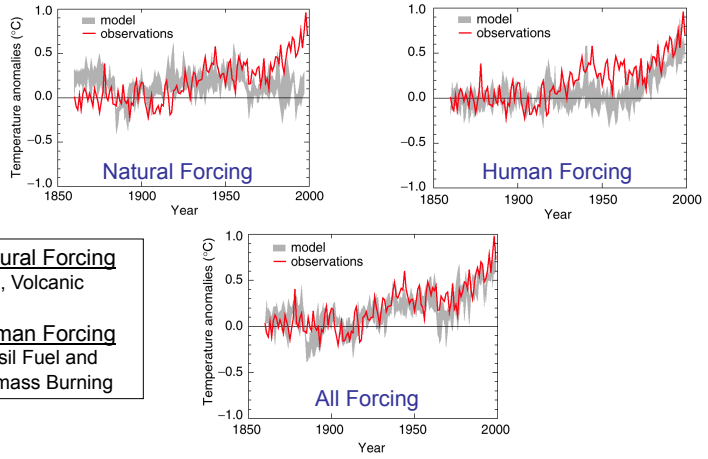
Comments on Human and Natural Forcings

- Human input of GH gases (carbon dioxide, methane, nitrous oxide, ozone, CFCs) has warmed the planet:
  - *net* RF = +2.9 W/m^2

  The largest single warming factor is increased CO2: RF = 1.66 W/m^2
- Human input of aerosols cools the Earth
  - Aerosol RF = -1.3 [-0.3 to -2.5 W/m^2]
  - This cooling is localized to nearby the source region
- The *net* forcing of the climate system due to human activities is positive (a warming):
  - *net* RF = +1.6 [+0.6 to +2.4 W/m^2] = +2.9 – 1.3
- Hence, the 20th Century warming would have been much greater without human caused aerosols
- The time scale to get back to pre-industrial forcing is determined by the time it takes for nature to remove the dominant human forcing agent, CO2 - about 10,000 years.

Climate Variability and Climate Change

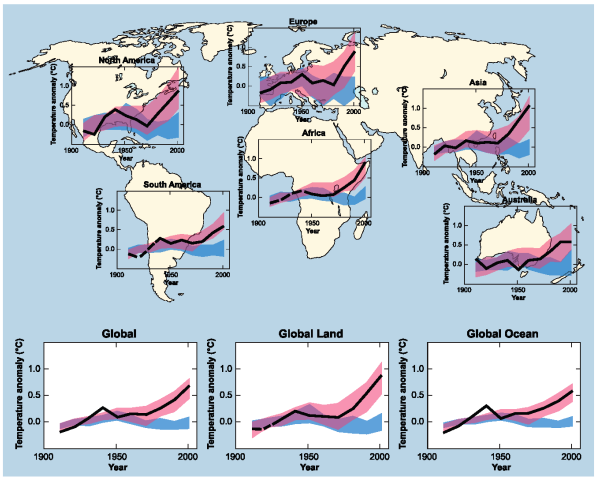
Modeled and Observed Temperature Change 1850-2000



Natural Forcing
Sun, Volcanic

Human Forcing
Fossil Fuel and Biomass Burning

Modeled and Observed Temperature Change 1900-2000



IPCC 2007

observations

Models using only natural forcings (Solar and volcanic)

Models using natural & human forcings (GH gases, aerosols)

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*[e]	*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*[f,h]

We know this by using models

Virtually certain > 99%

Very likely >90%

Likely >66%

More likely than not > 50%

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

IPCC 2007

IPCC Conclusions on *observed* Climate Changes:

- 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 0.85 ± 0. 2°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)

3. Projections of Climate Change: 2100 and beyond

- The projected forcings
- The projected climate change: 2000 to 2100
  - Global
  - Regional
  - Sea Level
  - Cryosphere
  - Extreme Events
- The long term outlook 2100 - 2300
  - Projections taken from the most recent consensus report from Intergovernmental Panel on Climate Change.
  - Focus on those changes that are "very likely" (i.e., those that are either deemed to have a greater than 90% chance to occur "based on quantitative analysis or an elicitation of the expert views")

3. Projections of Climate Change: 2100 and beyond

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How much Carbon Dioxide will be released into the atmosphere?

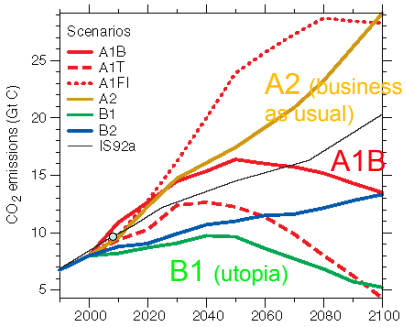
The Emission Scenarios

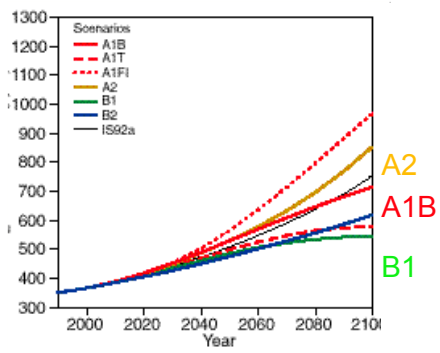
- **The A2 storyline and scenario family** describes a very heterogeneous world. The underlying theme is self reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.
- **The A1 storyline and scenario family**: very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system.
  - fossil intensive (A1FI), non fossil energy sources (A1T), or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source)
- **The B2 storyline and scenario family**: emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

Emission scenarios provided by economists, policy makers, etc.

How much Carbon Dioxide will be released into the atmosphere?

Emissions

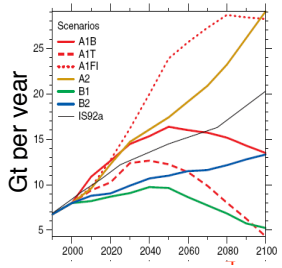


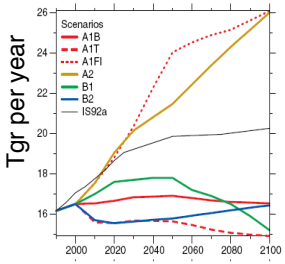


Estimates depends on population and economic projections, future choices for energy, governance/policy options in development (e.g., regional vs. global governance)

How much GH gas will be released into the atmosphere?

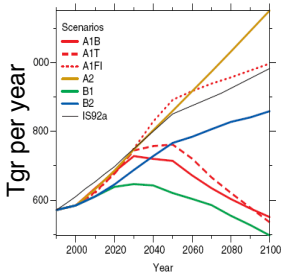
CO_2

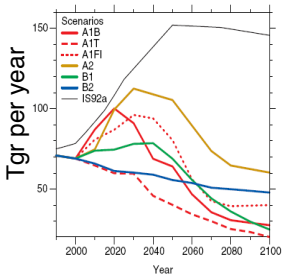




N_2O

CH_4





SO_2

Note: SO_2 gas leads to sulfate aerosol particles

IPCC 2001, WG I, TS, Fig 17

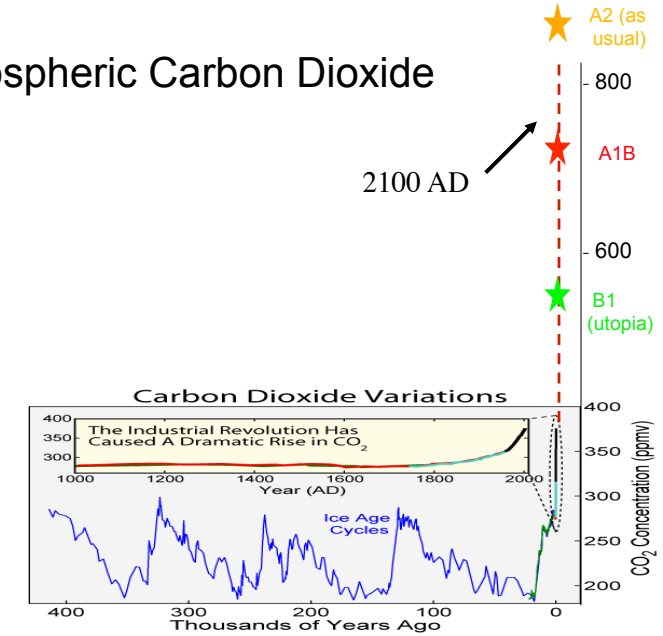
How much CO_2 *do you* think will in the atmosphere?

- … in 2100 if global emissions stayed the same as today (no population increase or development)
  - Information needed (rounded):
  - Current world-wide emissions 10Gt/yr
  - About 60% of the CO_2 remains in the atmosphere (the rest goes into the ocean and land)
  - There is 830Gt of carbon in the atmosphere today (392ppm)

- … in 2050 if everyone in the world lived life like an American?
  - 300M people live in the US and we emit 2Gt/yr (including land use)
  - 7B people in the world today, 9B by 2050

- If we wanted to stabilize CO_2 concentrations in the atmosphere, how much could the US emit fairly?
  - Information needed:
  - World emissions would must be less than 1Gt/yr

Atmospheric Carbon Dioxide



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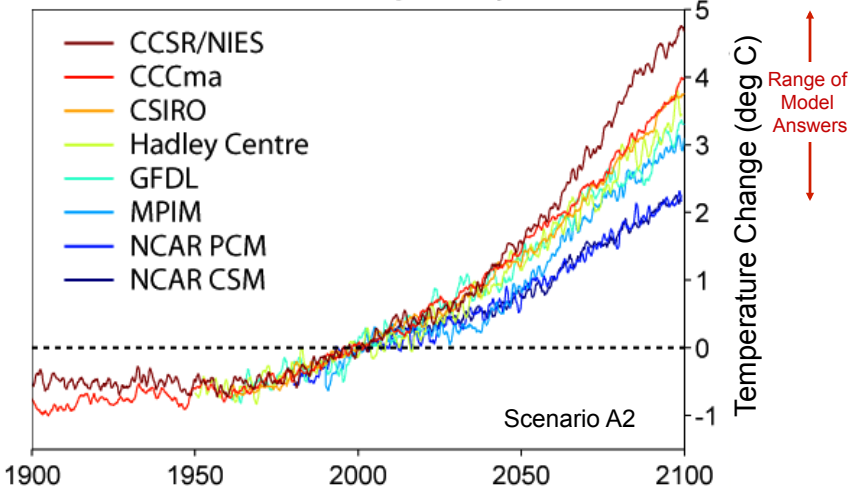
Climate change due to increasing greenhouse gases

Changes that are *highly likely** over the next 100 years include:

- the planet will warm, more so in middle and high latitudes than in the tropics
- the hydrologic cycle will speed up
- the area covered by snow and sea ice in winter will decrease
- the interior of continents will be drier in the summertime
- the sea level will rise
- the surface ocean will become 2-3 times more acidic

These changes will be ***much, much*** greater than the changes seen over the past 150 years that have been attributed to increased greenhouse gases and aerosols.

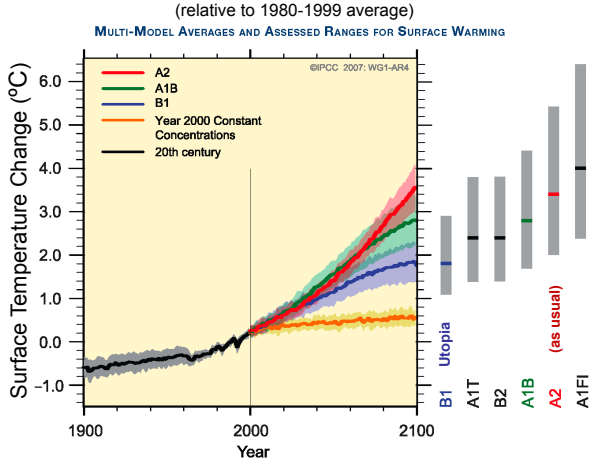
Global Warming Projections



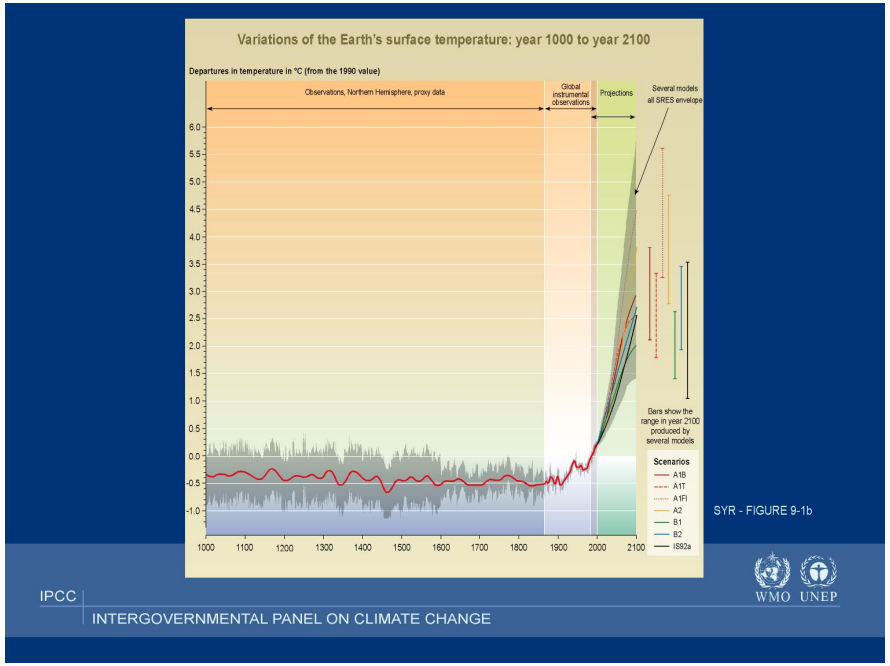
The range in projections is a measure of the uncertainty in the models, given a perfect emission forecast.

Global Average Temperature Change

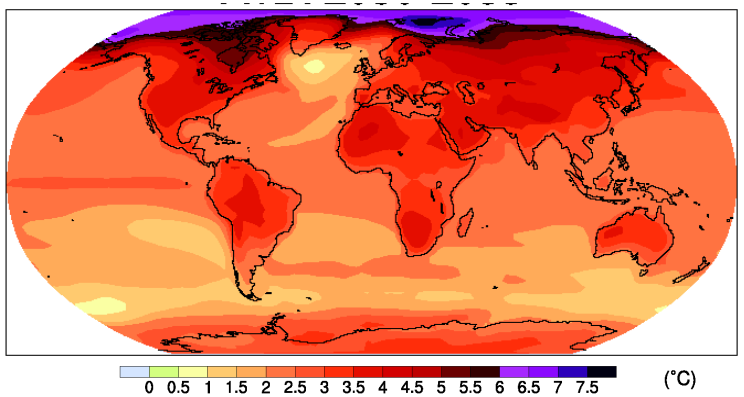
(relative to 1980-1999 average)



For a mid-range emission scenario, model project an global average warming over the next 100 years of 2.8 ºC: 3 to 4 times the warming over the past century.

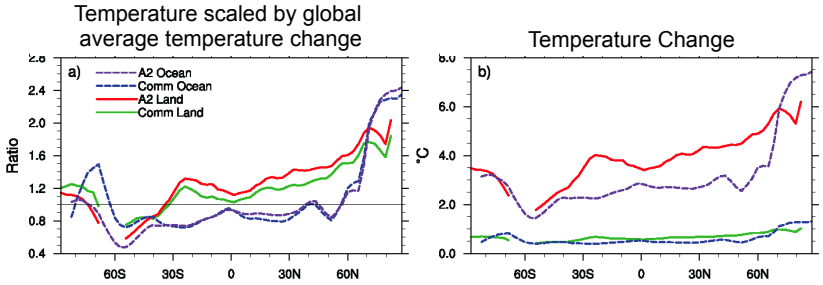


Projected Annual Average Surface Temperature Change:
"2080-2099" minus "1980-1999"



Average of 21 climate models forced by Scenario A1B.
Multiply by ~1.2 for A2 and ~0.7 for B1

Zonal (east-west) Temperature Changes: 2090 minus 1990

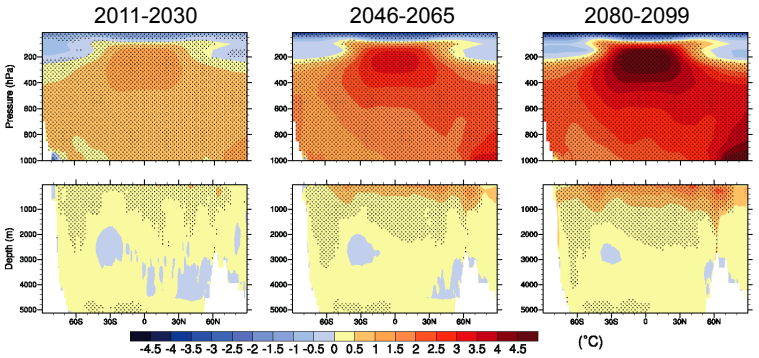


- Land warms more than ocean
- High latitudes warm more than tropics
- Land-Ocean and latitudinal amplification scale with the global average temperature change

Comm = commitment (don't worry about this)

IPCC AR4, Fig 10.6

Zonal (east-west) Temperature Changes: 2090 minus 1990 (scenario A1B)

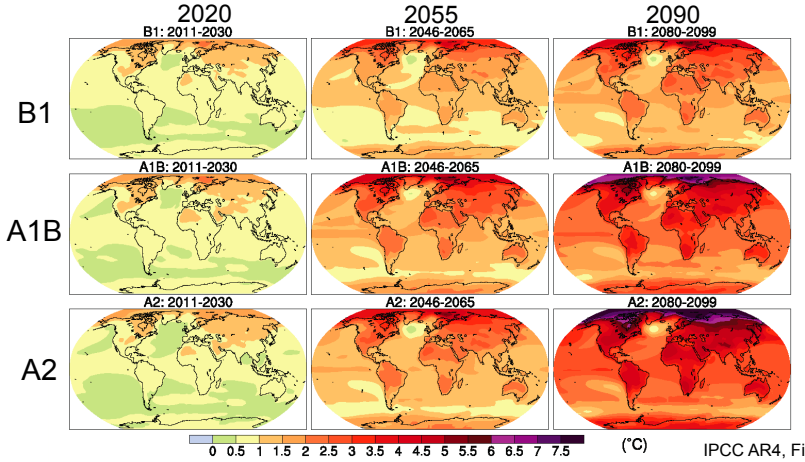


Warming throughout the atmosphere.

Warming in the surface ocean (top 200m), spreading downward over time; 1000 years to reach bottom.

IPCC AR4, Fig 10.7

Projected Annual Average Surface Temperature Change:



IPCC AR4, Fig 10.8

Average of 17/21/21 climate models forced by Scenario A2/A1B/B1.

A2 is about 1.2 times A1B; B1 is about 0.7 times A1B