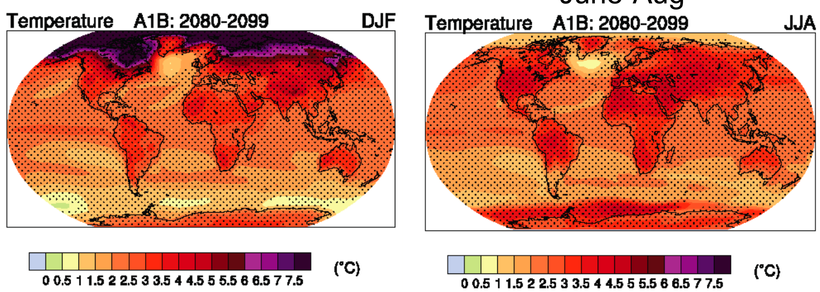
Seasonal Cycle of Temperature Changes: "2080-2099" minus "1980-1999"

Dec-Feb

June-Aug



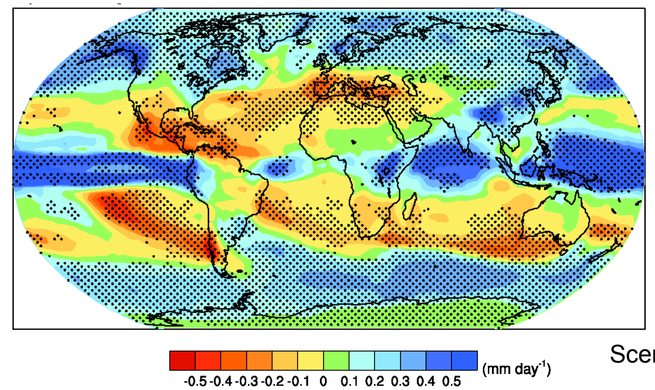
Scenario A1B

More warming in winter than summer (esp. in NH)

IPCC AR4, Fig 10.9

Stippling is where the multimodel average change exceeds the standard deviation of the models

Projected Annual Average Precipitation: "2080-2099" minus "1980-1999"

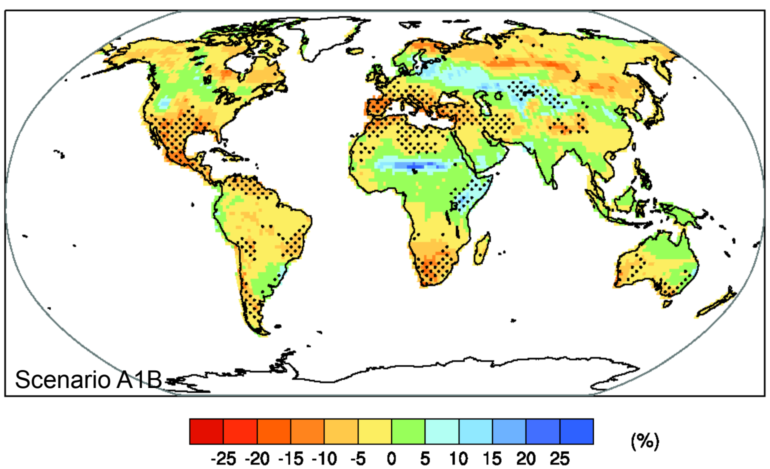


Scenario A1B

There is a *robust* drying of the subtropics, 20-35N&S.

Stippling is where the multimodel average change exceeds the standard deviation of the models

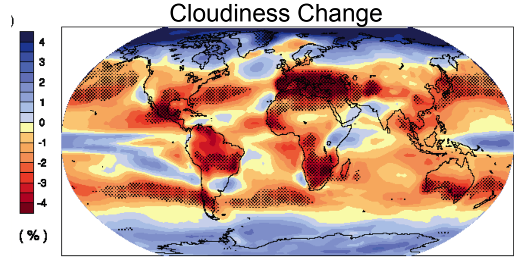
Projected Soil Moisture Change: "2080-2099" minus "1980-1999"



Percent Change

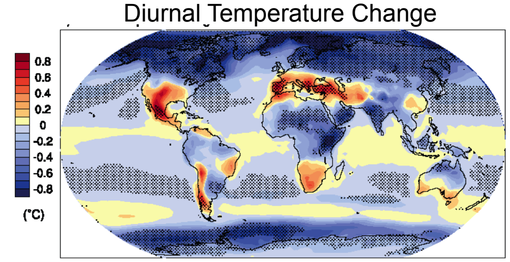
Changes in Cloudiness and the Diurnal Cycle in Temperature

Cloudiness Change



Most models show increasing clouds in high latitudes (cooling negative feedback) and less clouds in tropics

Diurnal Temperature Change

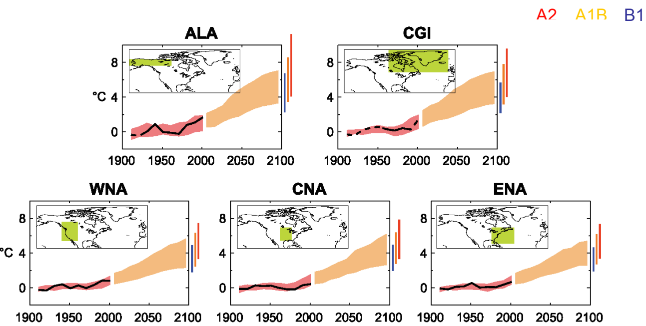


Most models show more warming at night than during day (a decrease in the diurnal temperature range)

Scenario A1B

IPCC AR4, Fig 10.10,11

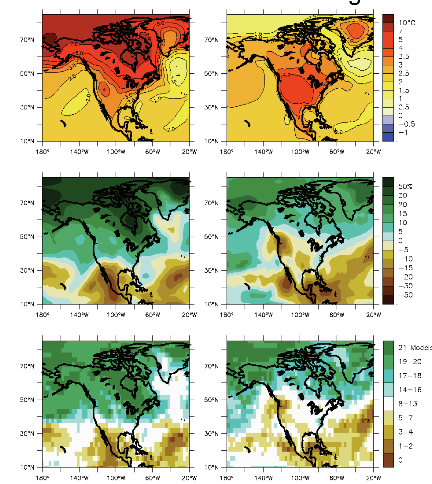
Changes in North American Climate: 2100 minus 2000 AD



IPCC 2007 Fig 11

Changes in North American Climate: 2100 minus 2000 AD

Dec-Feb June-Aug



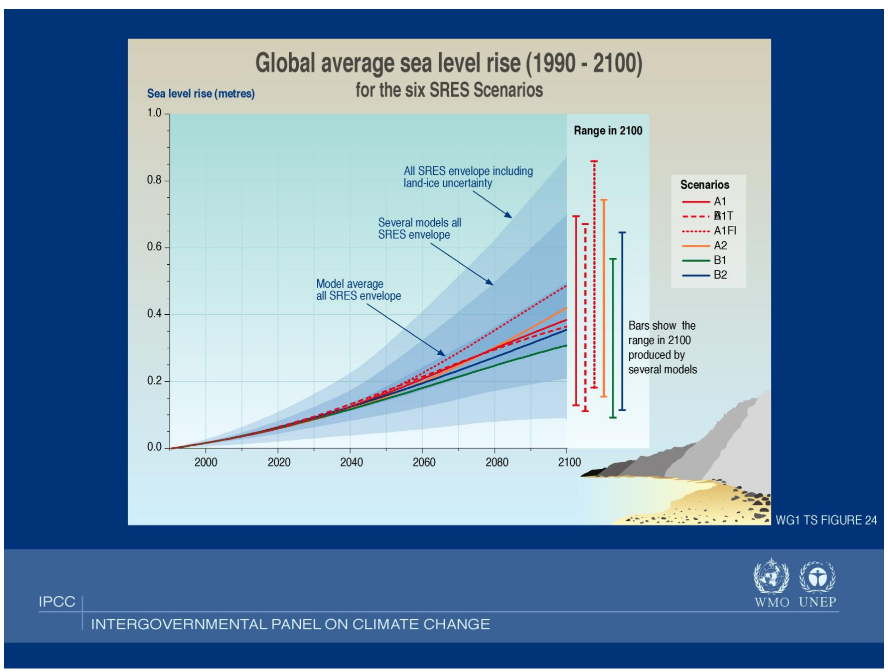
Temperature

Precipitation

# of models that agree on sign of precip

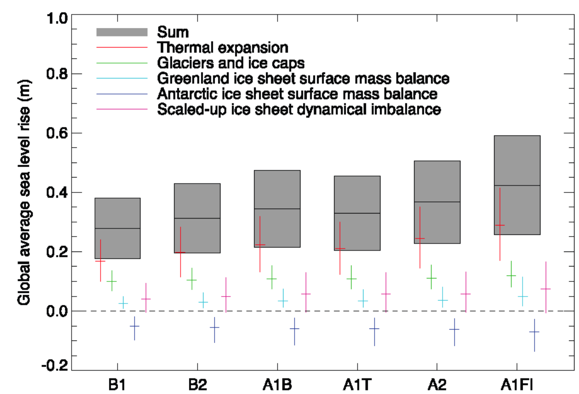
Scenario A1B

IPCC 2007 Fig 12



Projected Sea Level Rise: All sources

"2080-2100" minus "1980-2000"

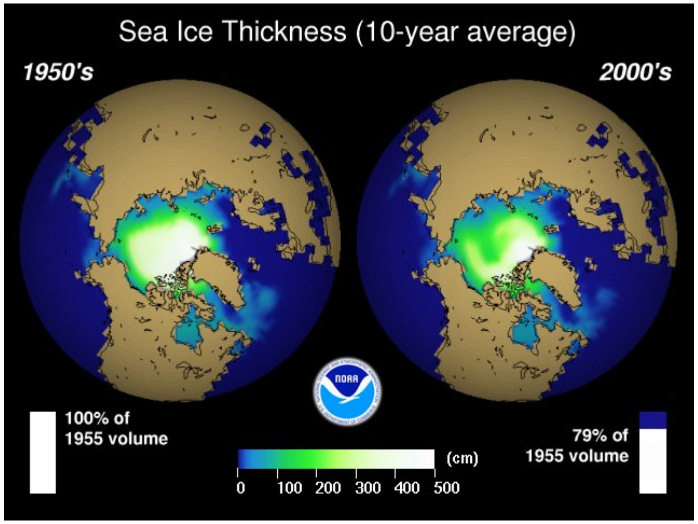


For reference, the sea level rise from 1961 to 2003 was 7.6cm (3 in)

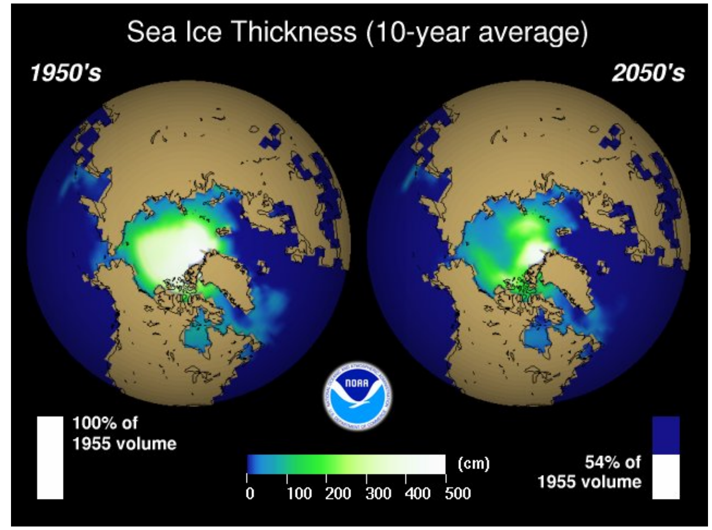
The total assumes no dynamical imbalance in the Antarctic or Greenland ice sheets.

IPCC AR4, Fig 10.33

Sea Ice Thickness



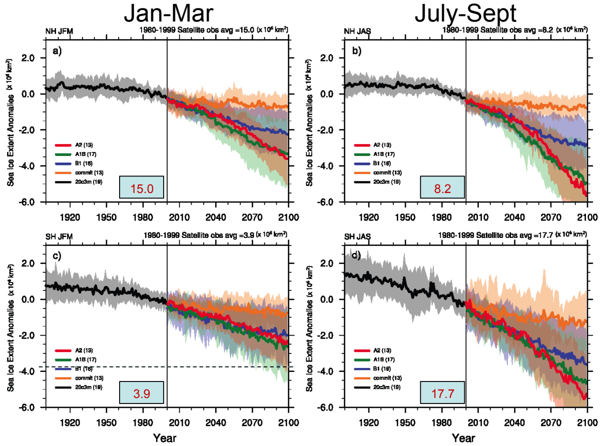
Sea Ice Thickness



Projected Sea Ice Extent

"2080-2100" minus "1980-2000"

Jan-Mar July-Sept



Northern Hemisphere

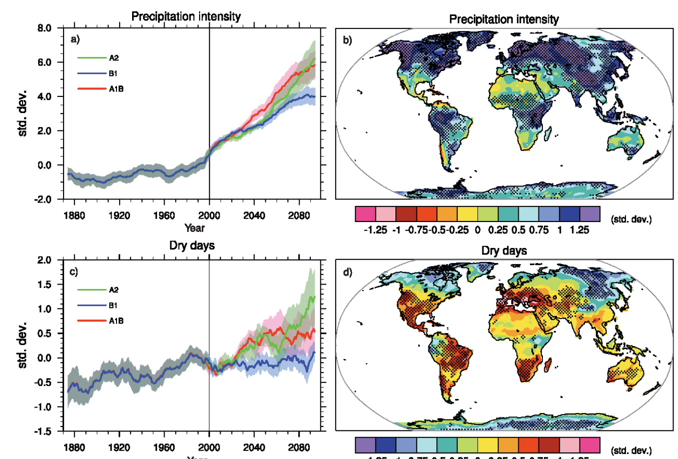
Southern Hemisphere

Largest decreases in northern hemisphere

Sea Ice Covered: when 15% of your neighborhood is covered by sea ice

IPCC AR4, Fig 10.13

Projected Hydrologic Changes: "2080-2099" minus "1980-1999"

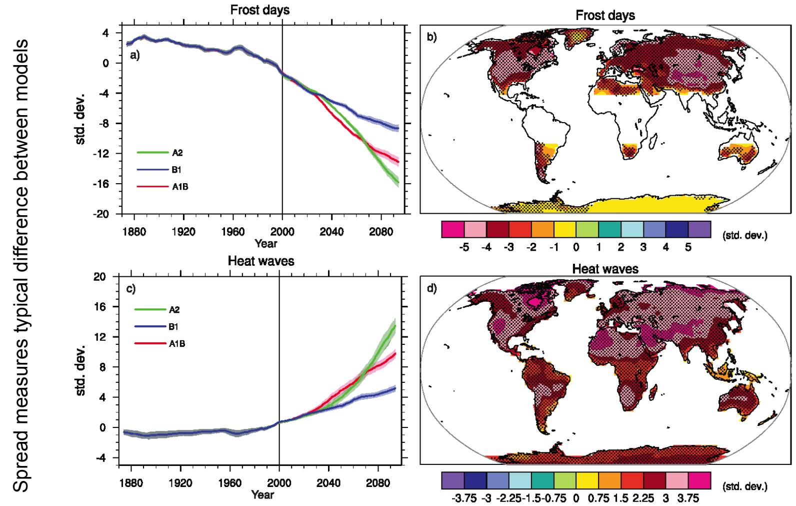


Scenario A1B

More Extreme Events?

- Increase in hurricane intensity or frequency?
  - Fuel for hurricanes is heat released from condensation of moisture in the air, which increases by ~ 7% per °C of increase in global average temperature. Why?
    - water vapor feedback: there will be 20-25% more water in the air by 20100!
  - Also depend on structure of mean wind
  - In the net, it is hard to tell how hurricane intensity, frequency or paths will change
- Abrupt climate changes?
  - Greenland sliding into the sea? No. Antarctica ?
  - The ocean circulation changing? No.

Projected Extreme Events: Frosts and Heat Waves



Scenario A1B

heat waves = the longest period in one year of at least five consecutive days with maximum temperature at least 5C higher than the climatology of the same calendar day

IPCC AR4, Fig 10.19

Climate changes 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]	Likelihood of future trends based on projections for 21st century using SRES scenarios
Warmer and fewer cold days and nights over most land areas	*Very likely*[c]	*Likely*[d]	*Virtually certain*[d]
Warmer and more frequent hot days and nights over most land areas	*Very likely*[e]	*Likely (nights)*[d]	*Virtually certain*[d]
Warm spells/heat waves. Frequency increases over most land areas	*Likely*	*More likely than not*[f]	*Very likely*
Heavy precipitation events. Frequency (or proportion of total rainfall from heavy falls) increases over most areas	*Likely*	*More likely than not*[f]	*Very likely*
Area affected by droughts increases	*Likely* in many regions since 1970s	*More likely than not*	*Likely*
Intense tropical cyclone activity increases	*Likely* in some regions since 1970	*More likely than not*[f]	*Likely*
Increased incidence of extreme high sea level (excludes tsunamis)[g]	*Likely*	*More likely than not*[f,h]	*Likely*[i]

IPCC 2007

Virtually certain > 99%   Very likely >90%   Likely >66%   More likely than not > 50%

Changes in Regional Temperature Extremes: 2100 minus 2000 AD

Temperature-Related Phenomena	
Change in phenomenon	**Projected changes**
Higher monthly absolute maximum of daily maximum temperatures (maxTmax) more hot / warm summer days	**VL (consistent across model projections)** maxTmax increases at same rate as the mean or median[1] over northern Europe,[2] Australia and New Zealand[3] **L (fairly consistent across models, but sensitivity to land surface treatment)** maxTmax increases more than the median over southern and central Europe,[4] and southwest USA[5] **L (consistent with projected large increase in mean temperature)** Large increase in probability of extreme warm seasons over most parts of the world[6]
Longer duration, more intense, more frequent heat waves / hot spells in summer	**VL (consistent across model projections)** Over almost all continents[7], but particularly central Europe,[8] western USA,[9] East Asia[10] and Korea[11]
Higher monthly absolute maximum of daily minimum temperatures (maxTmin); more warm and fewer cold nights	**VL (consistent with higher mean temperatures)** Over most continents[12]
Higher monthly absolute minimum of daily minimum temperatures (minTmin)	**VL (consistent across model projections)** minTmin increases more than the mean in many mid- and high-latitude locations,[13] particularly in winter over most of Europe except the southwest[14]
Higher monthly absolute minimum of daily maximum temperatures (minTmax), fewer cold days	**L (consistent with warmer mean temperatures)** minTmin increases more than the mean in some areas[15]
Fewer frost days	**VL (consistent across model projections)** Decrease in number of days with below-freezing temperatures everywhere[16]
Fewer cold outbreaks; fewer, shorter, less intense cold spells / cold extremes in winter	**VL (consistent across model projections)** Northern Europe, South Asia, East Asia[17] **L (consistent with warmer mean temperatures)** Most other regions[18]
Reduced diurnal temperature range	**L (consistent across model projections)** Over most continental regions, night temperatures increase faster than the day temperatures[19]
Temperature variability on interannual and daily time scales	**L (general consensus across model projections)** Reduced in winter over most of Europe[20] Increase in central Europe in summer[21]

VL
Very Likely
> 90%

L
Likely
> 66%

IPCC 2007 Tab 11.2

Changes in Regional Moisture Extremes: 2100 minus 2000 AD

Moisture-Related Phenomena	
Phenomenon	**Projected changes**
Intense precipitation events	**VL (consistent across model projections; empirical evidence, generally higher precipitation extremes in warmer climates)** Much larger increase in the frequency than in the magnitude of precipitation extremes over most land areas in middle latitudes,[22] particularly over northern Europe,[23] Australia and New Zealand[24] Large increase during the Indian summer monsoon season over Arabian Sea, tropical Indian Ocean, South Asia[25] Increase in summer over south China, Korea and Japan[26]
Intense precipitation events	**L (some inconsistencies across model projections)** Increase over central Europe in winter[27] Increase associated with tropical cyclones over Southeast Asia, Japan[28] **Uncertain** Changes in summer over Mediterranean and central Europe[29] **L decrease (consistent across model projections)** Iberian Peninsula[30]
Wet days	**L (consistent across model projections)** Increase in number of days at high latitudes in winter, and over northwest China[31] Increase over the Inter-Tropical Convergence Zone[32] Decrease in South Asia[33] and the Mediterranean area[34]
Dry spells (periods of consecutive dry days)	**VL (consistent across model projections)** Increase in length and frequency over the Mediterranean area[35], southern areas of Australia, New Zealand[36] **L (consistent across model projections)** Increase in most subtropical areas[37] Little change over northern Europe[38]
Continental drying and associated risk of drought	**L (consistent across model projections; consistent change in precipitation minus evaporation, but sensitivity to formulation of land surface processes)** Increased in summer over many mid-latitude continental interiors, e.g., central[39] and southern Europe, Mediterranean area,[40] in boreal spring and dry periods of the annual cycle over Central America[41]

VL
Very Likely
> 90%

L
Likely
> 66%

IPCC 2007 Tab 11.2

Changes in Regional Storminess Extremes: 2100 minus 2000 AD

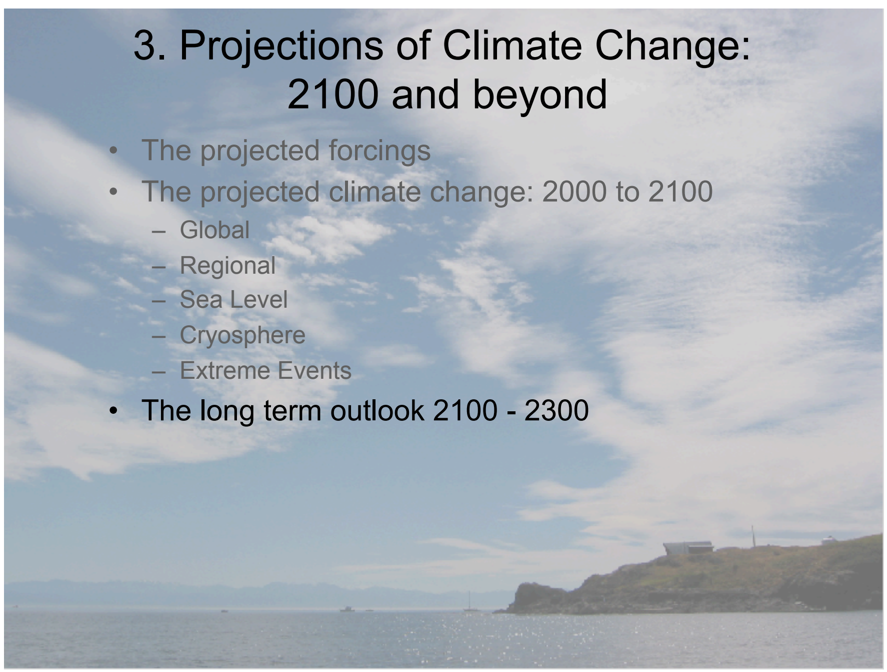
Tropical Cyclones (typhoons and hurricanes)	
Change in phenomenon	**Projected changes**
Increase in peak wind intensities	**L (high-resolution Atmospheric GCM (AGCM) and embedded hurricane model projections)** Over most tropical cyclone areas[42]
Increase in mean and peak precipitation intensities	**L (high-resolution AGCM projections and embedded hurricane model projections)** Over most tropical cyclone areas,[43] South,[44] East[45] and southeast Asia[46]
Changes in frequency of occurrence	**M (some high-resolution AGCM projections)** Decrease in number of weak storms, increase in number of strong storms[47] **M (several climate model projections)** Globally averaged decrease in number, but specific regional changes dependent on sea surface temperature change[48] Possible increase over the North Atlantic[49]
Extratropical Cyclones	
Change in phenomenon	**Projected changes**
Changes in frequency and position	**L (consistent in AOGCM projections)** Decrease in the total number of extratropical cyclones[50] Slight poleward shift of storm track and associated precipitation, particularly in winter[51]
Change in storm intensity and winds	**L (consistent in most AOGCM projections, but not explicitly analysed for all models)** Increased number of intense cyclones[52] and associated strong winds, particularly in winter over the North Atlantic,[53] central Europe[54] and Southern Island of New Zealand[55] **More likely than not** Increased windiness in northern Europe and reduced windiness in Mediterranean Europe[56]
Increased wave height	**L (based on projected changes in extratropical storms)** Increased occurrence of high waves in most mid-latitude areas analysed, particularly the North Sea[57]

VL
Very Likely
> 90%

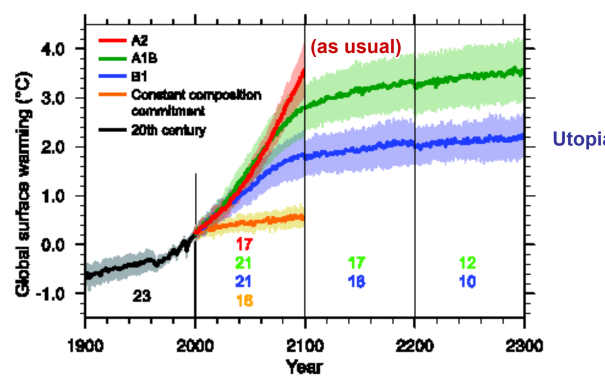
L
Likely
> 90%

M
Medium
Confidence

IPCC 2007 Tab 11.2



Global Annual Average Surface Temperature

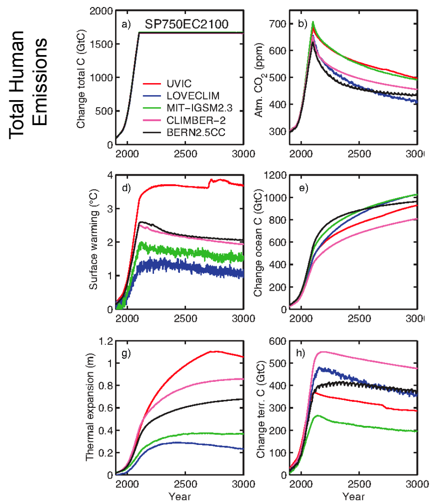


Referenced to the 1980-1999 Average Temperature

Solid lines: average of all models used. The number of models used varies; shaded area is the standard deviation of the models. **Zero** emission is assumed beyond 2100 (gold: beyond 2000)

The long term outlook: 2000-3000AD

If we stop CO_2 emissions in 2100, how long will it take to reach the pre-industrial climate*?

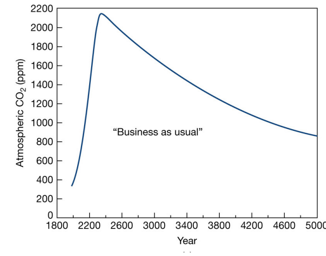


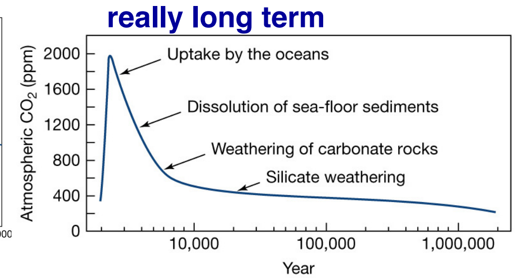
CO_2 in atmosphere peaks at 750 in 2100

CO_2 in ocean increases rapidly until ~2200, then slowly for 1000+ years

CO_2 in land biomass increases rapidly until ~2200, then slowly declines

The VERY long term adjustment





The atmospheric CO_2 concentration - and hence climate - returns to near pre-industrial (PI) levels by 10,000 yrs

Almost all of the human emissions of CO_2 end up in the ocean

Kump et al. (2003), T Earth System, Box Fig 13-2

How long would forcing by humans last if we suddenly stopped emitting everything?

- Carbon Dioxide
  - About 1/2 removed in **1000 years** (absorbed in the deep ocean)
  - Most gone by 10,000 years
- Methane
  - About 70% removed in 10 years (absorbed into soil)
  - Most gone by 20 years
- CFCs
  - 50 to 20,000 years, depending on compound
- Aerosols
  - In troposphere, about 5 days
  - In stratosphere, about 2 years