consider the Following Headline

## Heavy Rains Open Spigot on Costly Floods

**The Weather**

High water, caused by lengthy rains or sudden heavy storms, dealt misery to many Oklahoma homes during the 1980s, with flood damage ranging from minimal crops to lost homes and deaths.

Residents in many flood-prone areas looked for ways to cope with high water in the future.

Almost \$5 million in flood projects have been built or started in Tulsa, and Goshie has opened many residences east of the flood plain.

Some of the more serious floods of the decade include:

- 1980 Sept. 26: Floodwaters caused by two days of rain that dumped up to 8 inches in some parts of southern Oklahoma killed a 16-year-old woman when a car was swept from a bridge into a creek.
- 1981 Oct. 16: Floods in Tulsa, Logan over parts of southern Oklahoma. It brought major flooding on the first major Thunderbolt, the Little River at Tulsa and the Crow River near Lawton. Flood damage in 30 counties was estimated at nearly \$24 million.
- Oct. 15: Two oil-field workers were swept away by floodwaters after nearly 5 inches of rain in Muskogee, Broken Arrow and Lawton.
- 1982 Jan. 30: Three children drowned when a pickup truck was swept off a road in Oklahoma City into Lakeview Reservoir.
- May 31: Flooding damaged 250 bridges and caused a total of a federal major disaster designation for Logan, Carter, Kingfisher, Lincoln, Logan, Oklahoma, Payne and Washita counties.
- May 17: Two days of rain left about 200 people and their belongings homeless in up to 5 feet of water engulfed at Muskogee.
- 1983 Oct. 21: The Washita River and some streams rose with a torrential rain of about 16 inches. The resulting flood caused \$50 million worth of damage in 10 Oklahoma counties.
- 1984 May 27: Tulsa was inundated by what was called the worst flooding in its history on Memorial Day weekend after 10 inches of rain fell in six hours. The flooding killed 1 person and cost about 2100 families in damage. The disaster prevented the city to spend \$23 million on 19 flood management projects and cost \$72 million in other projects.
- 1985 Sept. 30: Torrential rains began what was called a "rainbow flood" as 25 inches of water were dumped across Oklahoma in five days.
- 1987 May 27: Floods caused about 100 fatalities in damage to roads, bridges, highways and farms in Oklahoma after an 11 day "rain" of "unprecedented" rainfall rates of up to 10 inches.
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**Weather Headline From The Sunday Oklahoman Printed on December 31, 1989 — To Summarize the Biggest Weather Headlines in Oklahoma During the 1980s.**



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### Consider Headlines Already Being Written (From The Norman Transcript)

**Barge operators count their losses**

**Water shortage looms for world**

**Friday, July 30, 2004**

**Our view: More water wars feared as the West goes dry**

**Desert in Disguise**



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### Or...From The National Geographic

**Supply CASE STUDY**

**California: Desert in Disguise**

**Introduction**

**When the well's dry, we know the worth of water.**

**California: Desert in Disguise**

BY RICHARD CONIFF  
PHOTOGRAPHS BY RICK RICKMAN



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**Consider the Reservoir at Lake Mead, NV**



*“The lake ... has a 50% chance of becoming unusable by 2021 ... if demand for water remains unchanged and if human-induced climate change follows. ... ‘We have 90% of our water supply coming from Lake Mead’.”*

*NY Times  
February 13, 2008*



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**An Even More Ominous Headline...**

*“Nuclear reactors across the southeast could be forced to throttle back or temporarily shut down later this year because drought is drying up the rivers and lakes that supply power plants with the awesome amounts of cooling water they need to operate.” ... “Water is the nuclear industry’s Achilles’ heel.” ... “Lake Norman near Charlotte is down to 93.7 feet — less than a foot above the minimum set in the license for Duke Energy Corp.’s McGuire nuclear plant.” ... “It would cost 10 times that amount [\$5-7per megawatt hour] if you had to buy replacement power — especially during the summer.”*

*Associated Press  
January 24, 2008*



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**Or... This Editorial From The National Geographic**

Report from the President



**Water for Our Future: A New Society Initiative**

**P**resident Bush has a new vision: Our freshwater supply is being used faster than ever... The 30 best freshwater reserves of northern California's Mono Lake are... **W**ater is the lifeblood of our society... **W**ater is the lifeblood of our society... **W**ater is the lifeblood of our society...

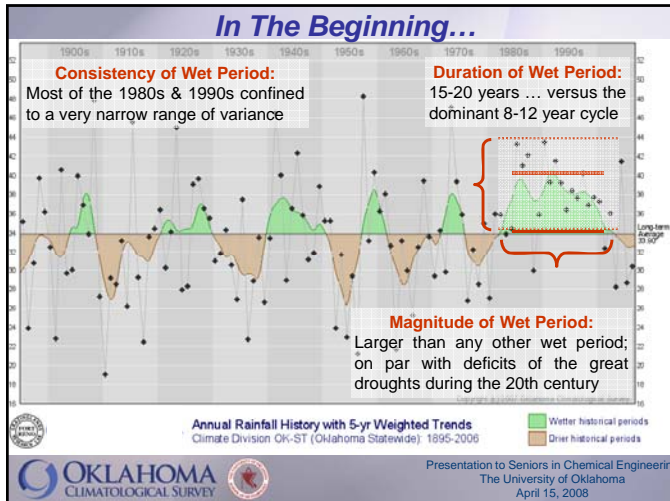


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**Regionalizing Climate Change: A Look at Oklahoma**



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### Implications for Oklahoma

- The warm season becomes longer and arrives earlier.
- The cool season warms and shortens which leads to a longer frost-free period and growing season.
- Earlier maturation of winter wheat and orchard crops leave them more vulnerable to late freeze events.
- Year-round evaporation from the ground increases as does transpiration from green vegetation.
- Drought frequency and severity increases, especially during summer.
- Drier and warmer conditions will increase the risk of wildfires.
- Rain-free periods will lengthen, but individual rainfall events will become more intense.
- More runoff and flash flooding will occur.

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## The Oklahoma Climatological Survey's Official Stance

**We conclude the following to be true:**

- The earth's climate has warmed during the last 100 years
- The earth's climate will continue to warm for the foreseeable future
- Much of the global average temperature increases over the last 50 years can be attributed to human activities, particularly increasing greenhouse gases in the atmosphere
- **Oklahoma will be impacted.**

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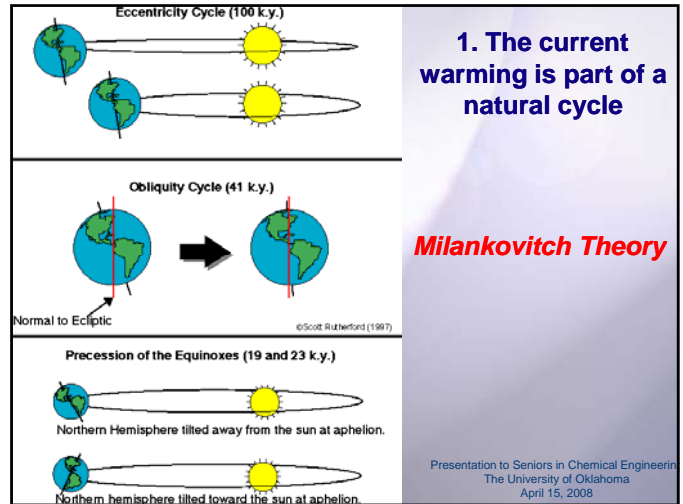
## Global Warming: The "Top Ten" Myths

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## 1. The current warming is part of a natural cycle

**Claim: The earth has warmed (and cooled) throughout history...how is this different?**

- Past global climate changes have physical explanations
  - Ice Ages – Orbital changes (Milankovitch Theory) and solar variations
  - Cooling of the 1940s through 1970s – pollution and volcanism
- The warming of the past 50 years cannot be explained by natural variations alone

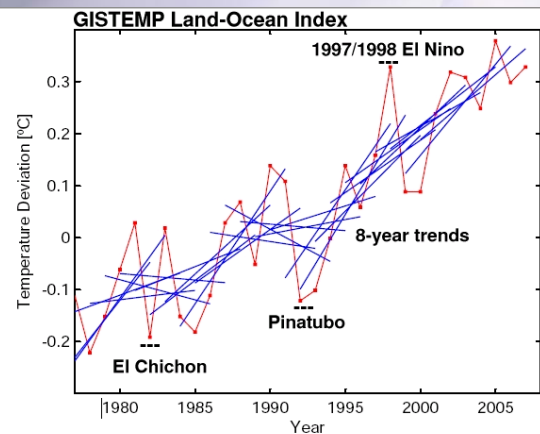


## 2. The earth has begun cooling again

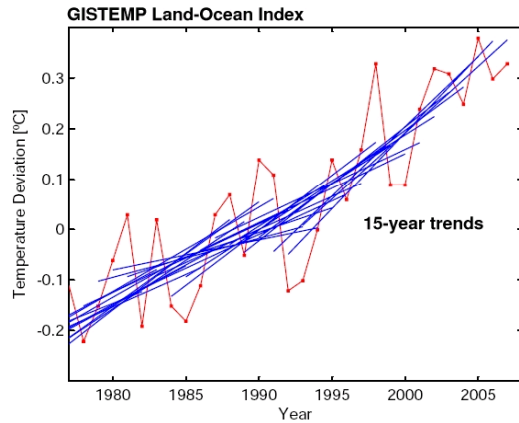
**Claim: 2007 was cold, warming has plateaued since 1998, etc.**

- It is incorrect to mistake short-term variability (weather) for climate change
- Others have happened recently, but the long-term trend has remained positive
- 1988, 1991-92, 1998
- La Nina is the likely culprit for the cold 13 months between from January 2007-2008

## 2. The earth has begun cooling again



## 2. The earth has begun cooling again

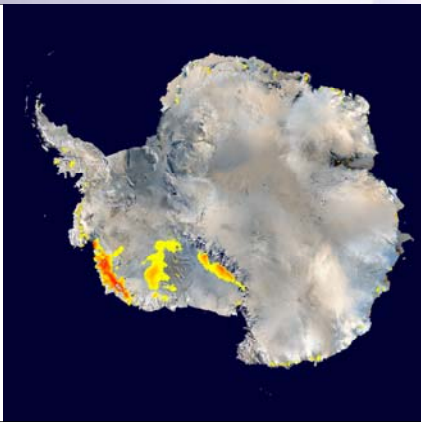


## 3. Antarctica is cooling and gaining ice

**Claim: AHA!!! Gore was wrong!**

- Antarctic cooling is a regional phenomenon, and is related to the ozone hole
  - Ozone hole above south pole causes cooling in stratosphere
  - This strengthens the polar vortex, keeping E. Antarctica and Antarctic Plateau from receiving warm air
- The Antarctic Peninsula, on the other hand, has experienced some of the most rapid warming over the last 50 years
- The above scenarios are consistent with the GCM projections
- Antarctica as a whole is losing ice
- Larsen Ice Shelf partially gone, Wilkins Ice Shelf is going fast

## 3. Antarctica is cooling and gaining ice

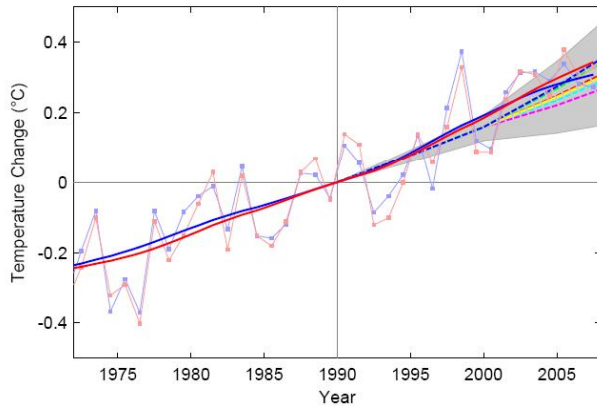


## 4. Climate models are unreliable

**Claim: Scientists can't even predict the weather next week, let alone 100 years from now**

- There is a difference between weather, which is chaotic and unpredictable and climate which is weather averaged out over time.
- "You can't predict with certainty whether a coin will land heads or tails, you can predict the statistical results of a large number of coin tosses."
- Climate models are based on the same physical equations as weather forecasting models, which are very successful and validated every day.
- The chaos that renders weather forecasts useless after a few days "goes away" as the model results are averaged over longer periods of time

#### 4. Climate models are unreliable



#### 4. Climate models are unreliable

Other results successfully predicted and reconstructed by models:

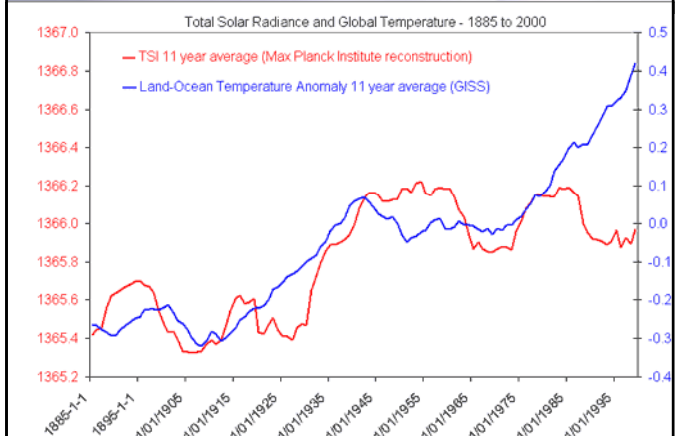
- Cooling of the stratosphere
- Warming of the lower, mid, and upper troposphere
- Warming of ocean surface waters (Cane 1997)
- Trends in ocean heat content (Hansen 2005)
- An energy imbalance between incoming sunlight and outgoing infrared radiation (Hansen 2005)
- Amplification of warming trends in the Arctic region (NASA observations)

#### 5. The sun is the culprit

**Claim: Sun activity and the number of sunspots have increased as we have warmed**

- Solar variations DO affect climate
- No positive trends in any solar index since the 1960s
- The correlation between solar activity and temperature ended around 1975

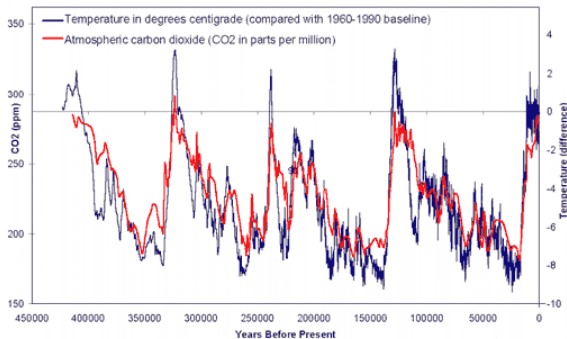
#### 5. The sun is the culprit





## 6. Carbon dioxide changes lag temperature changes

Claim: The warming that ended the ice ages came first, then the increases in CO<sub>2</sub>



## 6. Carbon dioxide changes lag temperature changes

- Warm periods that end ice ages typically last about 5000 years
- Orbital eccentricities help warm the planet
  - Feedback effects (albedo) allowed for melting of ice
- CO<sub>2</sub> is released as melting continues for about 800 years
- CO<sub>2</sub> then becomes the primary cause for the next ~4200 years
- CO<sub>2</sub> does not initiate the warming but acts as an amplifier once it is underway

## 7. Water vapor is more important than CO<sub>2</sub>

Claim: Increased water vapor is actually causing the warming

- Water vapor is in balance on most timescales (the hydrologic cycle)
  - Too much water vapor in the air will quickly (by climate timelines) rain out
  - Not considered a climate forcing because it is a function of temperature
  - It is a feedback effect
- CO<sub>2</sub> and other greenhouse gases stay in the atmosphere for centuries

## 8. "It was cold in Slapout this morning!"

Claim: If global warming is happening, why am I freezing?

- No conclusion about climate can ever be drawn from a single data point, hot or cold
  - A single data point is known as "weather"
- Remember, THINK DECADALLY AND GLOBALLY
- **CLIMATE VARIABILITY WILL CONTINUE, EVEN IN A WARMING CLIMATE!**
  - Hot year, cold years, wet years, and dry years will continue to exist

### 9. There is no consensus

**Claim: Lots of reputable scientists are skeptical that manmade CO2 emissions are causing global warming.**

- With more and more evidence revealed, the skeptical viewpoint has steadily gone from “the earth is not warming” to “CO2 is not the cause” to “what is the scale of the future warming”
- A survey of 1000 scientific papers on global climate change in 2004 – not one rejected the consensus position
- The IPCC not your cup of tea?

### 9. There is no consensus

These organizations backed the consensus view of the IPCC:

- \* National Oceanic and Atmospheric Administration
- \* Environmental Protection Agency
- \* NASA's Goddard Institute of Space Studies
- \* American Geophysical Union
- \* American Institute of Physics
- \* National Center for Atmospheric Research
- \* American Meteorological Society
- \* State of the Canadian Cryosphere
- \* The Royal Society of the UK
- \* Canadian Meteorological and Oceanographic Society

### 9. There is no consensus

And these:

- \* Academia Brasileira de Ciencias (Brazil)
- \* Royal Society of Canada
- \* Chinese Academy of Sciences
- \* Academie des Sciences (France)
- \* Deutsche Akademie der Naturforscher Leopoldina (Germany)
- \* Indian National Science Academy
- \* Accademia dei Lincei (Italy)
- \* Science Council of Japan
- \* Russian Academy of Sciences
- \* Royal Society (United Kingdom)

### 9. There is no consensus

Or these:

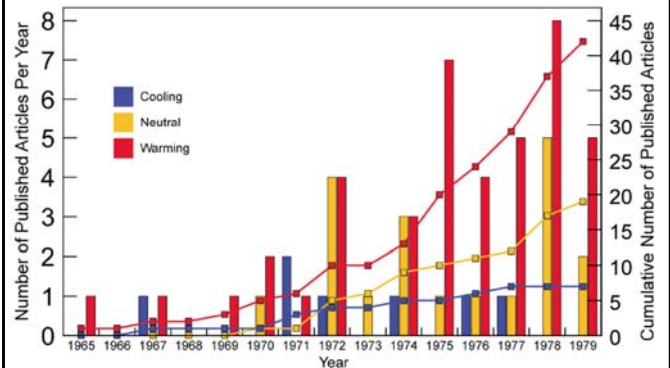
- \* National Academy of Sciences (United States of America)
- \* Australian Academy of Sciences
- \* Royal Flemish Academy of Belgium for Sciences and the Arts
- \* Caribbean Academy of Sciences
- \* Indonesian Academy of Sciences
- \* Royal Irish Academy
- \* Academy of Sciences Malaysia
- \* Academy Council of the Royal Society of New Zealand
- \* Royal Swedish Academy of Sciences

## 10. Scientists warned of global cooling in the 1970s

**Claim: First it was global cooling, now global warming!**

- The 1970s was an unusually cold decade, however...
- Survey of peer-reviewed scientific articles from 1965-1979 found only SEVEN supported global cooling (including the famous Newsweek article) while 44 predicted warming
- Review of the literature suggests that greenhouse warming even then dominated climate scientists' thinking

## 10. Scientists warned of global cooling in the 1970s



## Areas Still Under Debate

The fine details should always be debated!

- Hurricanes
- Severe weather
- Climate sensitivity

## Check things out for yourself

- The IPCC site: [ipcc.ch](http://ipcc.ch) (start with the technical summary or the FAQ)
- A site run by climate change scientists: [realclimate.org](http://realclimate.org)
- Skeptical de-bunking: [skepticalscience.com](http://skepticalscience.com)
- Skeptical view on global warming: [globalwarming.org](http://globalwarming.org)
- When in doubt: GOOGLE

## *Thank You — Questions?*



Presentation to Seniors in Chemical Engineering  
The University of Oklahoma  
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