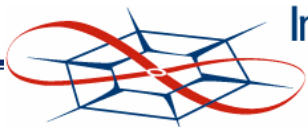


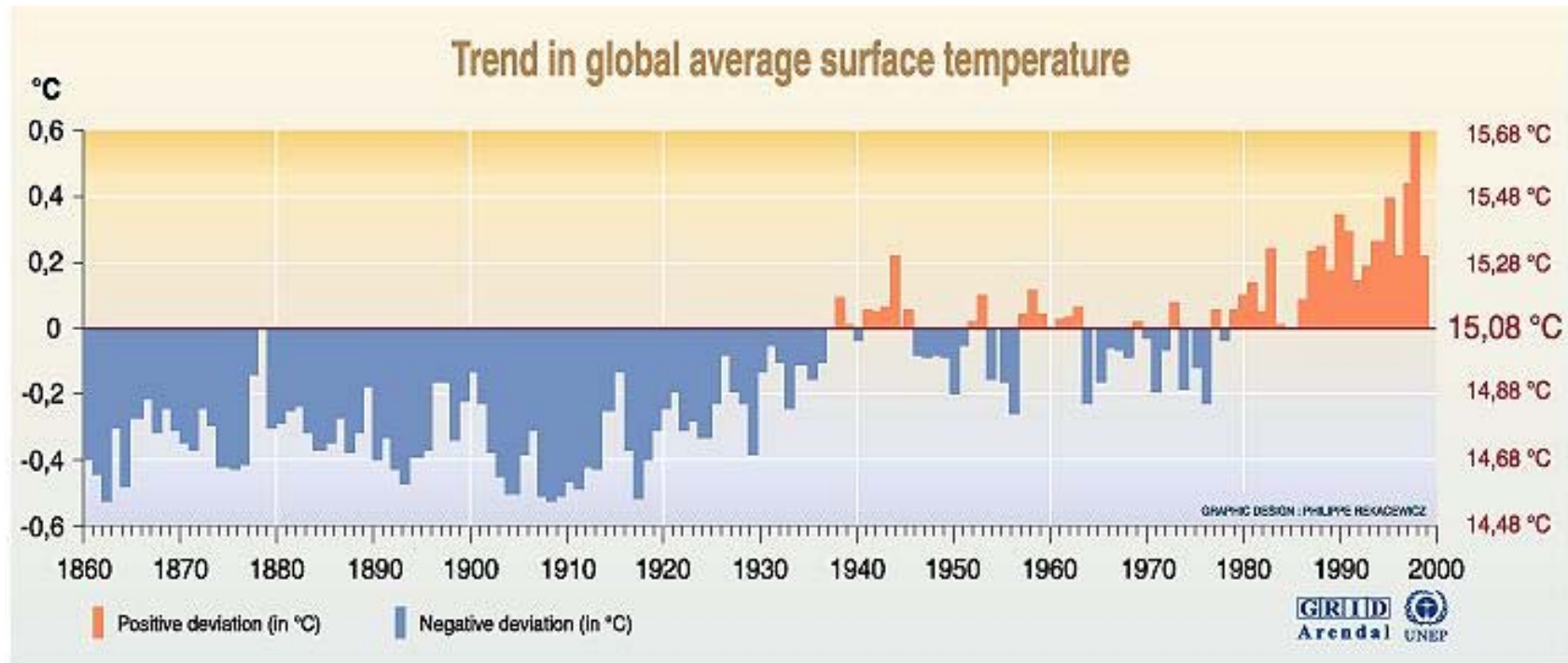
Global Climate Change



The picture's pretty bleak, gentlemen.... The world's climates are changing, the mammals are taking over, and we all have a brain about the size of a walnut.



Global Average Temperature Changes



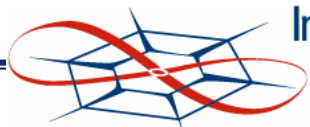
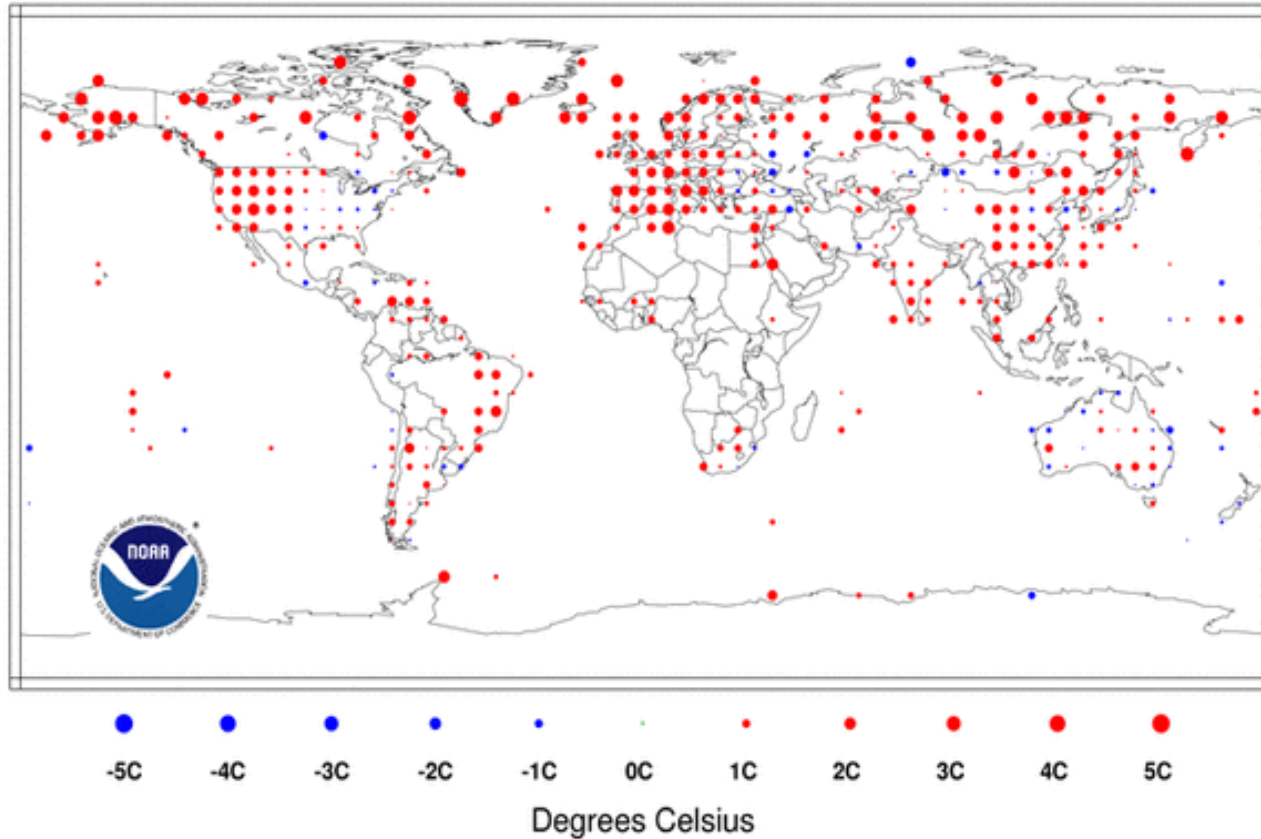
Source: School of environmental sciences, climatic research unit, university of East Anglia, Norwich, United Kingdom, 1999.

(Relative to the average temperature between 1961 and 1990)

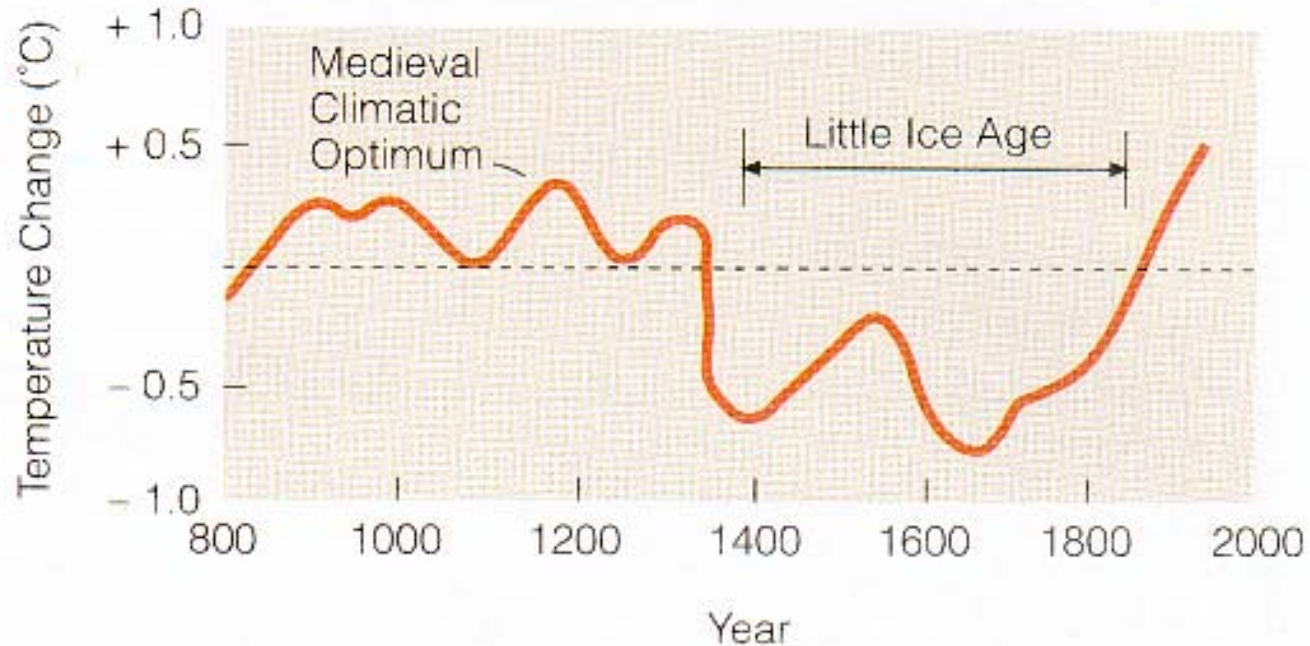
2002 and 2003 are tied for the second warmest years on record.

Annual 2003 Temperature Anomalies

National Climatic Data Center/NESDIS/NOAA

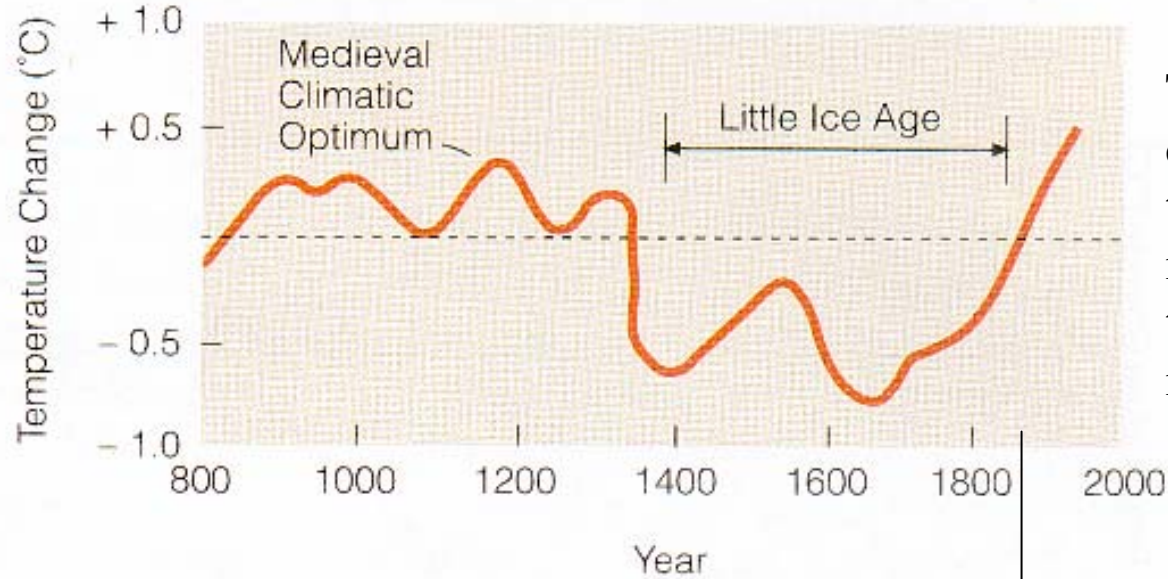


Global climate fluctuations are not unusual



- Medieval Climactic Optimum – Vikings settled Greenland.
- Little Ice Age – Long, severe winters; short, wet summers. Temperate glaciers advanced.
- Current Warming – Warmest in 1000 years.

Climate Data



The most disturbing trend of the past 50 years is the rate at which temperature is increasing.

Paleoclimate records

Instrument records

Ice core chemistry
Ocean core sediments
Tree rings

Written descriptions
Paintings

Thermometer

Greenland Ice Core – July 2003



Depth: ~3,050 meters.
This ice formed from snow
that fell in Greenland about
120,000 years ago.



Thermal Balance of Planet Earth - Radiative Equilibrium



Incoming versus Outgoing Radiation

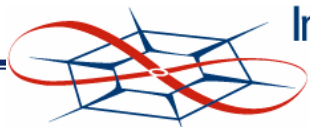
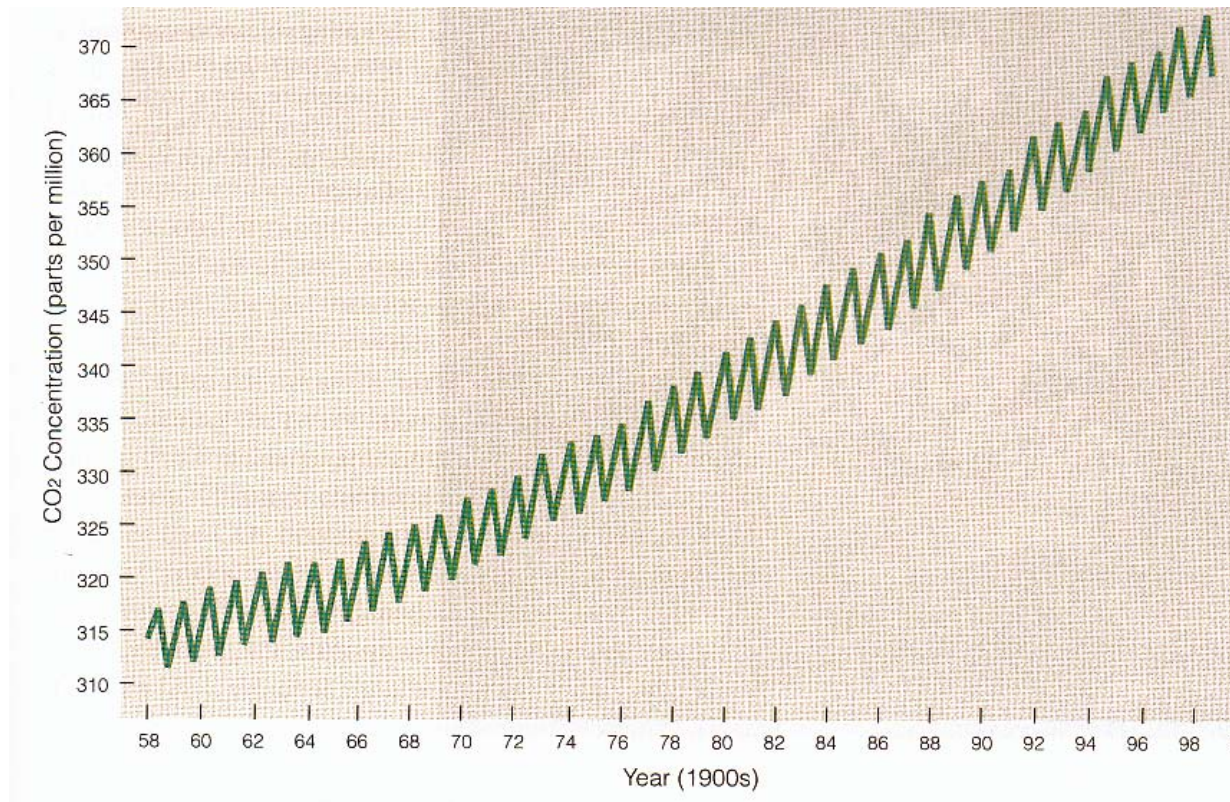
Outgoing radiation controlled by
“greenhouse gases.”

- Carbon Dioxide (increasing 0.4%/yr)
- Methane (increasing 0.5%/yr)
- Nitrous Oxide (increasing 0.25%/yr)
- Chlorofluorocarbons (leveled off)
- Water vapor

Without “greenhouse gases” in the atmosphere, the planet would be a frozen wasteland, with a global average temperature of -18°C .

Carbon Dioxide (CO₂)

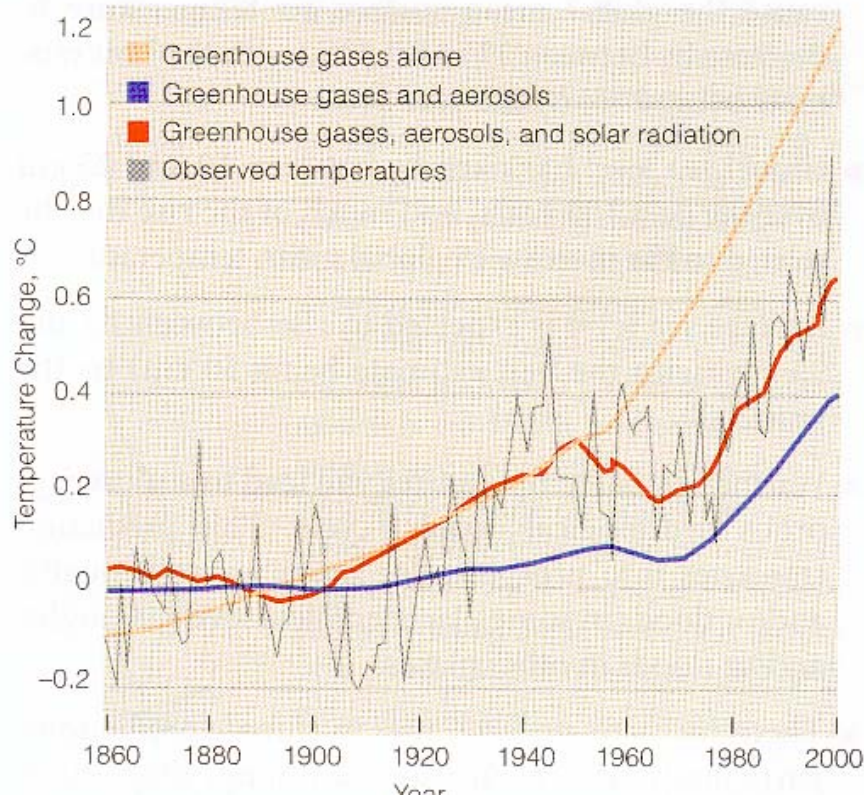
At the current rate of increase, the concentration will reach 500 parts per million in about 100 years.



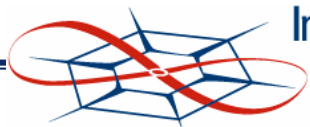
Other Factors in the Energy Balance of Earth

- Oceans – Can store vast amounts of energy and CO₂.
- Clouds – Reflect solar radiation back to space (**cooling effect**), but absorb infrared radiation from Earth (**warming effect**)
 - High clouds (cirrus): net warming
 - Low clouds (stratus): net cooling
- Sulfate aerosols from combustion (Haze): net cooling

Observations versus the Models



Between 1990 and 2100 there is a 90% probability that global temperatures will rise by 1.7 °C to 4.9 °C.



Consequences of Global Warming

- A faster rise in sea level.
- More extreme weather events (floods and property destruction).
- More heat waves and droughts.
- Greater potential for heat-related illnesses and deaths.
- Wider spread of infectious diseases (via insects and rodents).

The Threat of Climate Change

Climate change is a far greater threat to the world than international terrorism, according to the UK's chief scientific adviser, Sir David King.

BBC, January 9, 2004

Climate Change, Ice Sheets, and Sea Level Rise

The Great Ice Sheets



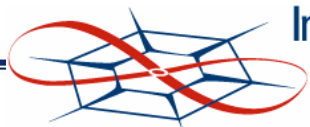
Greenland: 1.8×10^6 km² area
Enough water to raise sea level
about **7 meters**.



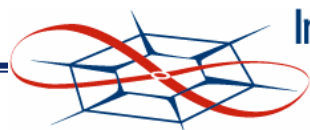
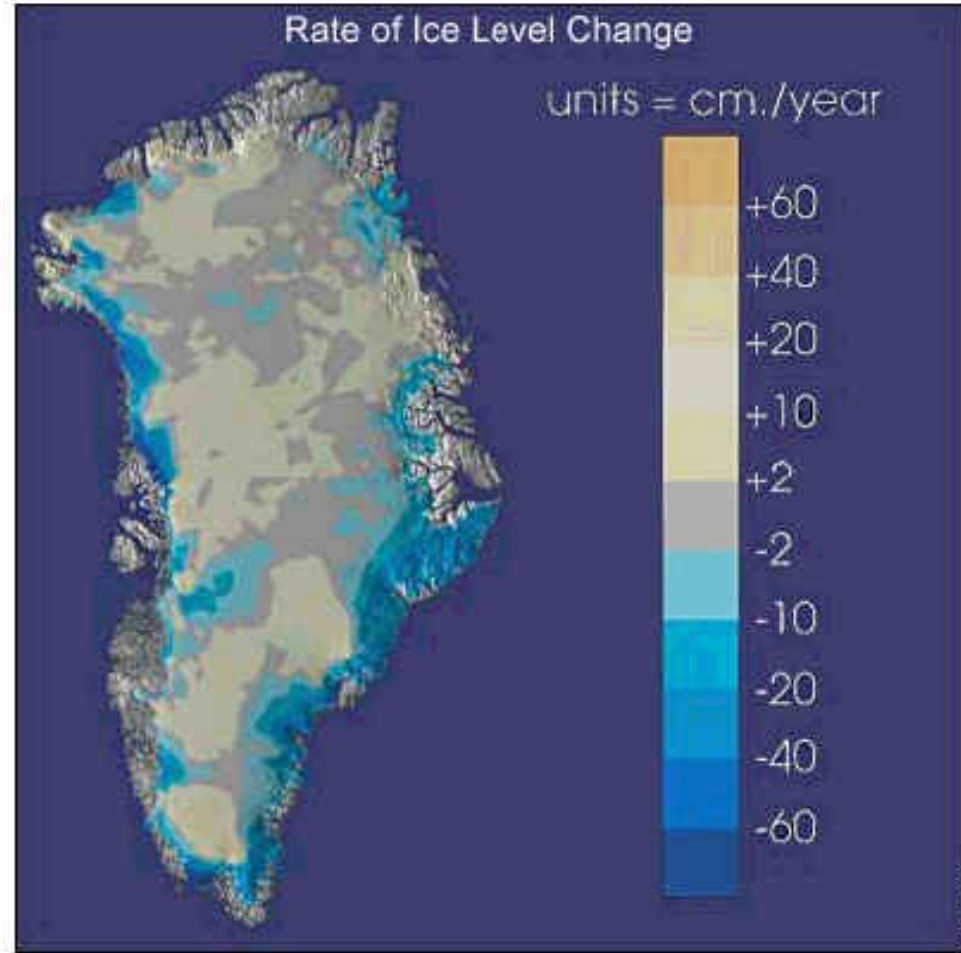
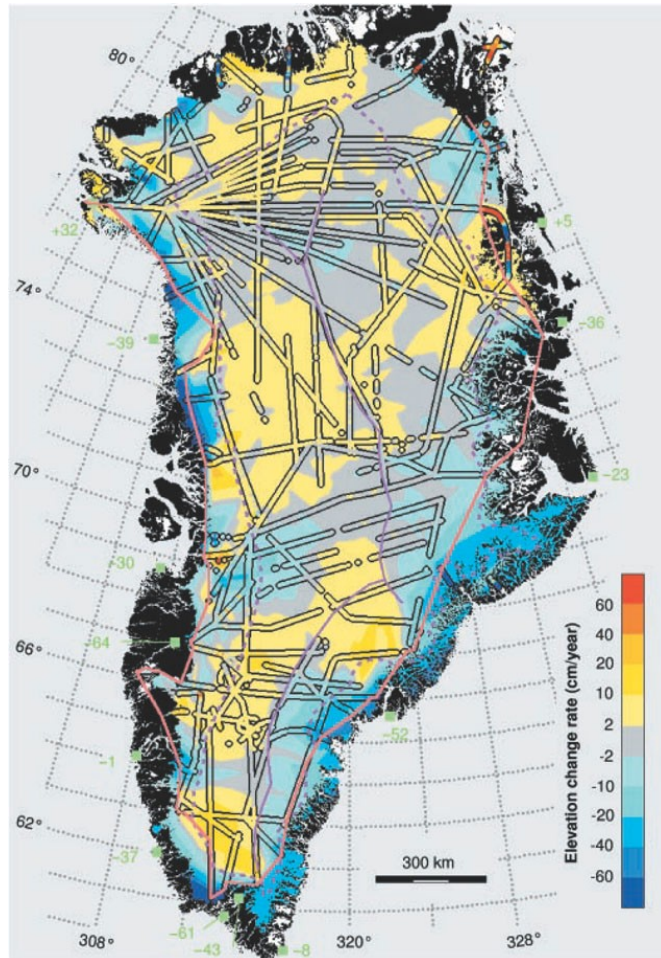
Antarctica: 1.3×10^7 km² area
Enough water to raise sea level
about **60 meters**.

Polar Ice Sheets and Sea Level

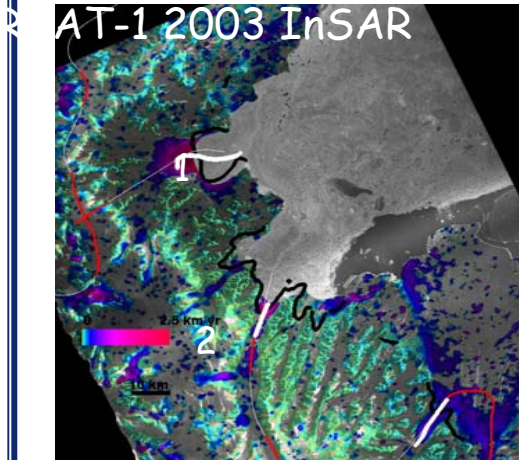
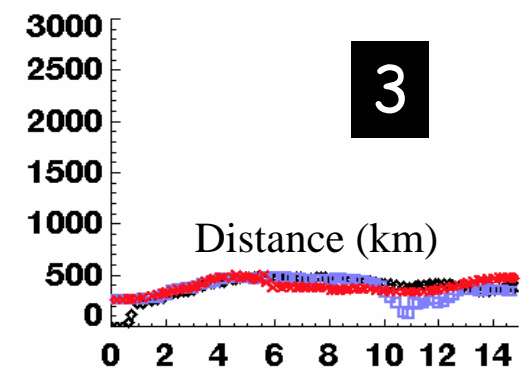
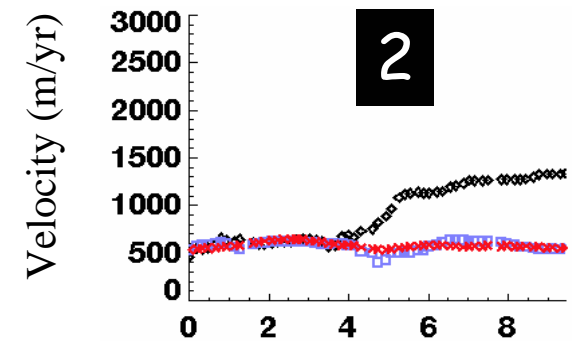
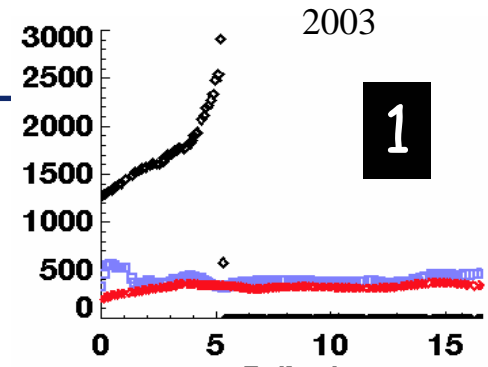
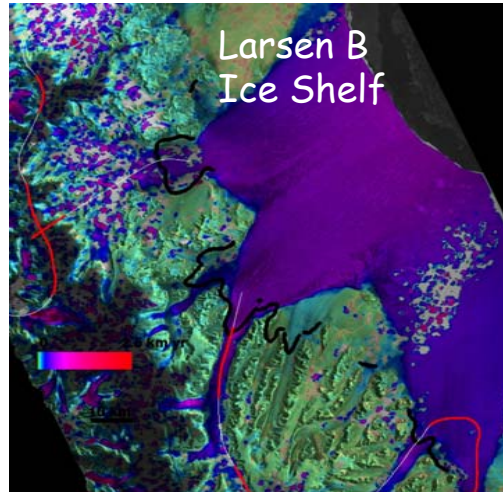
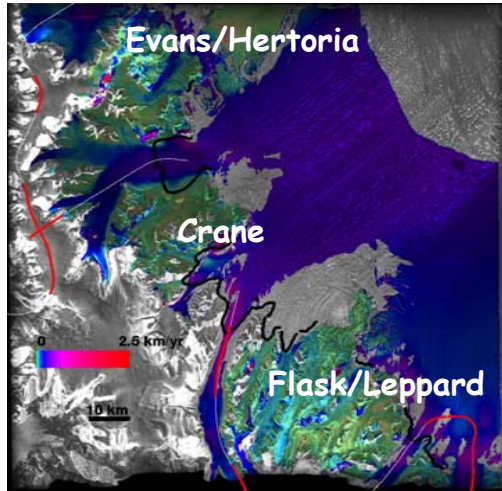
- Sea level rose by about 2 mm/yr over the last century.
- Expected to rise by 48 ± 40 cm over the next century.
- ~60% of the world population live in coastal zones.
- 1 m of sea level rise is estimated to cost \$275-\$450 billion for the US alone.
- 1 m of sea level rise will affect about 25 million people worldwide.



Recent observed changes to Greenland



Ice flow changes, Antarctic Peninsula 1996-2000-2003



Following the disintegration of Larsen B ice shelf in March 02 in response to atmospheric and ocean warming, major Antarctic Peninsula glaciers have accelerated their ice discharge by 3 to 10 times.

Polar Ice Sheet Studies

- Mass balance– net input and output
- NASA and ESA have deployed satellites and will launch others that will tell us where the ice sheets are changing.
- Why are they changing?
 - Ice dynamics
 - Regional climate fluctuations
- Models to explain observations and predict future behavior
 - A key boundary condition in model development is bed conditions.
- KU PRISM project
 - Tools and techniques to measure mass balance
 - Develop and demonstrate technology to determine bed conditions

Other Global Warming Consequences

Extreme (Unusual) Weather Events

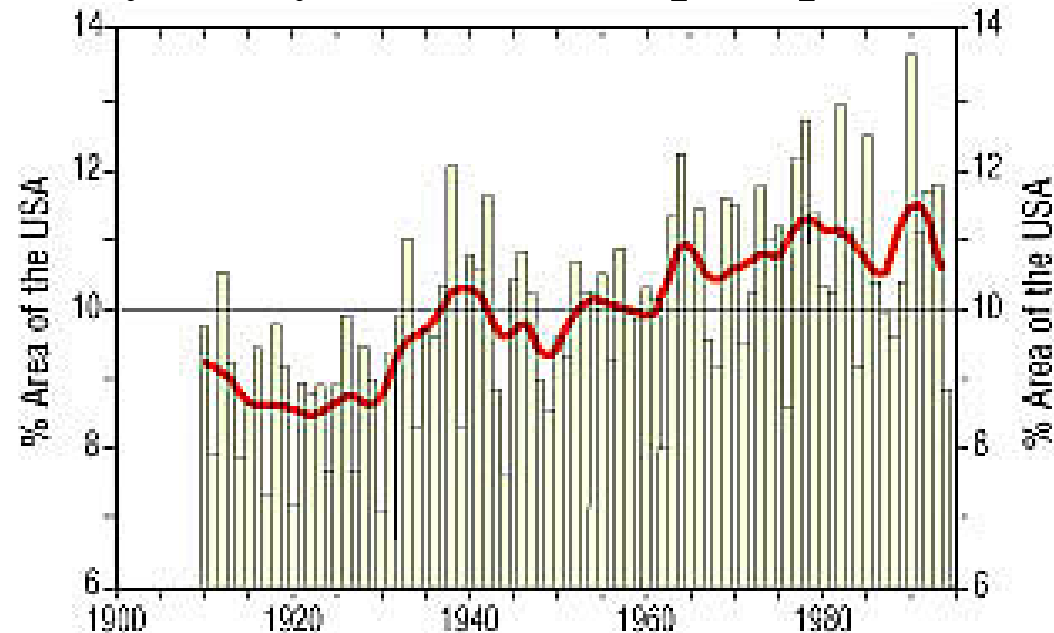
Note: not possible to link any particular weather or climate event definitively to global warming.

The natural climate system often produce local or regional events that appear uncharacteristic of the recent climate.

Relationship between extreme weather frequency and global warming can only be determined through **statistical analyses** of long-term data.

Extreme Precipitation Events

As the Earth warms, we expect more precipitation and it is likely to fall over shorter intervals of time - increased frequency of very heavy and extreme precipitation events.

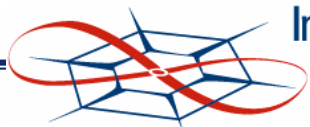


Extreme precipitation events (more than 2 inches). Red line – 10 year average.

Other Regions

Increased frequency of extreme precipitation events has also been identified in:

- Australia
- South Africa
- Japan



Increased Blizzards and Snow Storms with Global Warming?

Colder locations: Storms expected to increase in **intensity** and **frequency** (due to increases in atmospheric moisture).

Temperate locations: expected to **decrease in frequency**, but **increase in intensity**.

Observations to date:

- Snowfall has increased in the high latitudes of North America.
- Snow accumulations have melted faster because of more frequent and earlier thaws.

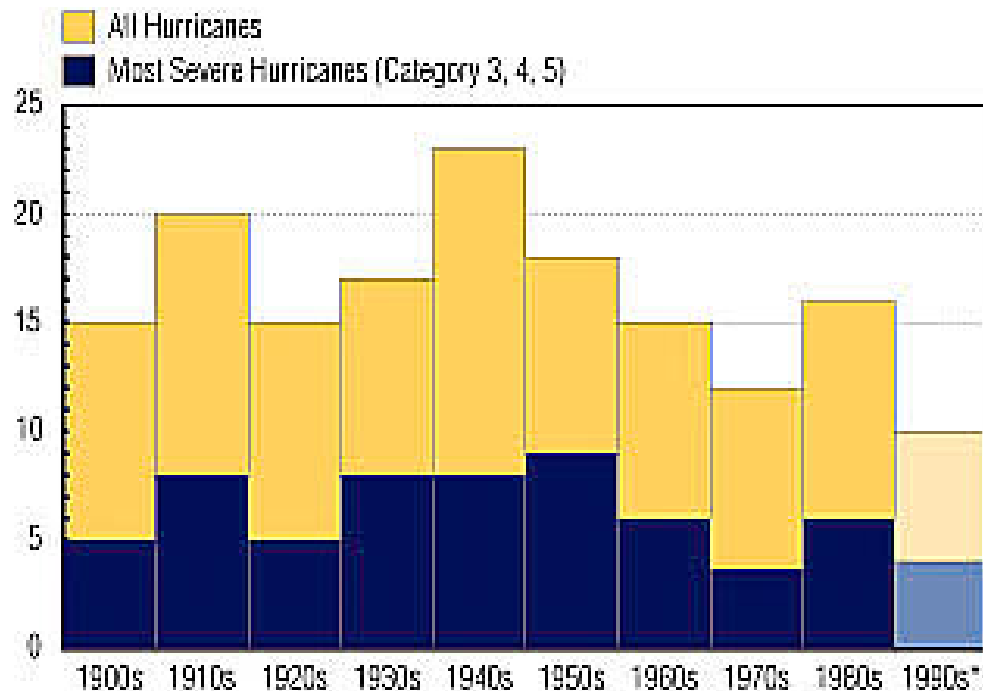
Changes in Midlatitude Storms?

During the past few decades...

- Observed **increase** in frequency of intense storms: northern North Atlantic and adjacent areas of Europe.
- But a **decrease** in frequency of intense storms: southern North Atlantic (south of 30°N).
- Uncertain whether changes are natural fluctuations or related to global warming.

Tropical Storms and Hurricanes

No evidence of long-term trends in the **frequency or intensity** of tropical storms or hurricanes in the North Atlantic during the past several decades.



Also, no trends seen in other ocean basins.



Increased Frequency of Drought?

- No evidence for an increase in the frequency of droughts in North America over the past century. Not surprising because the severe droughts of the 1930's dominate the historical record.
- But studies of past drought variability in the U.S. Great Plains indicate the potential for more severe and frequent droughts in the future.

Conclusions

Global warming and its implications are potentially very serious.

- Sea level rise and changes in the ice sheets – **Yes**

Do we see a global warming signal in weather events?

- More Extreme Precipitation Events – **Yes**
- Increased Intensity of Snowstorms – **Yes**
- Increased Frequency of Strong Mid-lat Cyclones – **Maybe**
- Increased Frequency and Intensity of hurricanes – **No**
- Increased Frequency of Droughts – **Maybe**

It may take **decades** before an unmistakable human caused influence on the **weather** emerges from the background of natural climate fluctuations.

Will the Problem Fix Itself?

