

# The Science Behind Global Climate Change

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Presentation to CSS 235, Society & Natural Resources

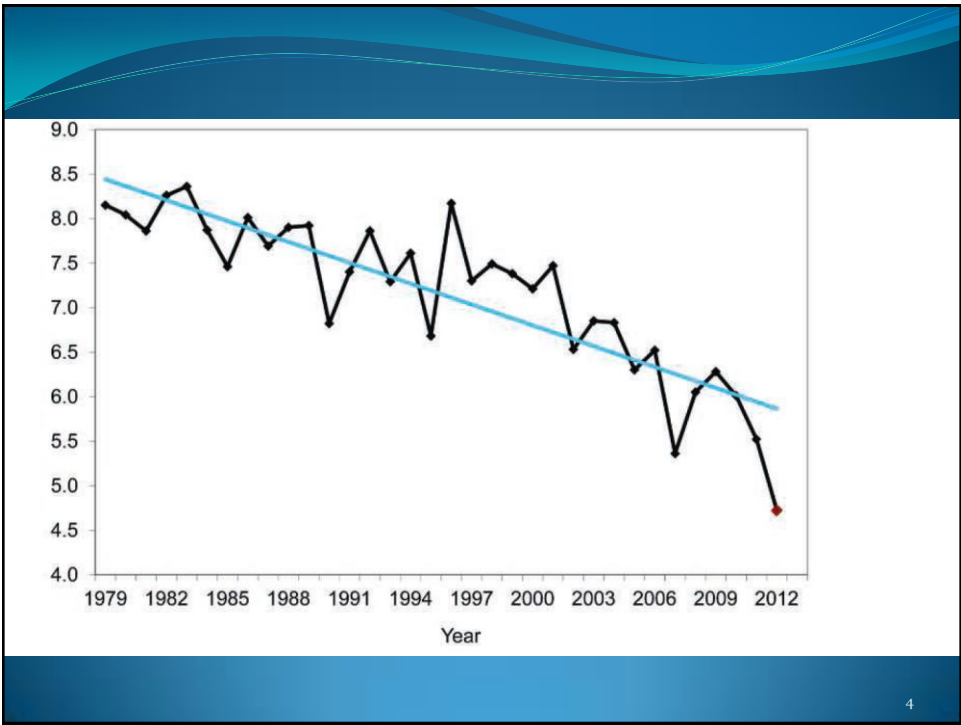
**Everyone is entitled to his  
own opinion, but not to  
his own facts**

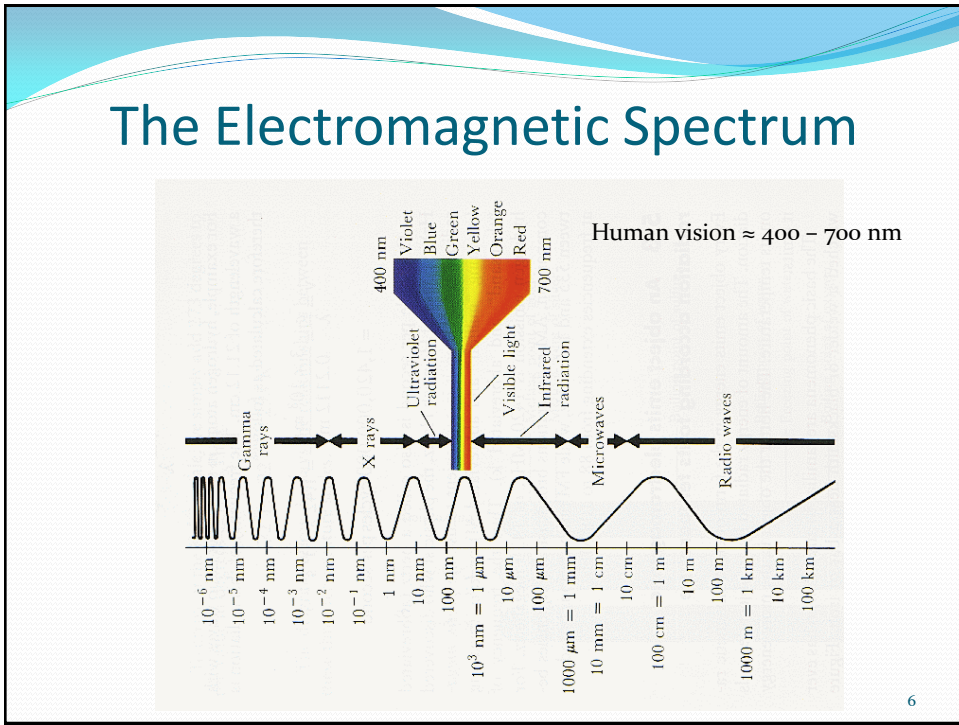
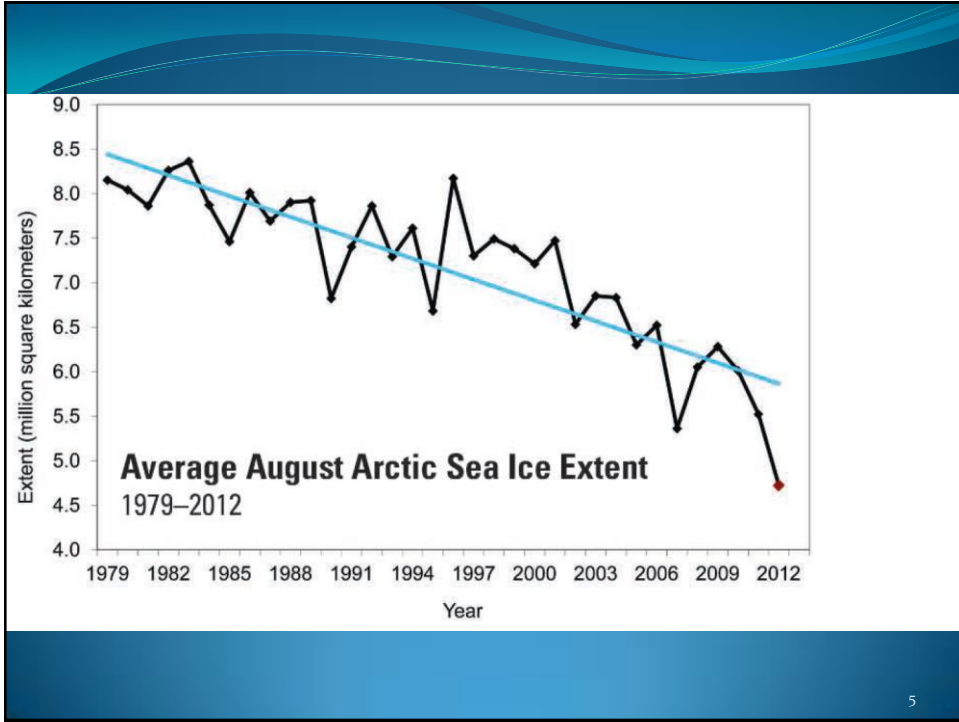
Attributed to  
Sen. Daniel Patrick Moynihan

*“...the debate on the authenticity of global warming and the role played by human activity is largely nonexistent among those who understand the nuances and scientific basis of long-term climate processes”.*

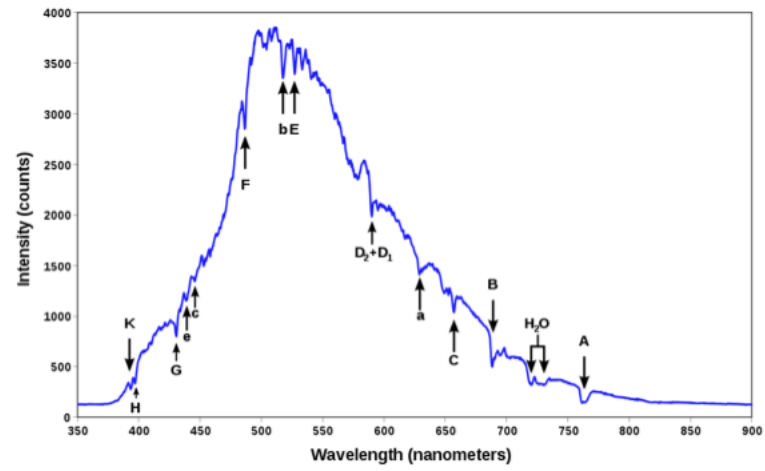
P. T. Doran and M. K. Zimmerman, EOS 90, 2009, 22

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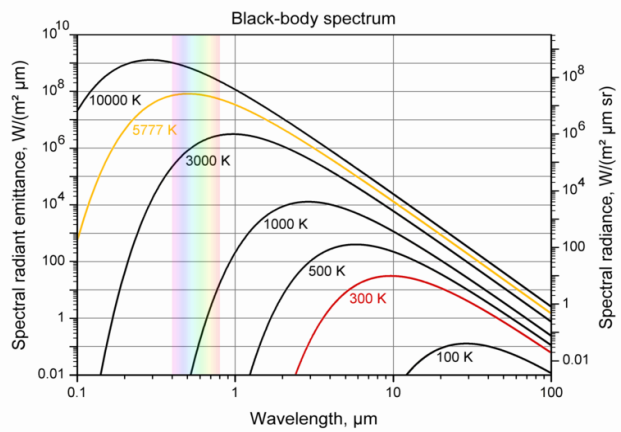


### Solar Spectrum at the Surface of the Earth



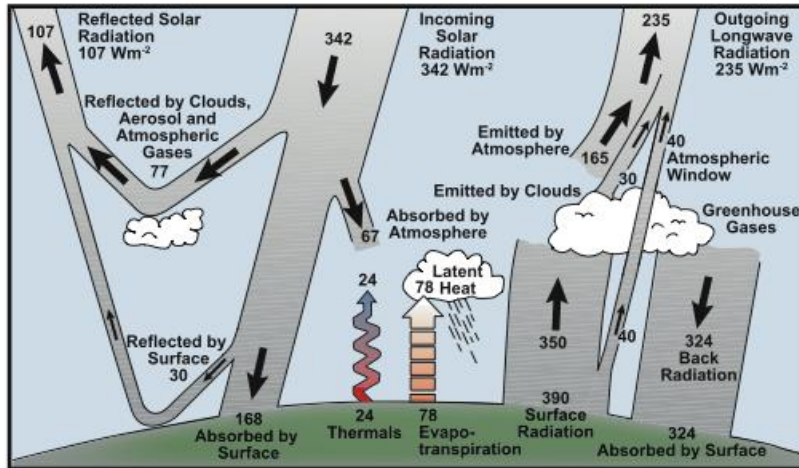
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### Black Body Radiation



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## Earth's Energy Balance



FAQ 1.1, Figure 1. Estimate of the Earth's annual and global mean energy balance. Over the long term, the amount of incoming solar radiation absorbed by the Earth and atmosphere is balanced by the Earth and atmosphere releasing the same amount of outgoing longwave radiation. About half of the incoming solar radiation is absorbed by the Earth's surface. This energy is transferred to the atmosphere by warming the air in contact with the surface (thermals), by evapotranspiration and by longwave radiation that is absorbed by clouds and greenhouse gases. The atmosphere in turn radiates longwave energy back to Earth as well as out to space. Source: Kiehl and Trenberth (1997).

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## What do Greenhouse Gases do?

- These gases absorb light in the infrared part of the spectrum.
- $\text{N}_2$  and  $\text{O}_2$  make up the vast majority of the atmosphere and these gases are transparent to infrared light.
- Without greenhouse gases the Earth's temperature would be  $0^\circ\text{F}$  ( $-18^\circ\text{C}$ ) as opposed to its actual temperature of  $57^\circ\text{F}$  ( $14^\circ\text{C}$ ).

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## What are the Greenhouse Gases?

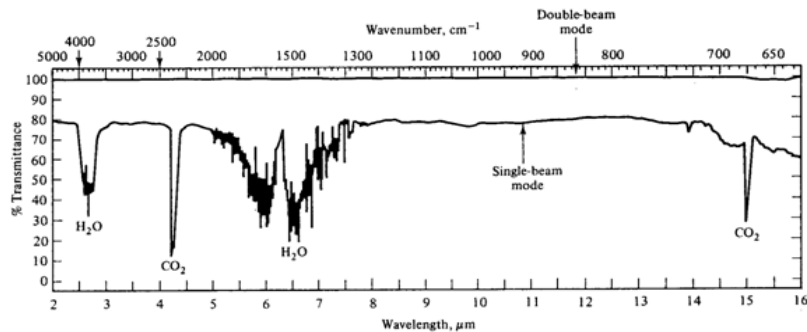
Greenhouse Gas	% Contribution on a Clear Day
Water	60
CO <sub>2</sub>	26
Ozone	8
Methane and Nitrous Oxide	6

Kiehl, Bull. Am. Meteorological Soc., 78, 1997, 197

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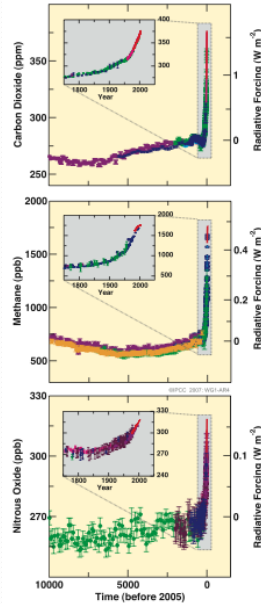
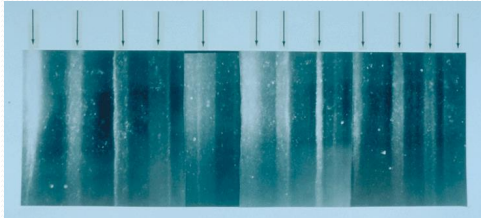
## IR Spectrum of Air

O<sub>2</sub> and N<sub>2</sub> do not absorb IR radiation



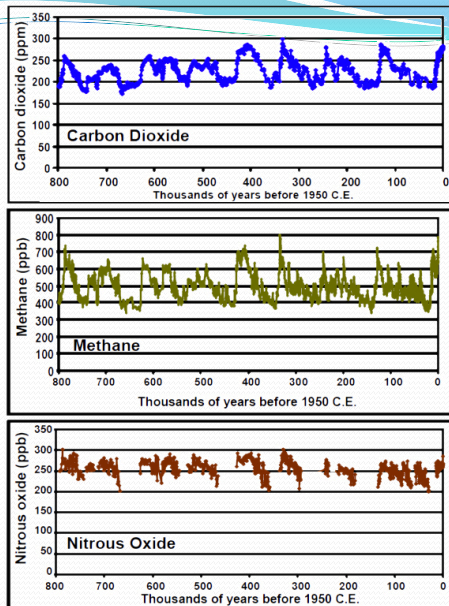
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# Atmospheric Gas Record from Vostok Ice Cores

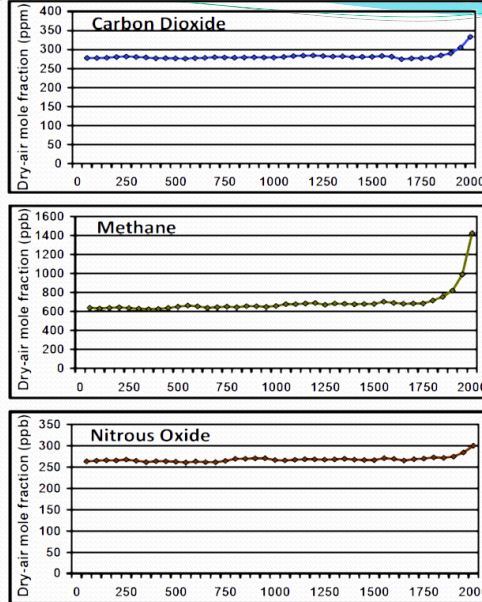


IPCC, 2007: Summary for Policymakers. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

## 800 kY Record

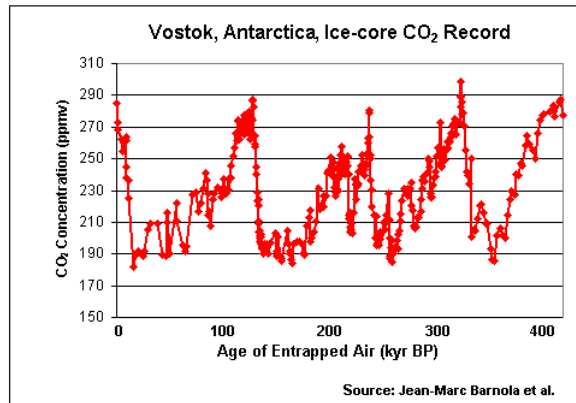


## 2000 Y Record



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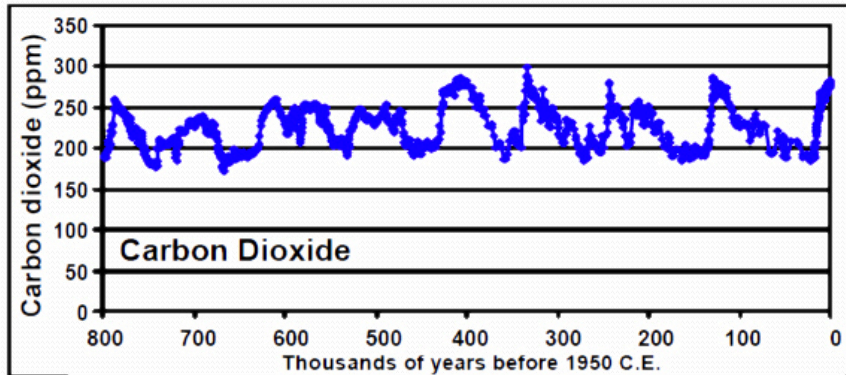
## Current CO<sub>2</sub> ca. 390 ppm



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390 ppm exceeds any value for the last 800,000 years



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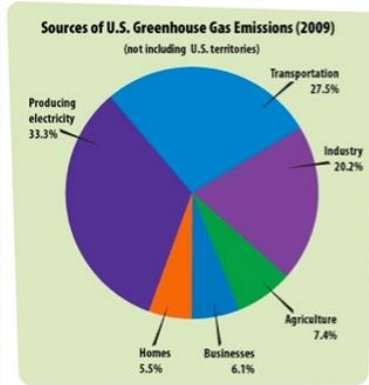
## Natural Sources and Sinks of CO<sub>2</sub>

- CO<sub>2</sub> is produced by all living things that utilize O<sub>2</sub> in their metabolisms
- CO<sub>2</sub> is released in volcanic events
- CO<sub>2</sub> is converted to plant materials by photosynthesis
- Soils absorb CO<sub>2</sub>
- CO<sub>2</sub> is absorbed into the oceans –
  - $\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3$  (carbonic acid)

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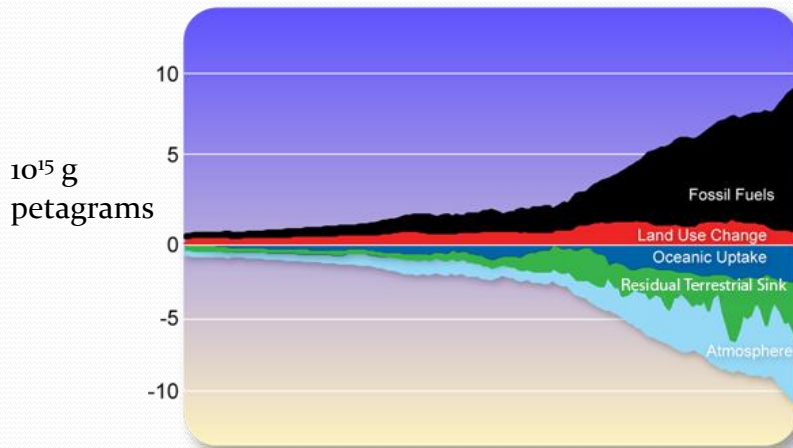
## Anthropogenic Sources of CO<sub>2</sub>

- Fossil fuel (coal, oil, gas) burning
- Iron and steel
- Cement manufacture



Source: EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks (2011).

## Global CO<sub>2</sub> Balance



1850 1865 1880 1895 1910 1925 1940 1955 1970 1985 2000

<http://www.whrc.org/global/carbon/residual.html>

How much CO<sub>2</sub> has been added since 1850?

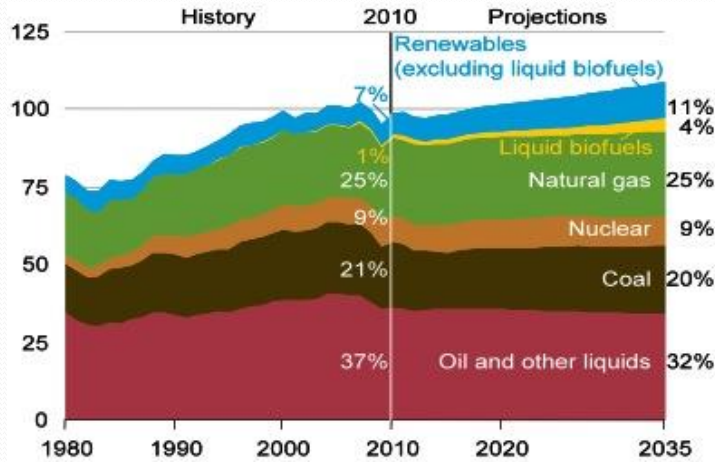
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How much CO<sub>2</sub> has been added since 1850?

**ca. 16 %**

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## US Fossil Fuel Use Projections



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## World Energy Use Projections

Figure 7. World Marketed Energy Consumption, 1980-2030

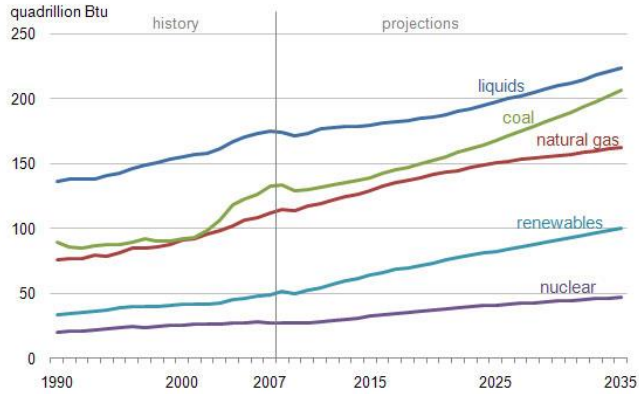


Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2003* (May-July 2005), web site [www.eia.doe.gov/iea/](http://www.eia.doe.gov/iea/). **Projections:** EIA, System for the Analysis of Global Energy Markets (2006).

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# World Energy Use by Fuel

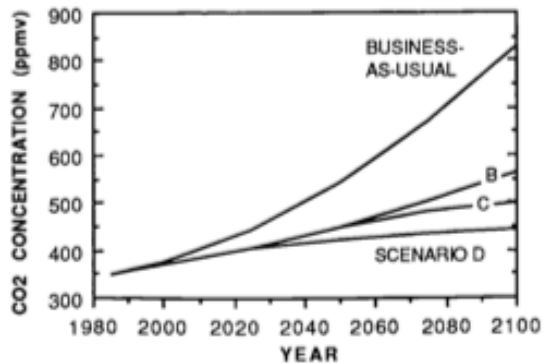
Figure 2. World marketed energy use by fuel type



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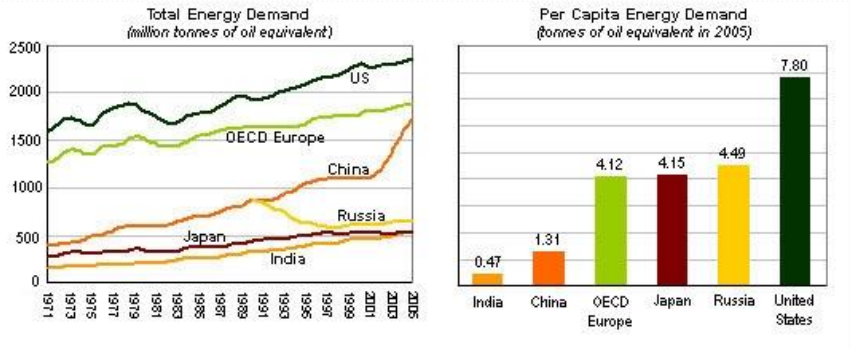
# Which Scenario Are We Following?

- In Scenario B
- The energy supply mix shifts towards lower carbon fuels, notably natural gas
- Large efficiency increases are achieved
- Carbon dioxide controls are stringent
- Deforestation is reversed
- The Montreal Protocol implemented with full participation

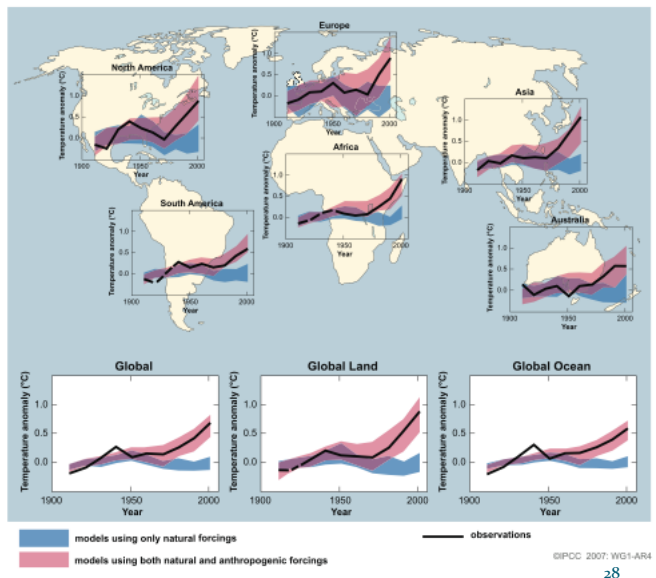
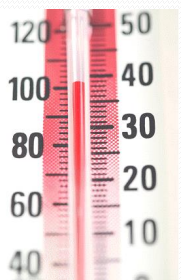


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# Per Capita Demand

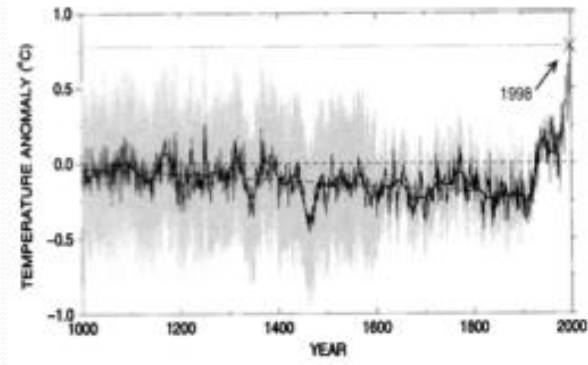


# Global Temperature Change



# Millennial Temperature Record

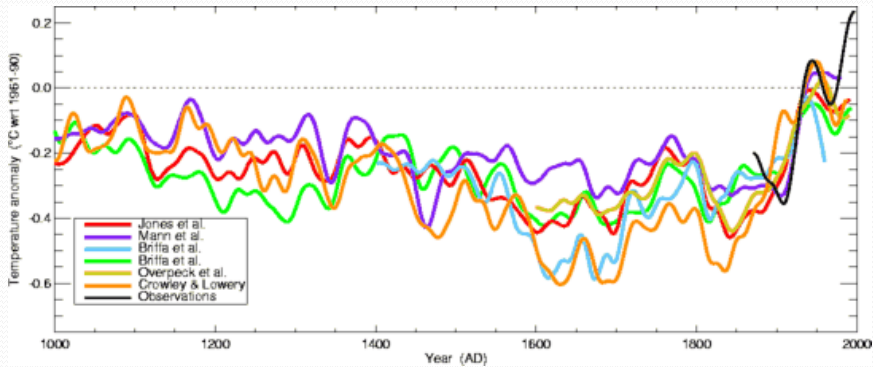
- The original “hockey stick”



Mann, Geophysical Res. Lett. 26, 1999, 759

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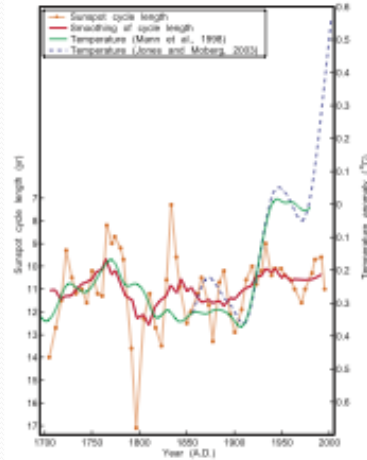
# Millennial Temperature Record



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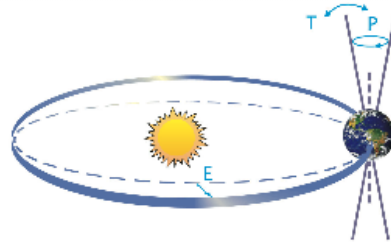
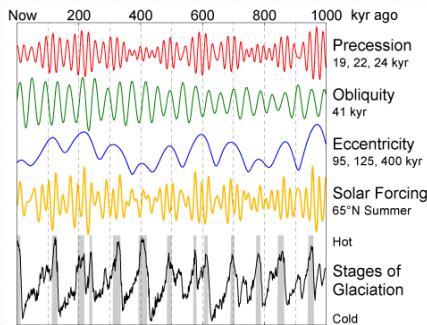
# What about the Sun?

- The sun is certainly a contributor to the Earth's temperature but solar variation is unable to account for the current rise



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# Milankovitch Cycle Variations



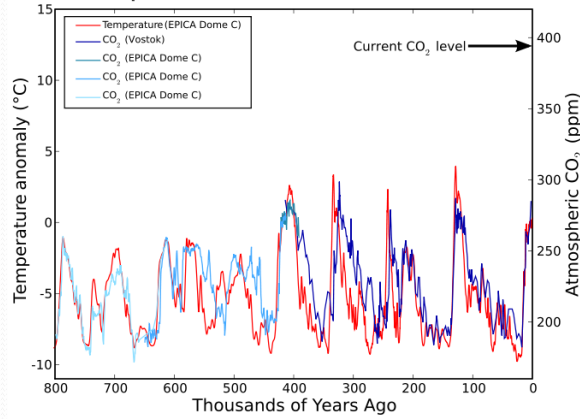
**FAQ 6.1, Figure 1.** Schematic of the Earth's orbital changes (Milankovitch cycles) that drive the ice age cycles. "T" denotes changes in the tilt (or obliquity) of the Earth's axis, "E" denotes changes in the eccentricity of the orbit (due to variations in the minor axis of the ellipse), and "P" denotes precession, that is, changes in the direction of the axis tilt at a given point of the orbit. Source: Rahmstorf and Schellnhuber (2006).

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# Temperature and CO<sub>2</sub>

Temperature and CO<sub>2</sub> Records



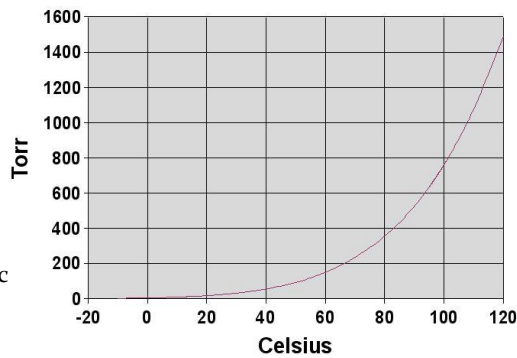
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# What about Water?

Temp (oC)	Pressure (MM Hg)
30	31.5
32	36
35	42

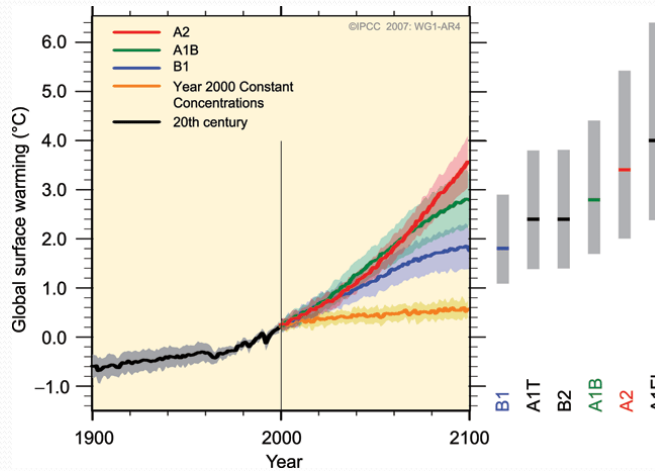
Water vapor is dependent upon atmospheric and oceanic temperatures

As T ↑; water vapor ↑  
This is a positive feedback



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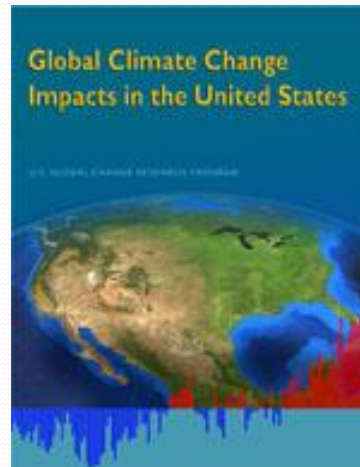
## Temperature Projections



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## Climate Change and the US

- <http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf>



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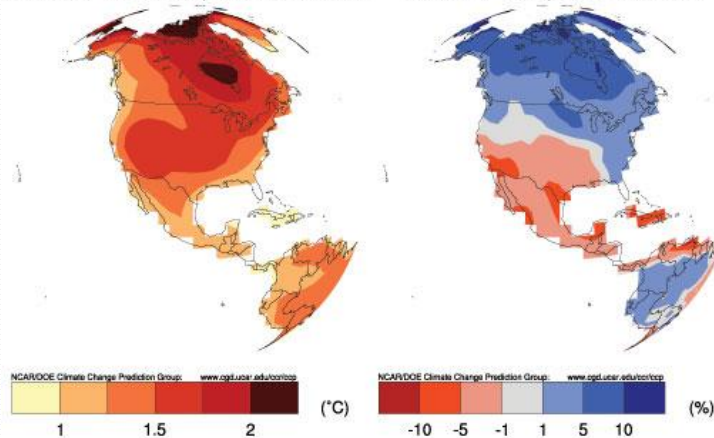
## What does it mean for me?

- Total yearly precipitation in the NW will remain about constant but summer will be drier and winter wetter.
- Warmer temperatures will mean lower snowpack in the Cascades with somewhat less of an impact in the Northern Rockies.
- Models predict a temp rise of 0.1 – 0.6 °C per decade or about 3 times the 20<sup>th</sup> century rate.

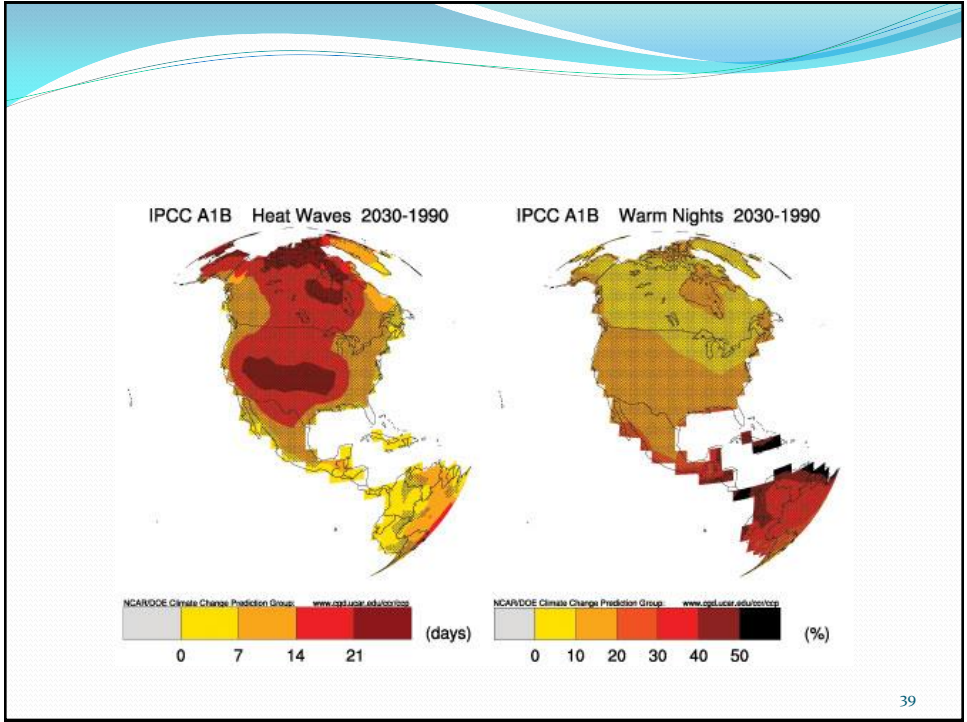
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## Projected Changes

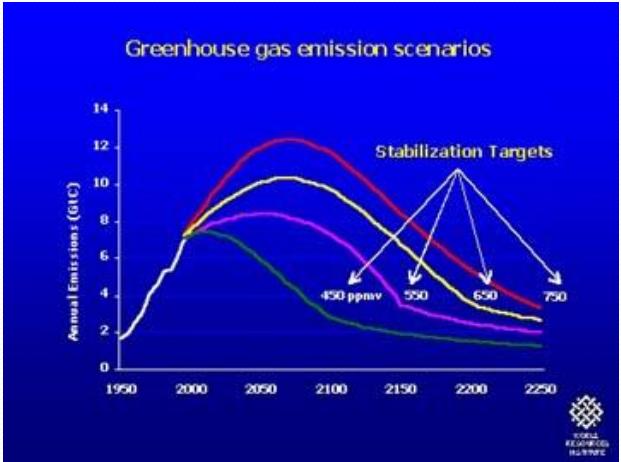
IPCC A1B Sfc Air Temperature 2030-1990      IPCC A1B Precipitation 2030-1990



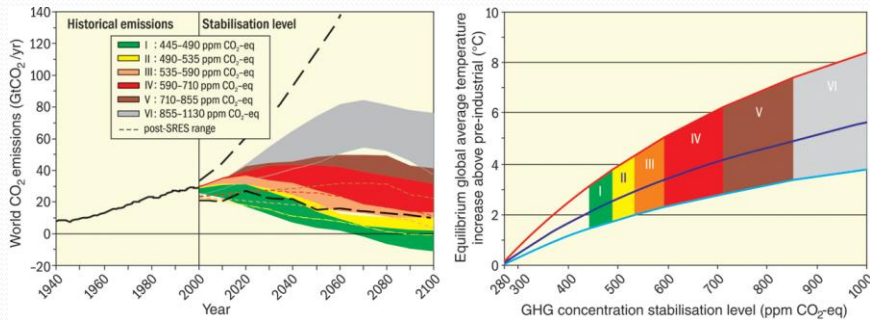
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# Stabilization Scenarios



## What this means to temperature



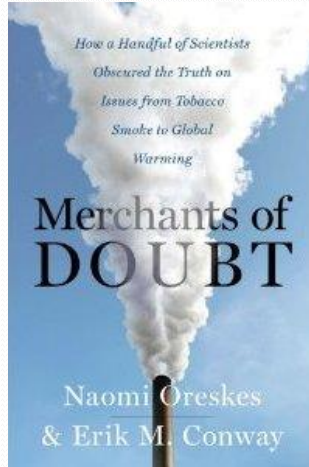
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## Biological Impact

- It's the Rate, Stupid!
- Environmental change typically takes place over periods of thousands of years giving plants and animals time to either move habitats or to adapt to the new conditions.
- Compressing those temperature changes into the space of 150 years will have a dramatic impact on species survival.

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## Why is there so much confusion?



- Heartland Institute document release shows efforts at deliberate misinformation of the public.  
<http://www.desmogblog.com/heartland-institute-exposed-internal-documents-unmask-heart-climate-denial-machine>

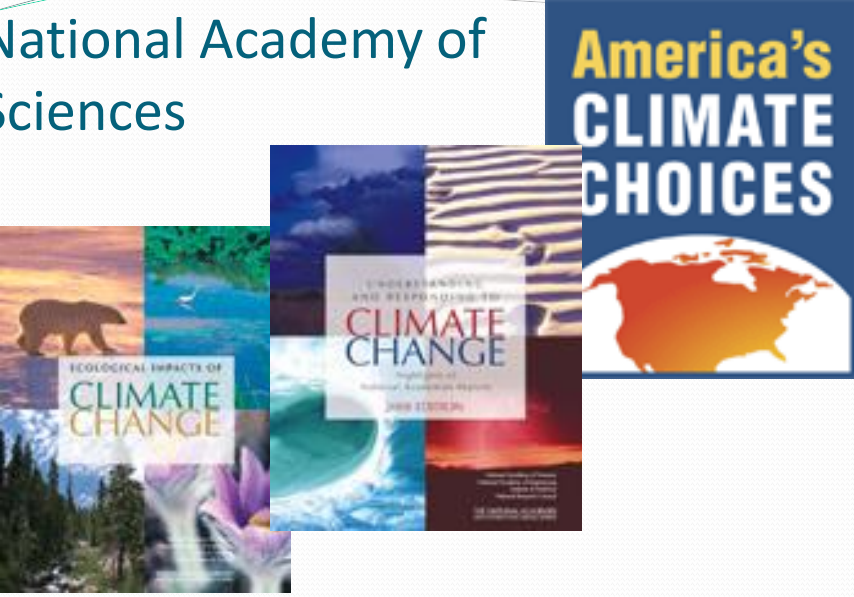
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## Where to go to learn more

- <http://climate.nasa.gov/>
- <http://epa.gov/climatechange/index.html>
- <http://www.noaa.gov/climate.html>
- <http://dels.nas.edu/Report/America-Climate-Choices/12781>
- [http://www.usda.gov/oce/climate\\_change/](http://www.usda.gov/oce/climate_change/)
- <http://www.ipcc.ch/>
- <http://www.aip.org/history/climate/co2.htm>
- <http://www.realclimate.org/>
- <http://www.skepticalscience.com>

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National Academy of Sciences



America's CLIMATE CHOICES

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The Bottom Line

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