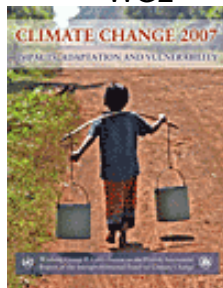


IPCC

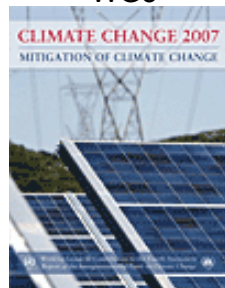
WG1



WG2



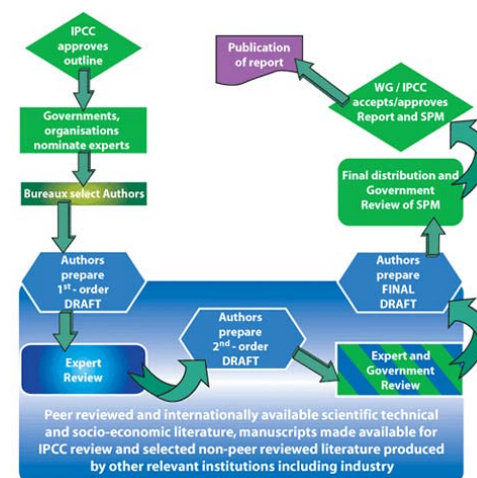
WG3



- Regular Assessments mandated by governments (UN) 1990, 1995, 2001, 2007, 2013 ...
- Summarize state of climate science* (WG1), impact of climate change (WG2), and possible mitigation options (WG3)

* Must be published in the peer-reviewed literature

IPCC



A four year process involving ~2700 scientists

Global Warming: Science, Projections and Uncertainties

An overview of the basic science

1. A Brief History of "Global Warming"
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4. What's new in Climate Science?
5. Conclusions

Greenhouse Effect: not a new problem



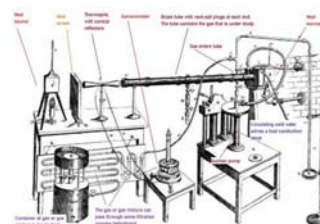
Joseph Fourier, 1827:

Recognized the earth (not the atmosphere) is mainly heated by the Sun, and gases in the atmosphere slow the heat loss to space and make the surface of the planet warmer than it would otherwise be.

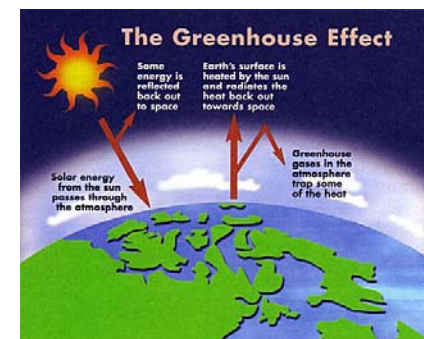


John Tyndall, 1860s:

Recognized water vapor and carbon dioxide are greenhouse gases.



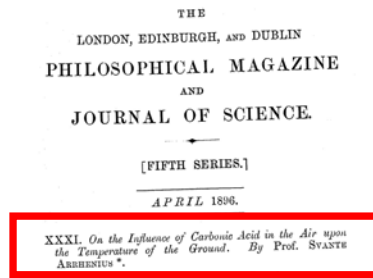
Tyndall's thermopile



Global Warming: not a new problem

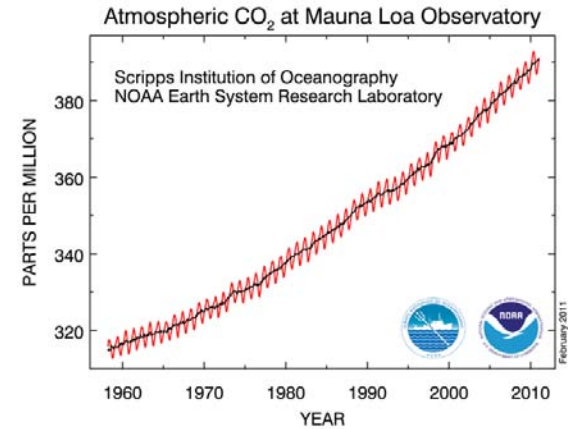


Svante Arrhenius, 1896



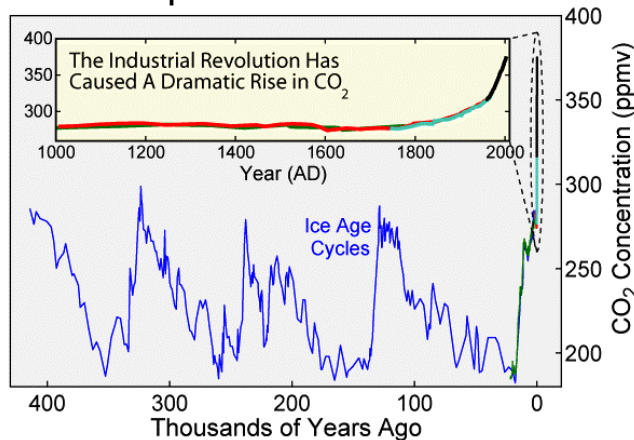
- In 1894, Hoggom calculated the amount of carbon dioxide added to the atmosphere due to burning coal
- In 1896, Arrhenius:
 - estimated that it would take 3000 years for humans to double atmospheric carbon dioxide ✗
 - *calculated that doubling atmospheric carbon dioxide would increase the global temperature by 5-6 degrees C.* ✓

Atmospheric Carbon Dioxide



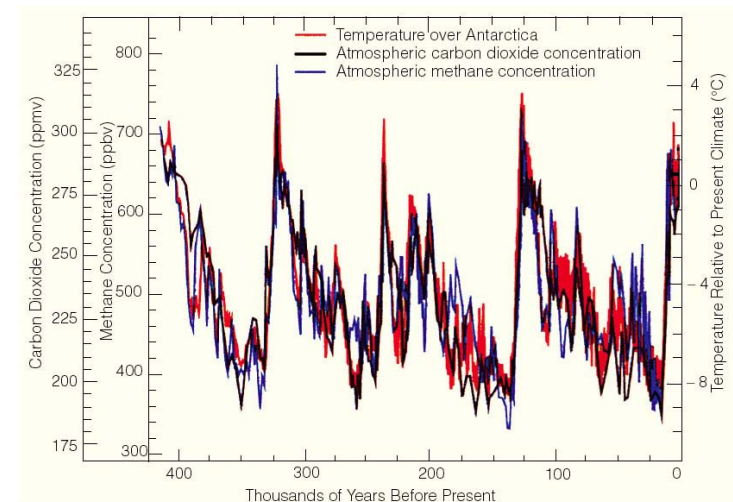
- Carbon Dioxide is increasing because of the burning fossil fuels (85%) and deforestation (15%)
 - 25% increase in the past 50 years; 10% increase since 1990;

Atmospheric Carbon Dioxide



- Carbon dioxide increased by 40% since 1750 because of the burning fossil fuels (75%) and deforestation (25%)
 - Fate: 40% in atmosphere, 35% in land and 25% in ocean
- The *rate of increase* is 100-1000 times faster than Nature can change CO₂

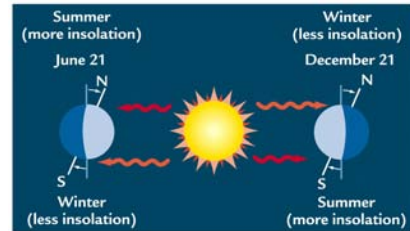
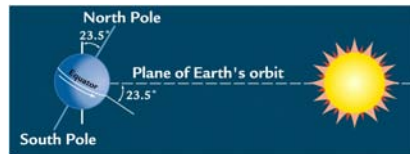
Vostok Station, South Pole CO₂, Methane and Temperature



Orbital Variations and Ice Ages

Obliquity or Tilt

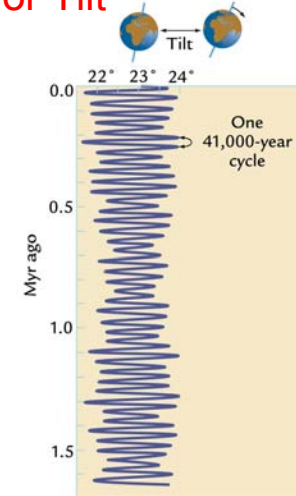
- Tilt angle is presently 23.44°
- Tilt is the main reason why we have large seasonal cycles in mid-latitudes and polar regions
- Variations in tilt angle have no impact on global average insolation



Orbital Variations and Ice Ages

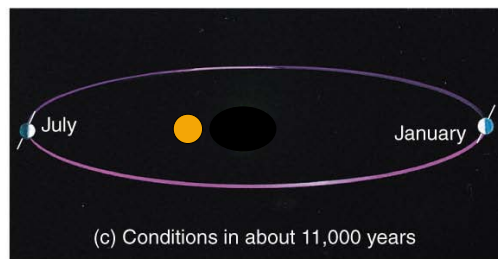
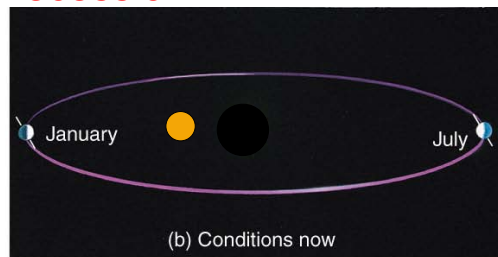
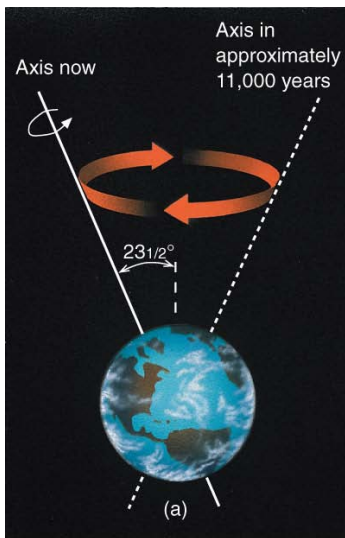
Obliquity or Tilt

- Tilt of axis of rotation varies from 22.5° and 24.5° .
 - Dominant period of 41 kyr
- Variations in tilt angle modulate seasonality, especially in high latitudes
 - Winter & summer insolation anticorrelated (warm winter when cold summer) -- good for Milankovitch's theory of ice ages
 - Northern and Southern Hemisphere are anti-correlated
- Variations in tilt angle have no impact on *global* average insolation



Orbital Variations and Ice Ages:

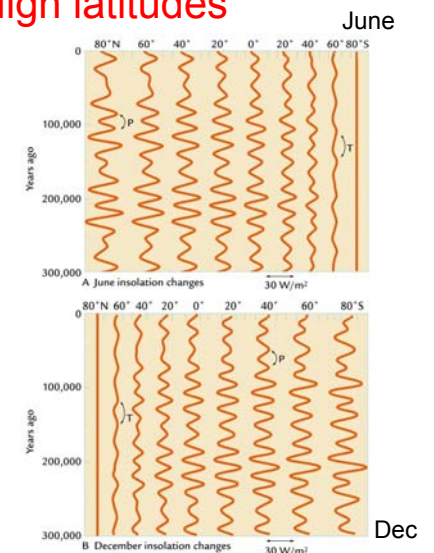
Precession



Orbital Variations and Insolation

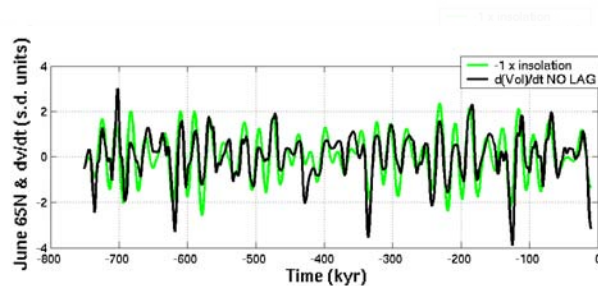
Tropics vs. High latitudes

- In the tropics, seasonal insolation changes are predominately due to changes in precession (23kyr)
- In the high latitudes, seasonal changes in insolation are due to both tilt (41kyr) and precessional (23kyr) changes



NH Summer Insolation and Ice Ages

- *Rate of change of ice volume* is directly related to high latitude NH summer insolation (less sun <--> increasing land ice)



- **maximum correlation of -0.8**

Ice Age Cycles: Some big solved problems

- Current climate is not the only possible one for Earth
 - indeed, glacial conditions seem to be preferred for the past 3Myr
- The ice Age Cycles wax and wane due to changes in the way the Earth Orbits the sun
 - Global climate and CO₂ are intimately intertwined
 - but CO₂ is acting as a *feedback* and not the driver of ice age cycles
- A change in global-mean surface temperature of about 5C is a massive climate shift (an ice age, with 3km of ice sitting on most of Canada)
- If the orbital parameter theory is right, small triggers can produce major climate changes under some conditions

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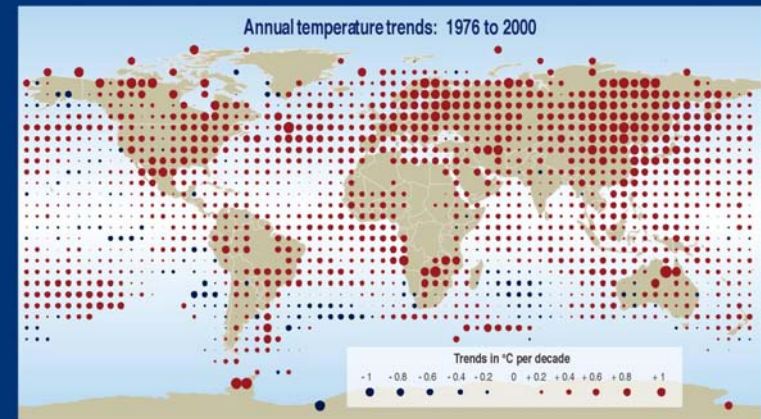
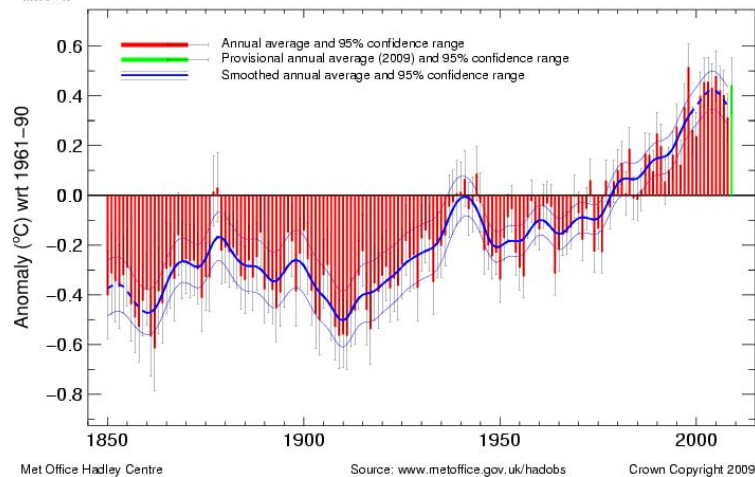
2. Climate Change: 1850-2007

- Intergovernmental Panel on Climate Change (IPCC)
 - Major reports in 1990, 1996, 2001, 2007 that summarize thousands of peer-reviewed scientific papers
 - A consensus report with contributions from more than 1000 scientists
- Greenhouse gases (carbon dioxide, methane, nitrous oxide) have been increasing since 1750 because of human activity.
- The Earth has warmed by $0.8 \pm 0.2^{\circ}\text{C}$ since 1900.
- The IPCC concludes:
 - “The balance of evidence suggests a discernible human influence on global climate” (1996)
 - “Most of the observed warming over the past 50 years is likely to have been due to the increase in greenhouse gas concentrations.” (2001)
 - “Most of the observed increase in global average temperature since the mid-20th century is very likely [$>90\%$ chance] due to the observed increase in anthropogenic greenhouse gas emissions” (2007)
 - Discernible human influences now extend to other aspects of climate, including ocean warming, continental-average temperatures, temperature extremes and wind patterns” (2007)



Global average temperature 1850–2008

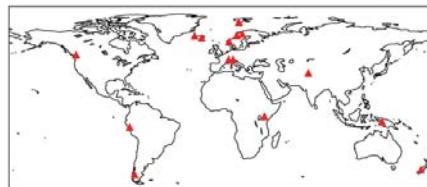
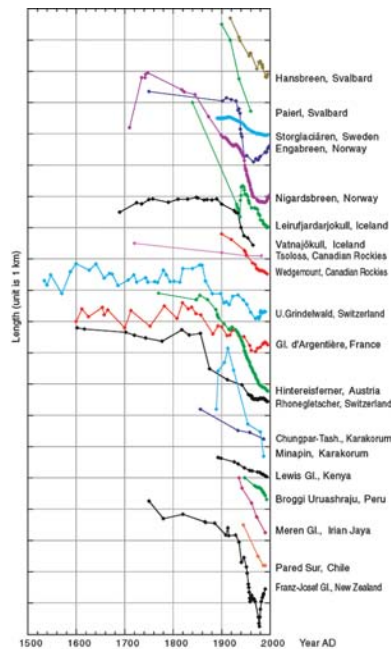
Based on Brohan et al. 2006



SYR - FIGURE 2-6b

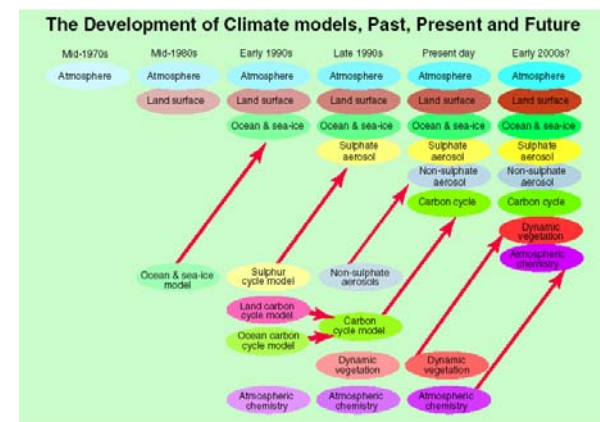
IPCC

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE



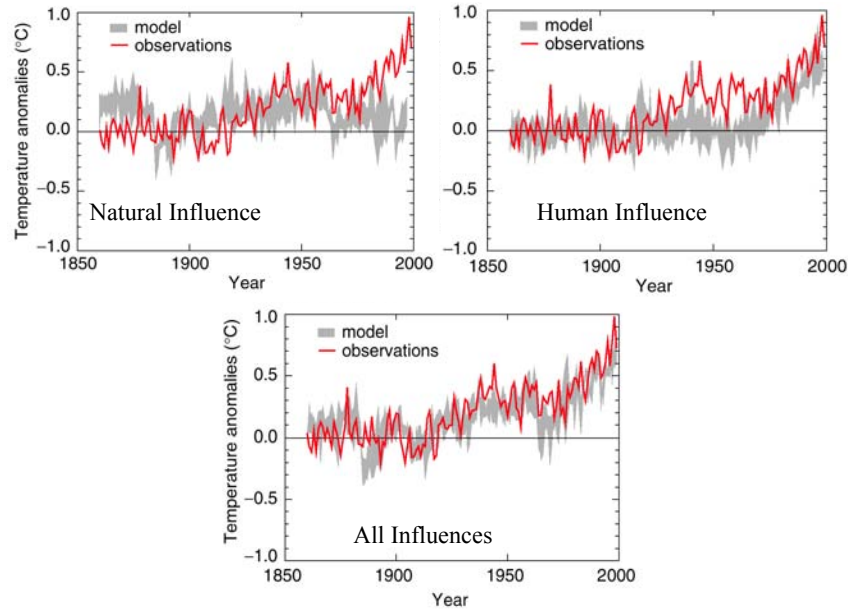
Most glaciers are receding.

Climate Models are used to understand the cause of the observed climate change, and to project the future

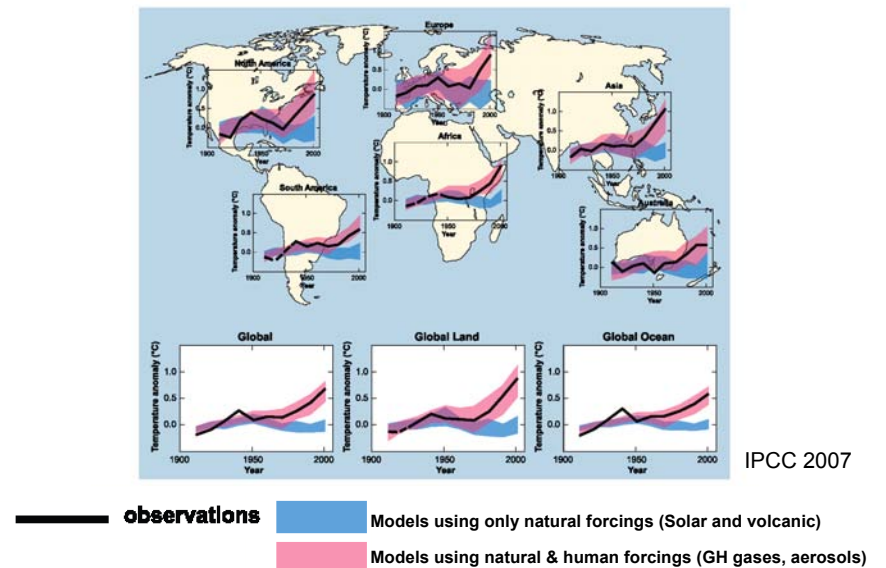


Climate Models are based on the laws of physics and chemistry, and used for ~40 years for various problems.

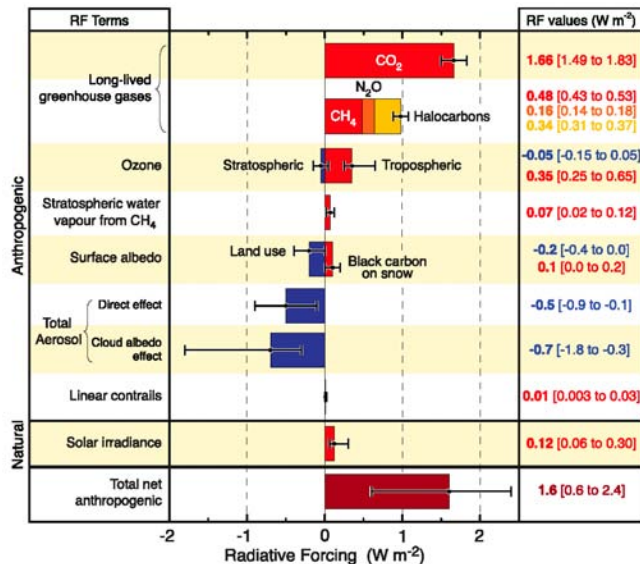
Modeled and Observed Temperature Change 1850-2000



Modeled and Observed Temperature Change 1900-2000



Why has the global average temperature increased? It's more than just CO₂



IPCC 2007

Climate changes (1900 to 2000) due to human activity

Phenomenon ^a and direction of trend	Likelihood that trend occurred in late 20th century (typically post 1960)	Likelihood of a human contribution to observed trend ^b
Warmer and fewer cold days and nights over most land areas	Very likely ^c	Likely ^d
Warmer and more frequent hot days and nights over most land areas	Very likely ^c	Likely (nights) ^d
Warm spells/heat waves. Frequency increases over most land areas	Likely	More likely than not ^f
Heavy precipitation events. Frequency (or proportion of total rainfall from heavy falls) increases over most areas	Likely	More likely than not ^f
Area affected by droughts increases	Likely in many regions since 1970s	More likely than not
Intense tropical cyclone activity increases	Likely in some regions since 1970	More likely than not ^f
Increased incidence of extreme high sea level (excludes tsunamis) ^g	Likely	More likely than not ^h

Virtually certain > 99%

Very likely > 90%

Likely > 66%

More likely > 50% than not

Probability "based on quantitative analysis or an elicitation of the expert views"

IPCC 2007