

The State of Climate Science: A Summary of the IPCC Assessment

Mark R. Abbott
College of Oceanic and Atmospheric Sciences
Oregon State University

17 March 2008

The IPCC Assessment Process

- Assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation
- Does not carry out research nor does it monitor climate related data or other relevant parameters
- Bases its assessment mainly on peer reviewed and published scientific/technical literature

Working Group I Assessed Science

- Progress in understanding of the human and natural drivers of climate change, observed climate change, climate processes and attribution, and estimates of projected future climate change
- Builds on past assessments and incorporates new findings
- Large amounts of more comprehensive data, more sophisticated analyses of data, improvements in understanding of processes and their simulation in models, and more extensive exploration of uncertainty ranges

Science Terminology

- *Climate change* refers to any change in climate over time, whether due to natural variability or as a result of human activity
- *Radiative forcing* is a measure of the influence that a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system
 - Index of the importance of the factor as a potential climate change mechanism
 - Positive forcing warms the surface while negative forcing cools it
 - Radiative forcing values are for 2005 relative to pre-industrial conditions defined at 1750

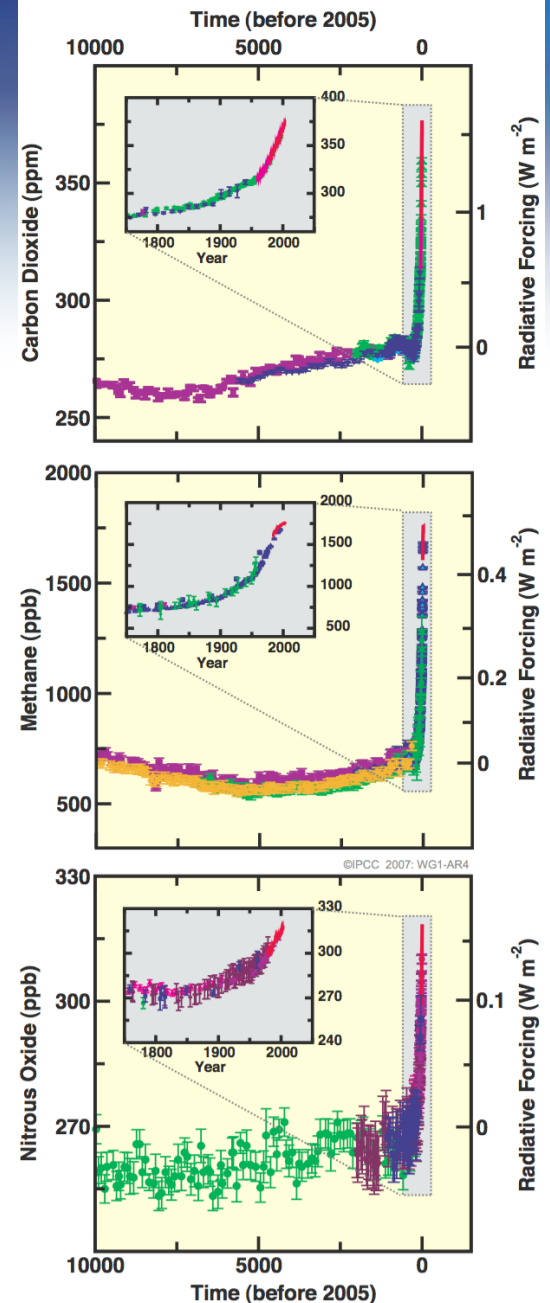
Statistical Terminology

- Likelihood of a particular outcome or result
 - *Virtually certain* > 99% probability of occurrence
 - *Extremely likely* > 95%
 - *Very likely* > 90%
 - *Likely* > 66%
 - *More likely than not* > 50%
 - *Unlikely* < 33%
 - *Very unlikely* < 10%
 - *Extremely unlikely* < 5%

Greenhouse Gases

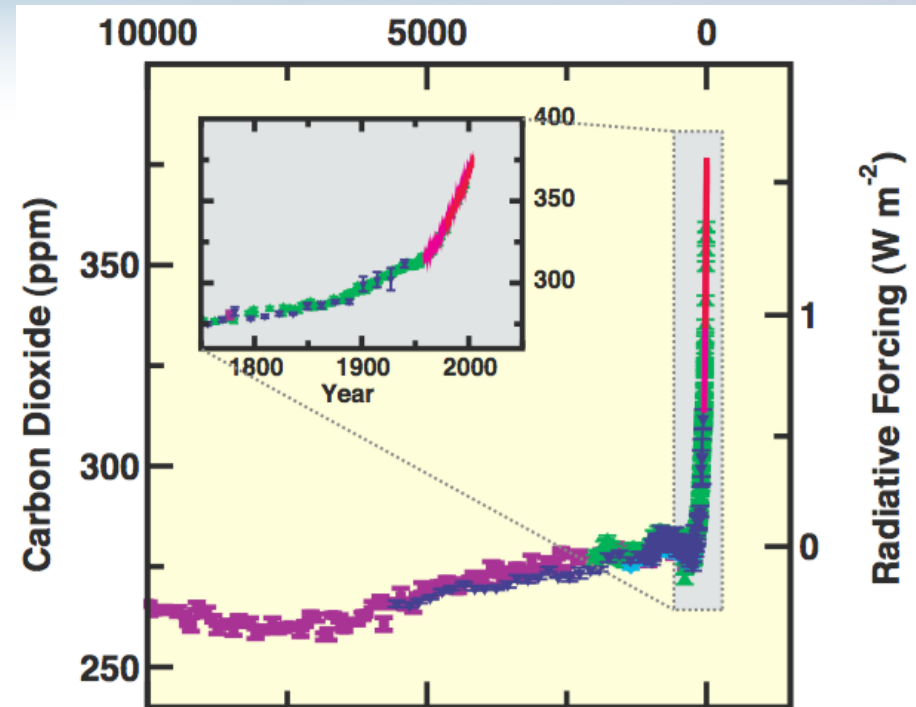
- Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years

Changes in Greenhouse Gases from ice-Core and Modern Data



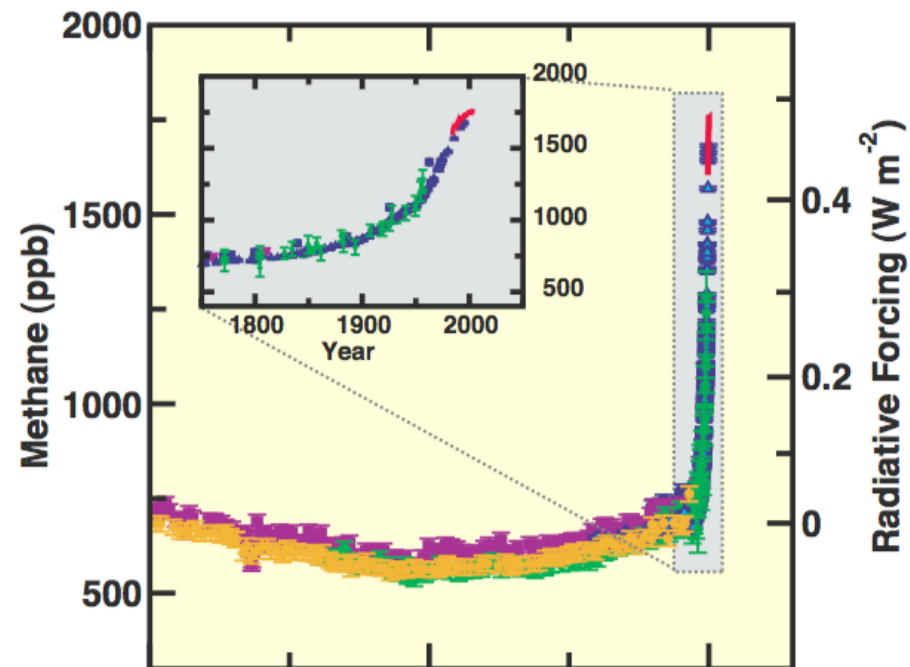
Carbon Dioxide

- CO₂ levels have increased from 280 to 380 ppm
- Highest levels in over 650,000 years
- Primarily fossil fuel use, but also impacts from changes in land use



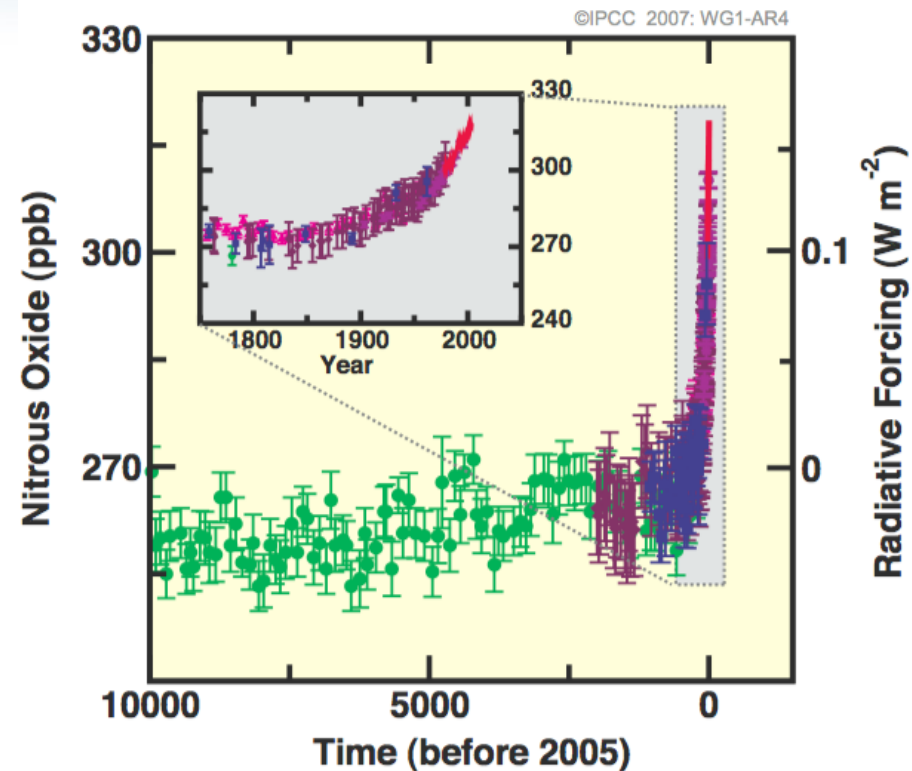
Methane

- Methane has increase from 715 to 1774 ppb
- Agriculture and fossil fuel
- Relative contributions from different sources not well determined



Nitrous Oxide

- Increased from 270 to 319 ppb
- A third of all sources are anthropogenic, mostly agriculture

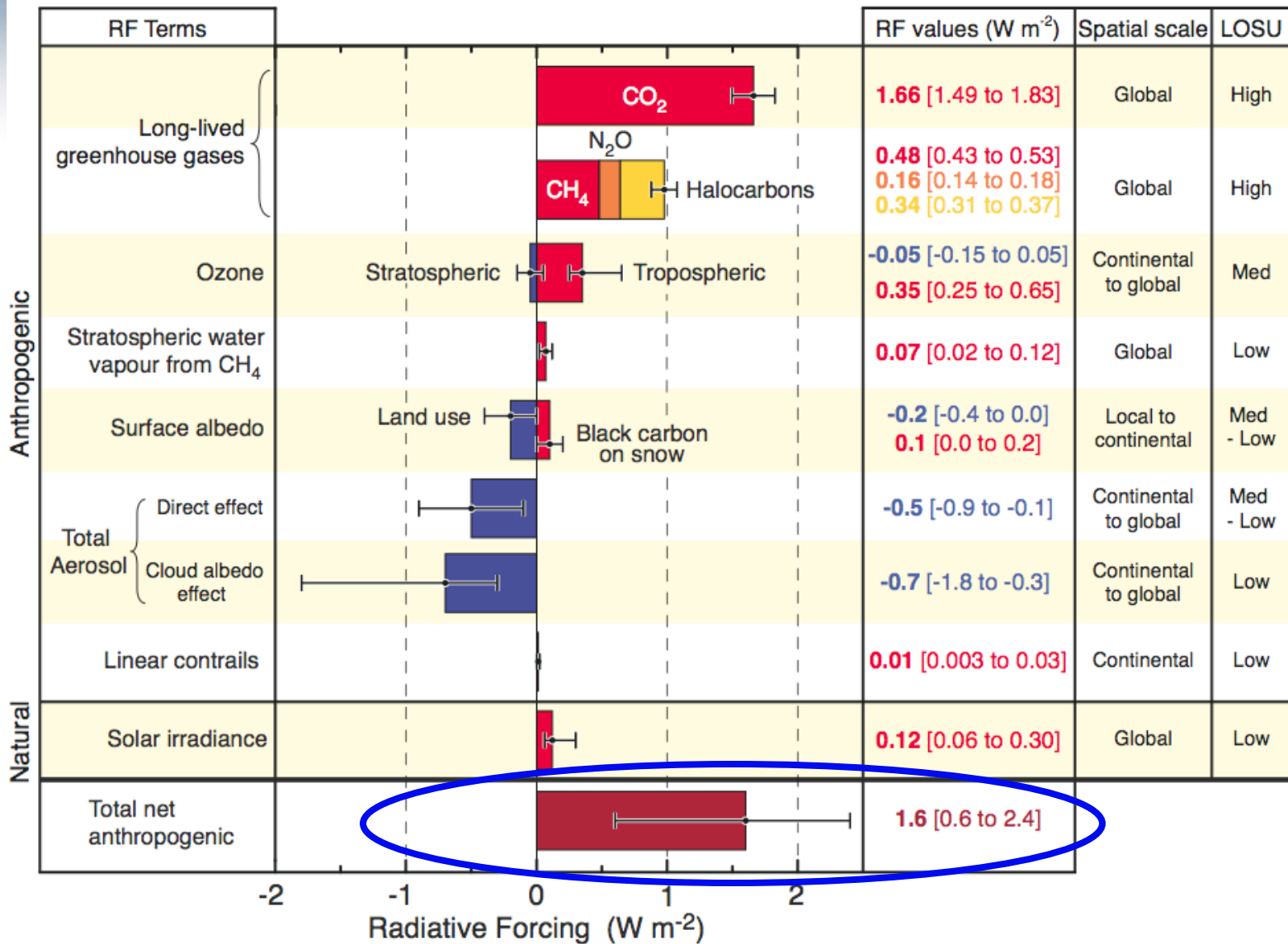


Recent Trends

- CO₂ concentration growth-rate was larger during the last 10 years (1995-2005) than any other time since the beginning of direct measurements (1960)
- Annual methane concentration growth rate has declined since the early 1990s
- Growth rate of nitrous oxide has been approximately constant since 1980

Radiative Forcing

Radiative Forcing Components

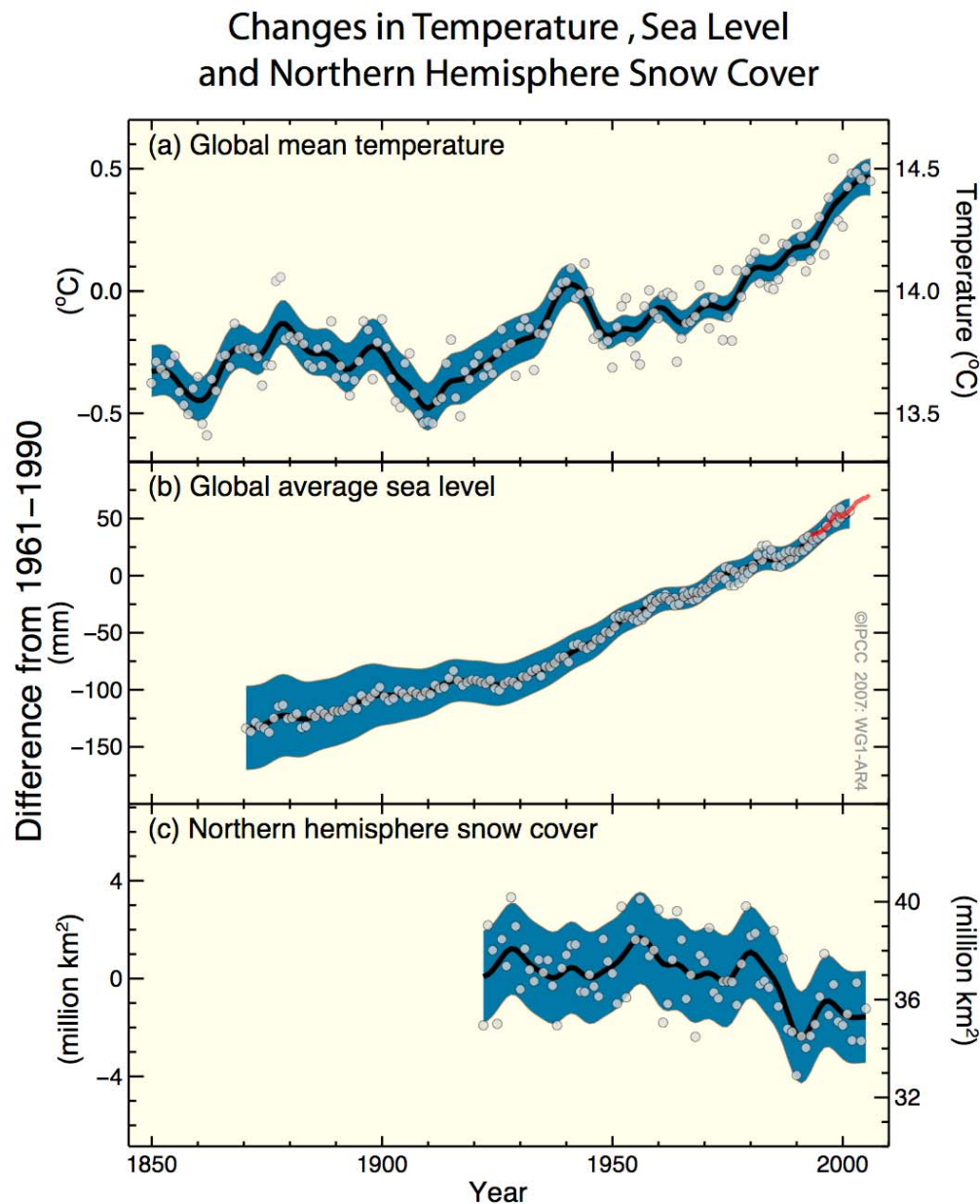


Findings

- *Very high confidence* that net effect of human activities since 1750 has been warming
 - CO₂ radiative forcing increased by 20% from 1995 to 2005
 - Anthropogenic aerosols produce a cooling effect
 - Aerosols remain area of greatest uncertainty
- **Changes in solar irradiance** since 1750 are estimated to cause a radiative forcing of +0.12 [+0.06 to +0.30] W/m²

Direct Observations of Climate Change

- Many important variables now showing impacts of climate change
- 11 of the last 12 years rank among the 12 warmest years
 - Urban heat island effects are real but are negligible (less than 0.006°C per decade)
- Global ocean temperature has increased to depths of at least 3000 m
 - The ocean has absorbed 80% of the heat added to the climate system



Changes in Sea Level

- Greenland and Antarctica have very likely contributed to sea level rise
 - Rate was 1.8 mm/year for 1961-2003
 - Rate was faster for 1993-2003, about 3.1 mm/year
- *High confidence* (80% likelihood) that the rate of observed sea level rise increased from the 19th to the 20th century

Other Climate Changes

- Continental, regional, and local scales
 - Arctic temperatures and ice
 - Precipitation amounts
 - Ocean salinity and acidity
 - Wind patterns
 - Aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones

Changes in the Arctic

- Average Arctic temperatures increased at almost twice the global average rate in the past 100 years
 - High decadal variability with a warm period from 1925 to 1945
- Satellite data since 1978 show that annual average Arctic sea ice extent has shrunk by 2.7% per decade, with larger decreases in summer of 7.4% per decade
- Temperatures at top of permafrost have increased since the 1980s by up to 3°C
 - Maximum area covered by seasonally frozen ground has decreased by 7%

Changes in the Water Cycle

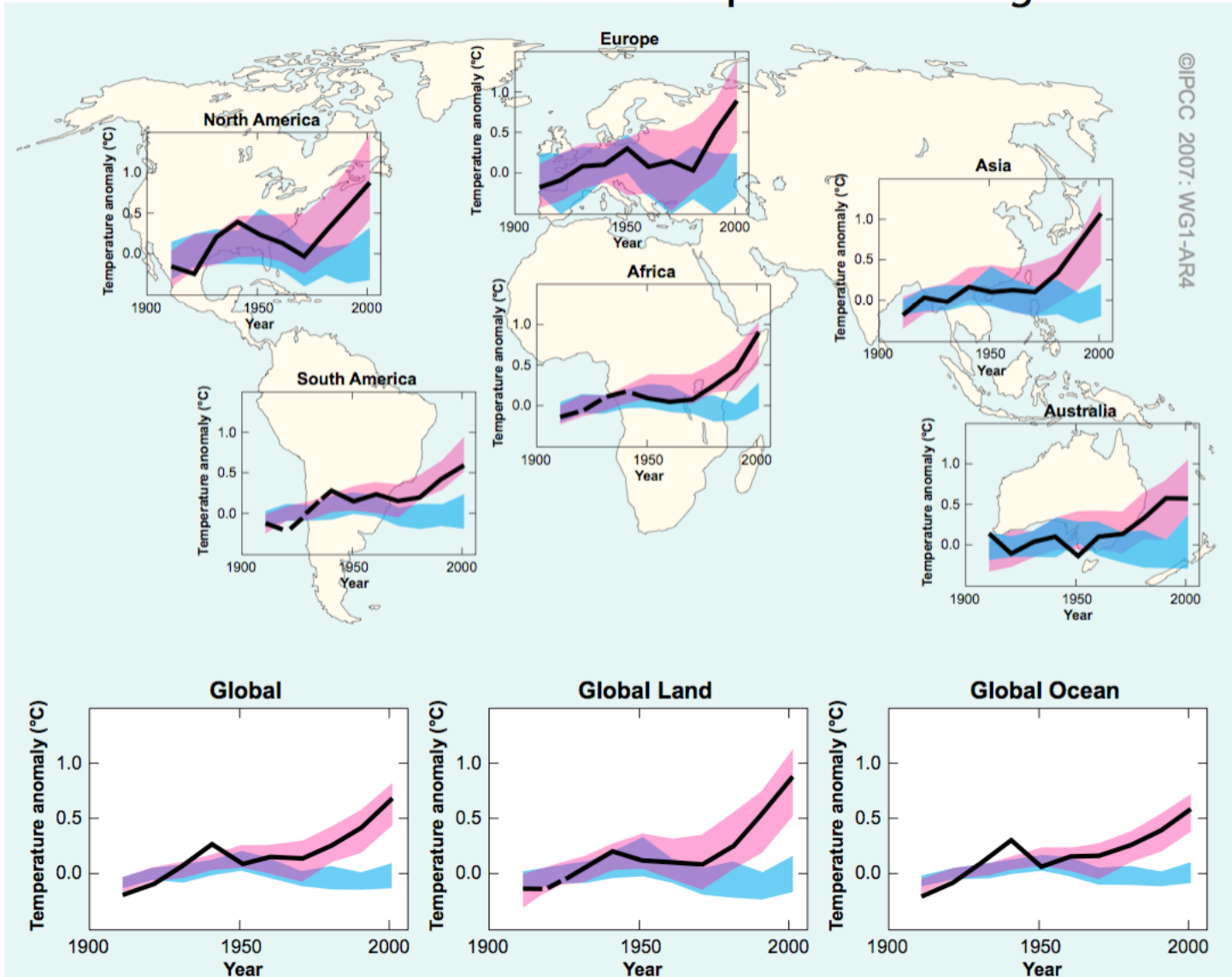
- More intense and longer droughts
 - Particularly in tropics and subtropics
- Changes in sea surface temperatures, wind patterns, decreased snowpack and snow cover have also been linked to droughts
- Frequency of heavy precipitation events has increased over most land areas, consistent with warming and observed increases of atmospheric water vapor

Attributing Climate Change

- Observed increase in global temperatures is *very likely* [$>90\%$ probability] due to the observed increase in anthropogenic greenhouse gas concentrations
- Discernible human influences now extend to other aspects of climate, including ocean warming, continental-average temperatures, temperature extremes and wind patterns

Models and Observation

Global and Continental Temperature Change



Climate Sensitivity

- New models and better observations increase confidence in predicting system response to changes in radiative forcing
- *Likely* to be in the range 2 to 4.5°C with a best estimate of about 3°C, and is *very unlikely* to be less than 1.5°C

Projections of Future Climate Change

CO₂ equivalent radiative forcing for each scenario in 2100:

B1 ~ 600 ppm

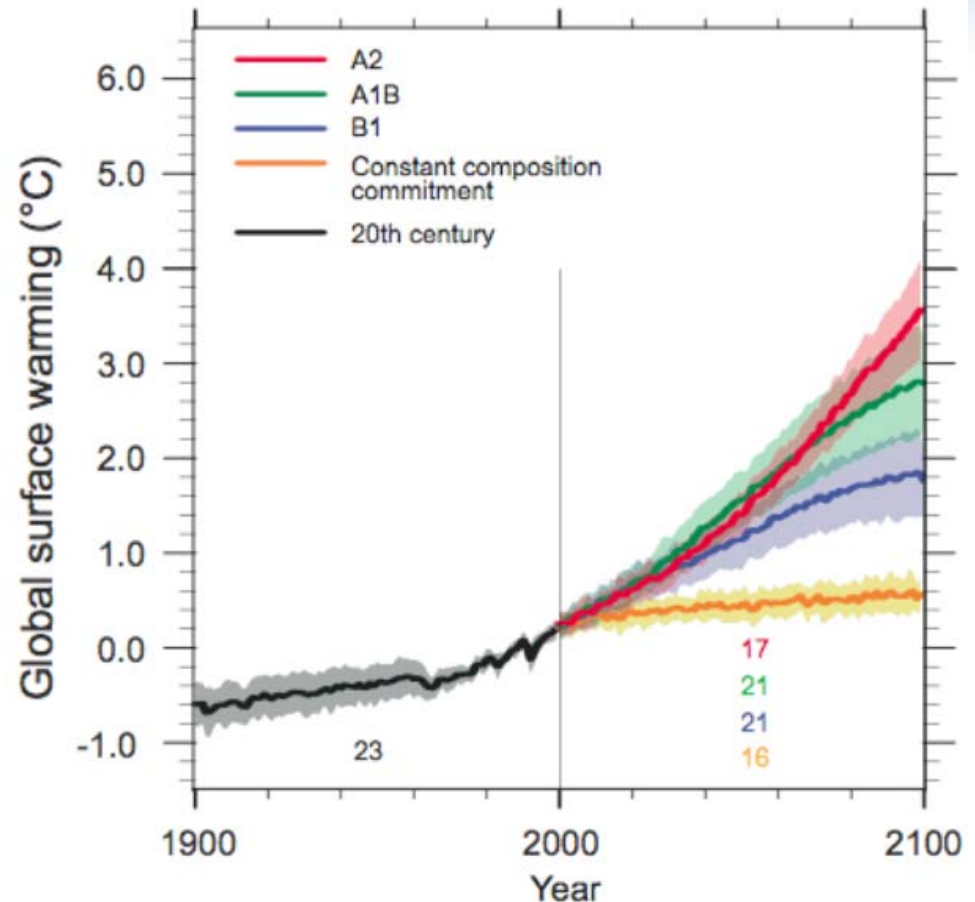
A1T ~ 700 ppm

B2 ~ 800 ppm

A1B ~ 850 ppm

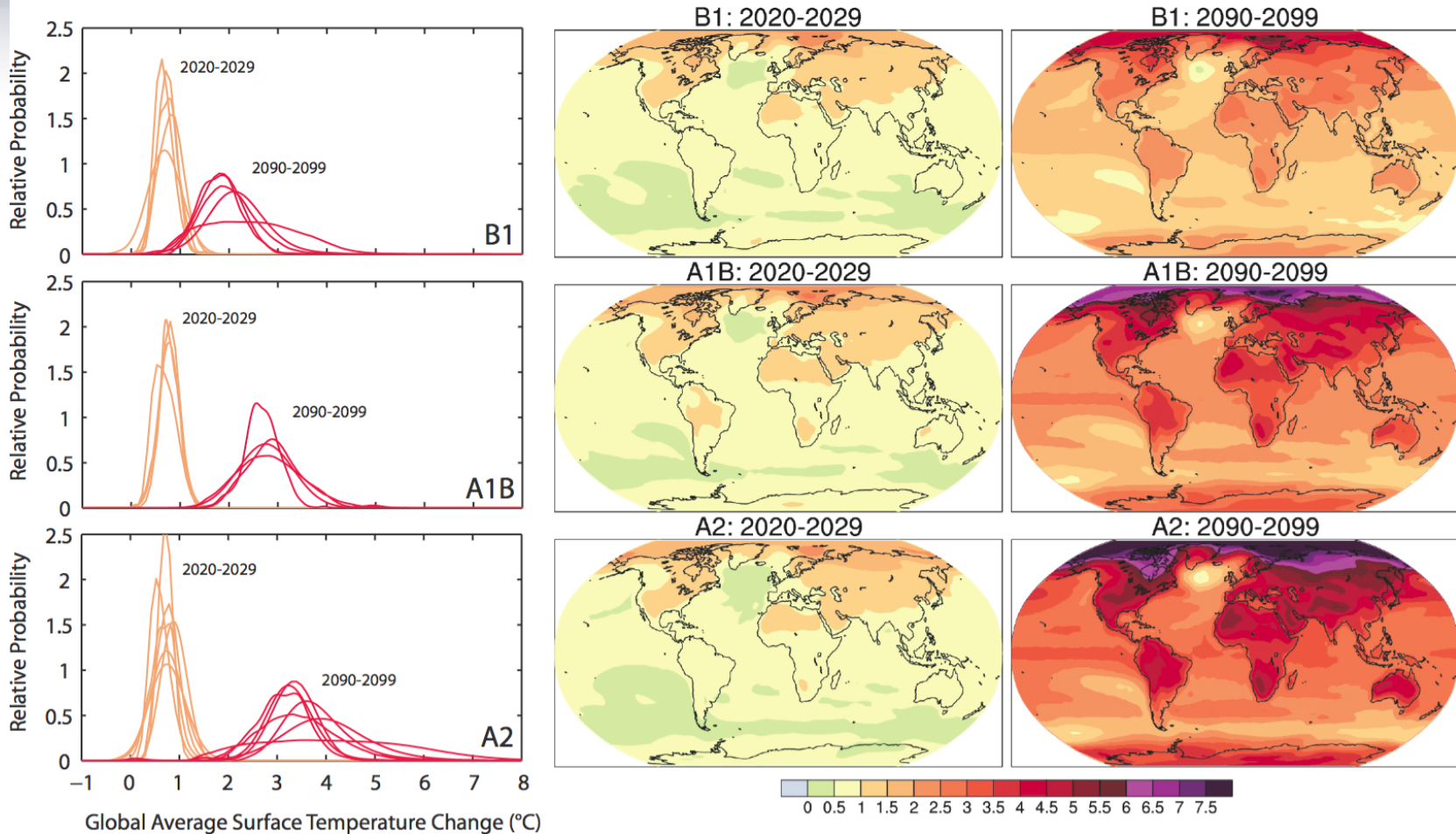
A2 ~ 1250 ppm

A1F1 ~ 1550 ppm



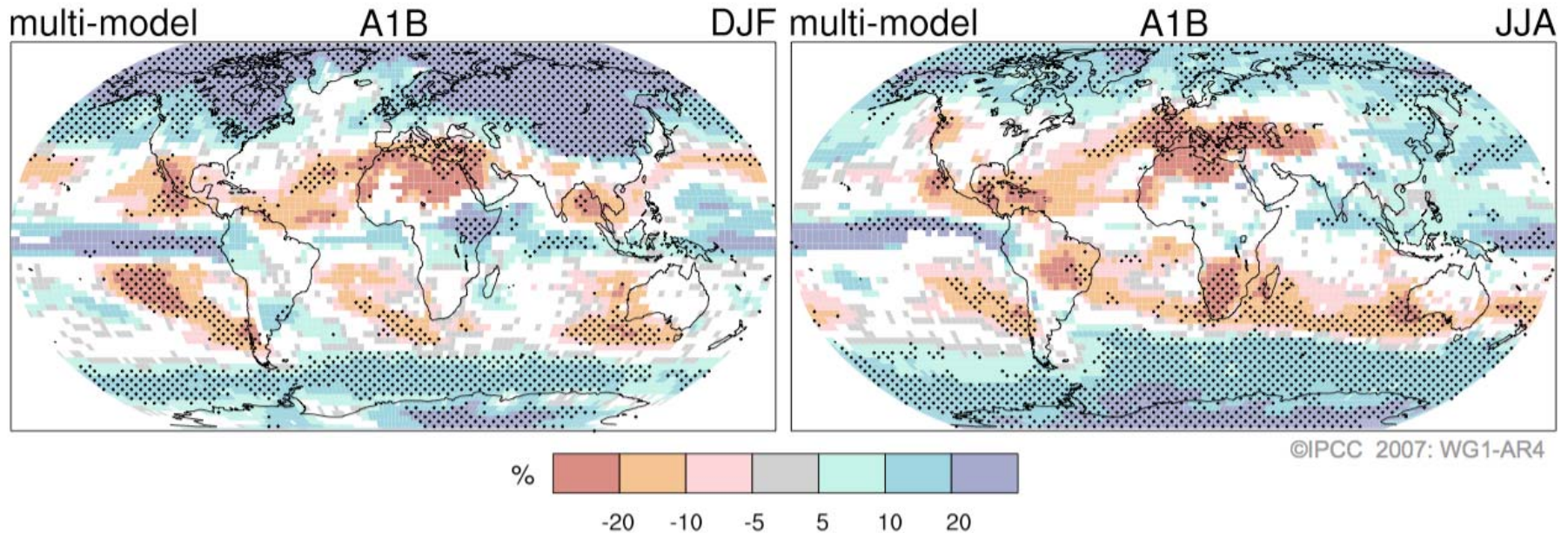
Projections of Future Temperatures

AOGCM Projections of Surface Temperatures



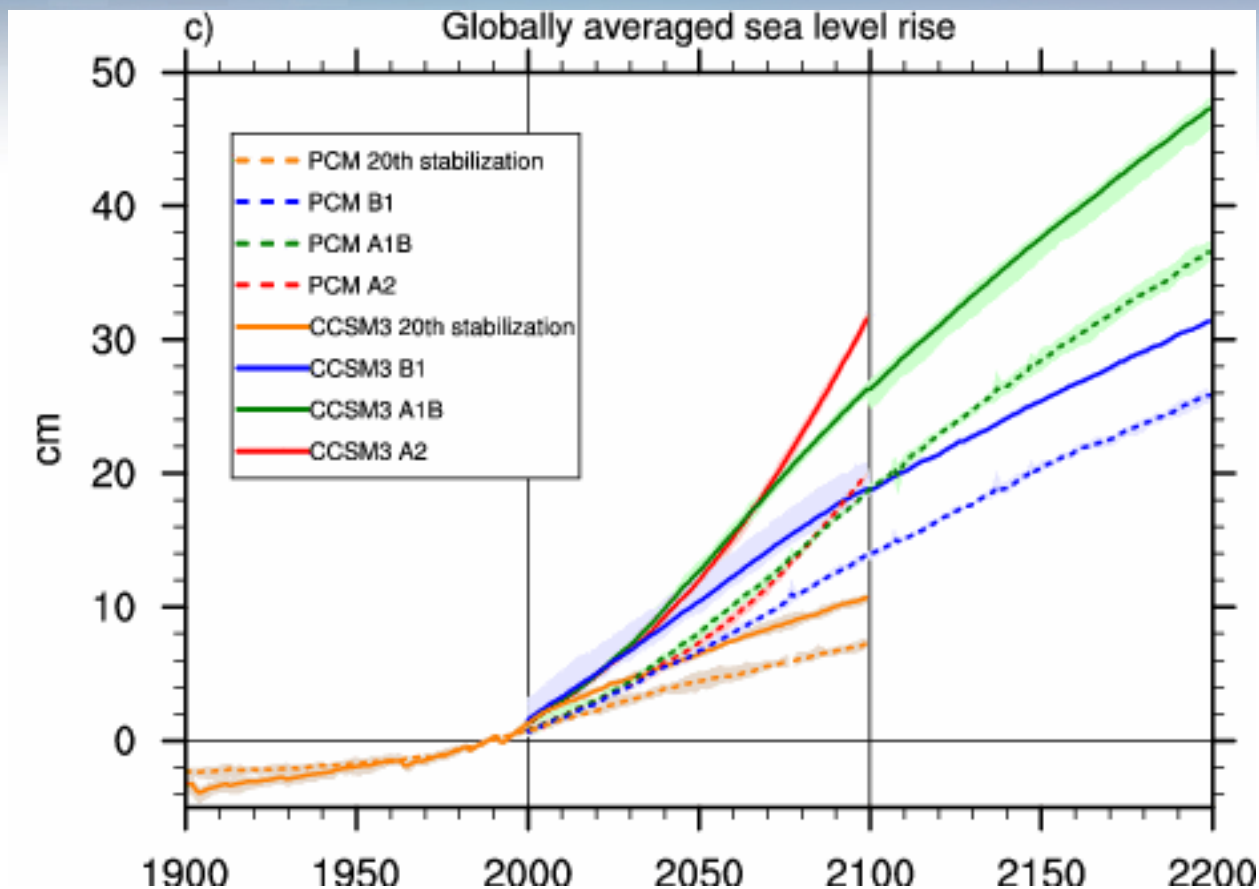
Projections of Future Precipitation

Projected Patterns of Precipitation Changes



Very likely to see increases in precipitation at high latitudes and **likely** decreases low latitudes over land

Projections for Future Sea Level Rise



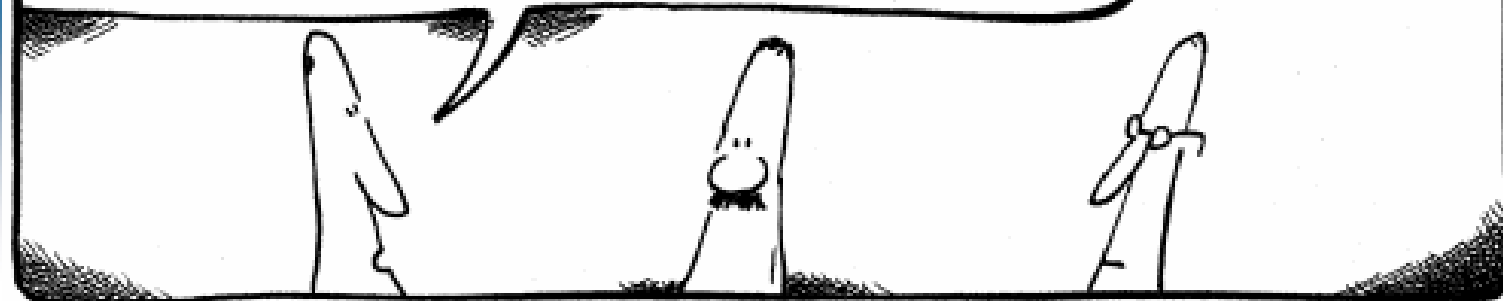
Summary

- Climate sensitivity is *likely* between 2 and 4.5°C for a doubling of CO₂
- Global atmospheric concentrations of CO₂, methane and nitrous oxide have increased markedly as a result of human activities since 1750
- Evidence of global warming exists from melting snow and ice, increased global average air and ocean temperatures, rising sea level, and increasing ocean acidity
- There are many observed long-term regional changes (e.g. the Arctic)
- Many extreme weather events are predicted to increase in the future

Summary (cont'd)

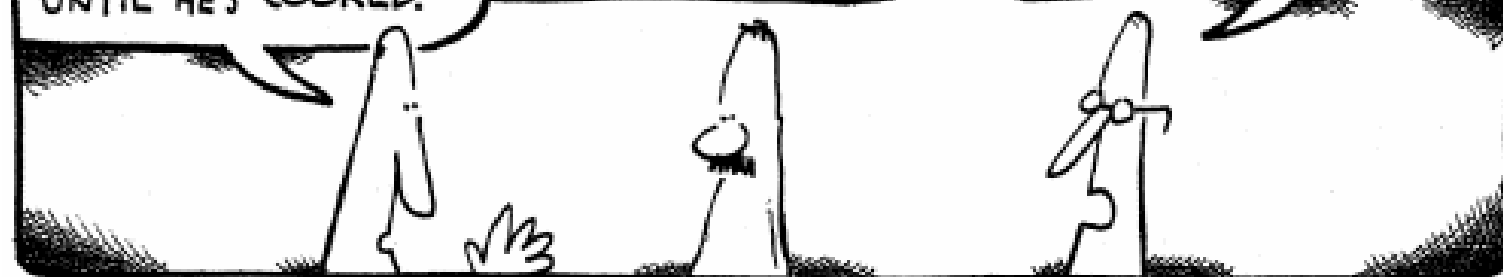
- *Very high confidence* that the globally averaged net effect of human activities since 1750 has been one of warming
- Most of the observed increase in globally average temperatures since the mid-20th century is *very likely* due to the observed increases in anthropogenic greenhouse gas concentrations
- For the next two decades a warming of $\sim 0.2^{\circ}\text{C}$ per decade is projected
- Greenhouse gas emissions at or above current rates would cause further warming and *very likely* induce 21st century changes in the global climate system that would be larger than those observed during the 20th century

SO THESE SCIENTISTS DID THIS EXPERIMENT THAT IF YOU DROP A FROG INTO BOILING WATER HE JUMPS OUT.



BUT IF YOU PUT HIM IN WARM WATER AND HEAT IT SLOWLY, HE JUST SWIMS AROUND UNTIL HE'S COOKED.

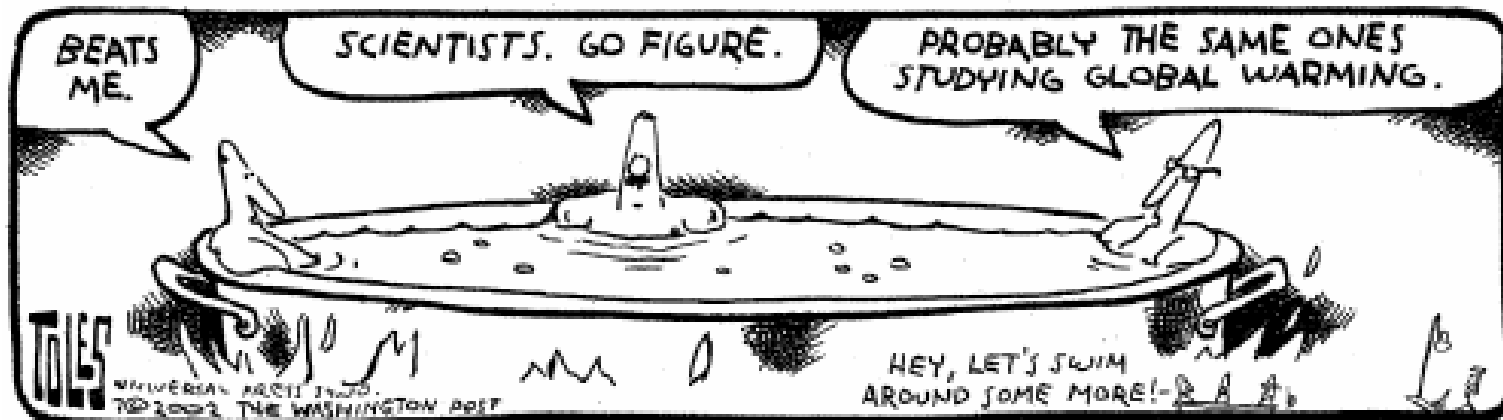
WHAT'S THE POINT OF THAT EXPERIMENT?



BEATS ME.

SCIENTISTS. GO FIGURE.

PROBABLY THE SAME ONES STUDYING GLOBAL WARMING.



HEY, LET'S SWIM AROUND SOME MORE!

TUES

UNIVERSAL PICTURES
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Acknowledgments

- IPCC Fourth Assessment Report
 - www.ipcc.ch
- Jeff Shaman, OSU