Global Climate Change: New Timelines

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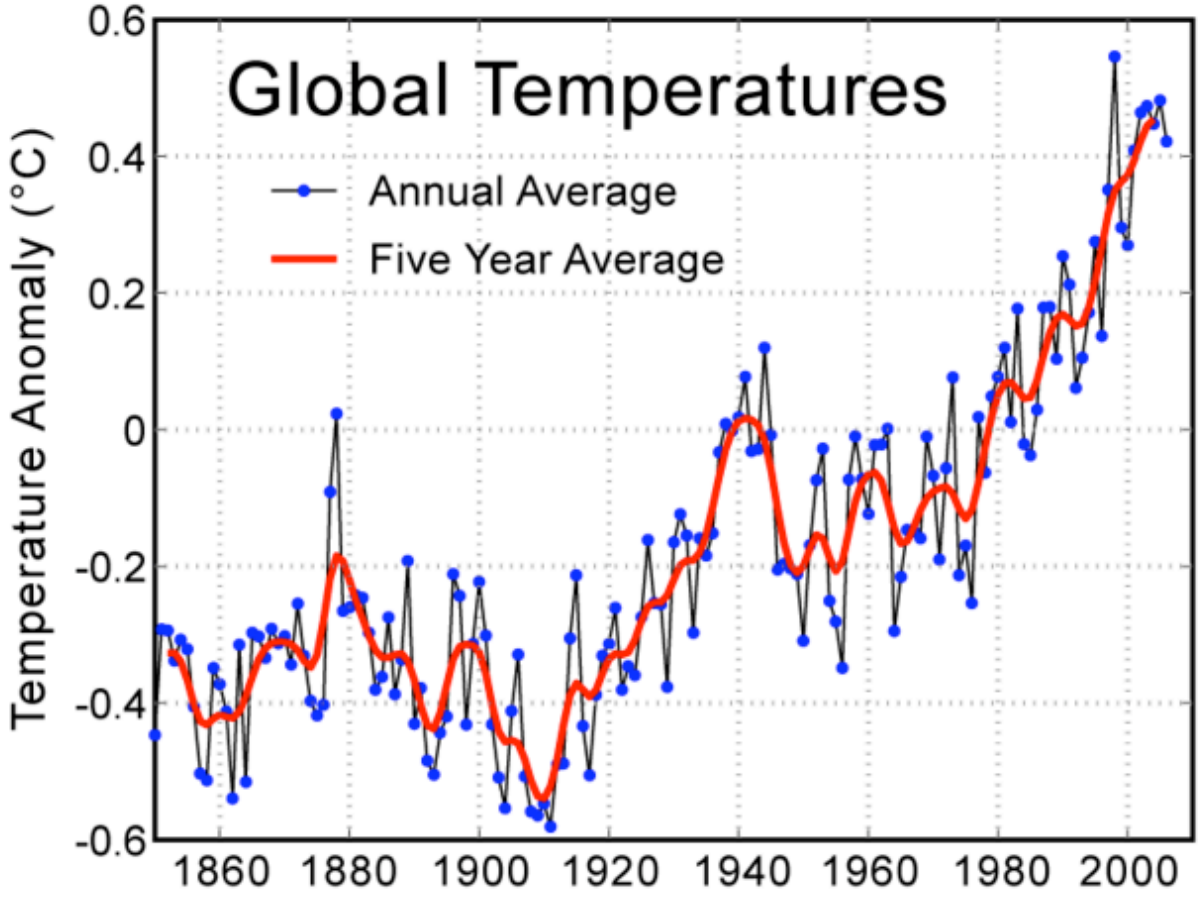
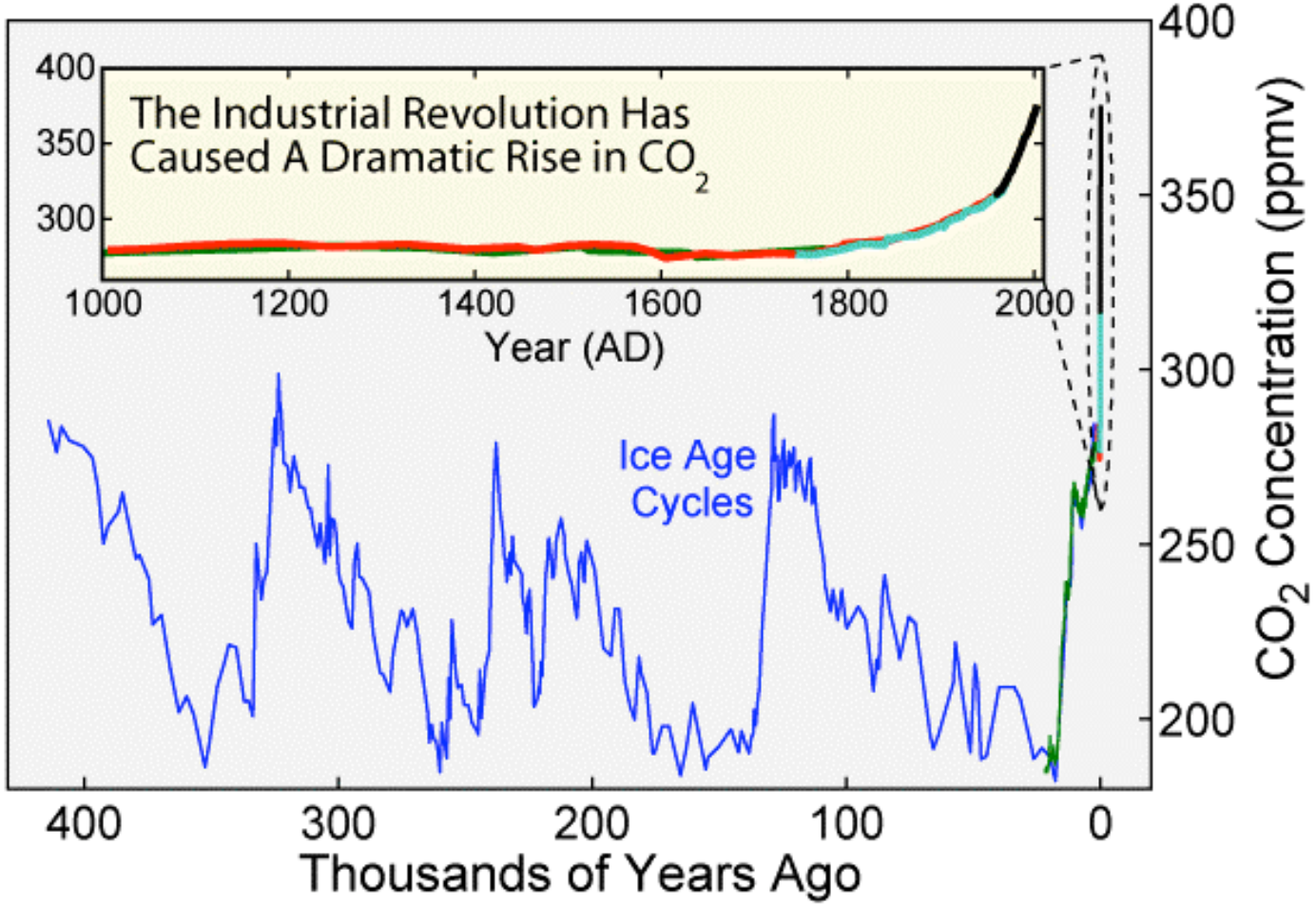
- Earth has warmed due to human activity
- Projections of the future climate: 2000 to 2100
  - Projected changes in greenhouse gases
  - Projected climate changes (focus on *very likely* changes)
- Summary

The Earth has warmed



The Earth has warmed about 0.85ºC in the past 100 years

Atmospheric Carbon Dioxide



•Carbon dioxide increased by 1/3 since 1750 because of the burning fossil fuels (80%) and deforestation (20%)

–Fate: 40% in atmosphere, 35% in land and 25% in ocean

•The *rate of increase* is 100-1000 times faster than Nature can change CO_2

Attribution of 20th Century climate changes

How do we know the warming (and other climate changes) in the past 100 years is due increasing carbon dioxide?

- Run climate models with and without natural and human forcings
  - Natural: Changes in sun strength, volcanic emissions of aerosols
  - Human: Increasing greenhouse gases (fossil fuel burning), changes in atmospheric aerosols (fossil fuel burning)

- *Conclude that the warming trend 1900-2000 can only be explained (and is consistent with) human induced increases in greenhouse gases.*

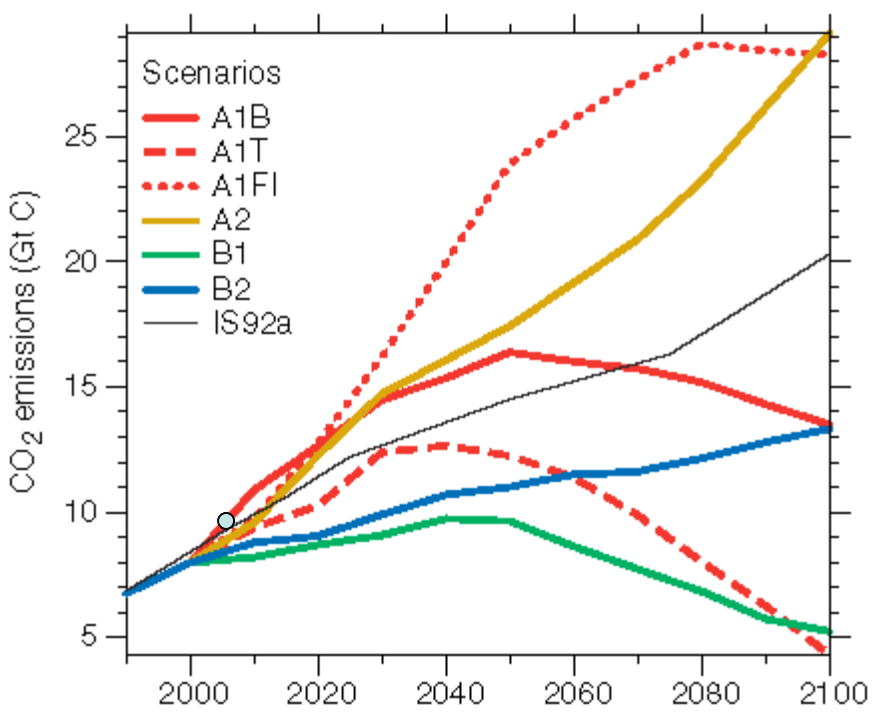
Projections of Future Climate: 2000-2100

We need to know:

- How much humans will change the atmosphere?
  - *How much greenhouse gas will be emitted?*
  - How much aerosol will be emitted?
  - How will the land use change?
- How will the climate change due to these changes?
  - What can we reliably know from the climate models?

How much Carbon Dioxide will be released into the atmosphere?

Scenarios provided by economists, policy makers, etc.



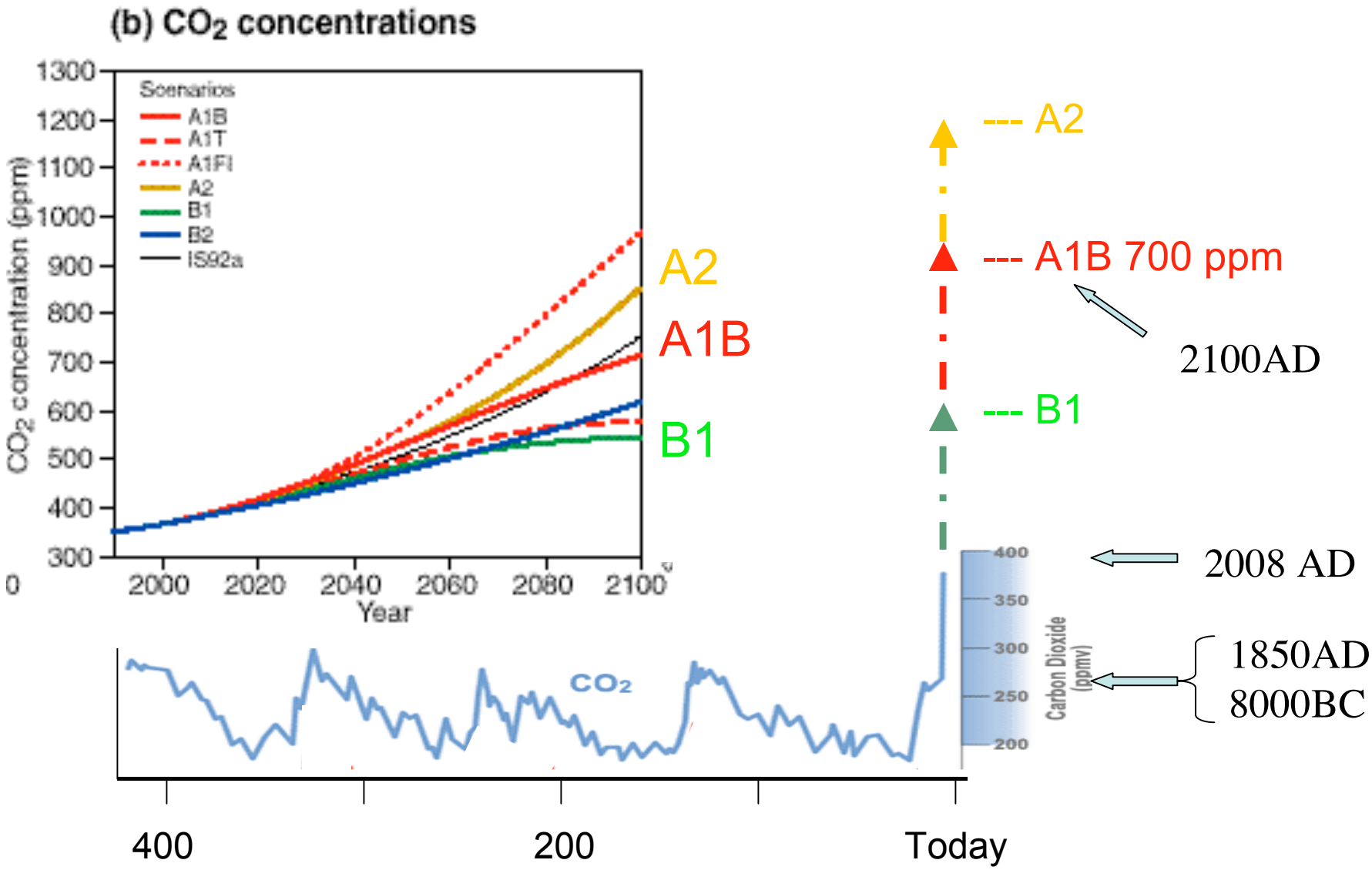
A2 (business as usual)

A1B

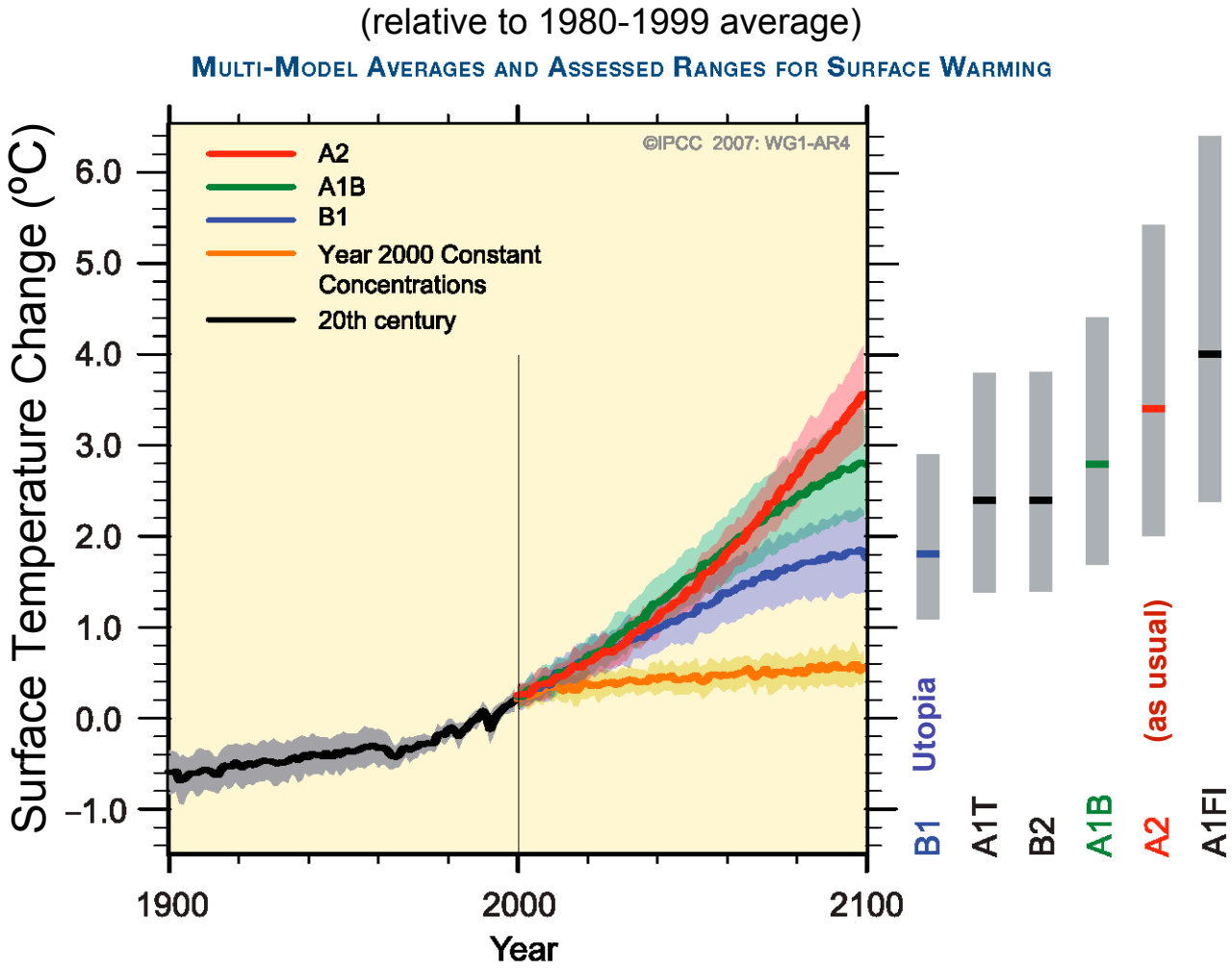
B1 (utopia)

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

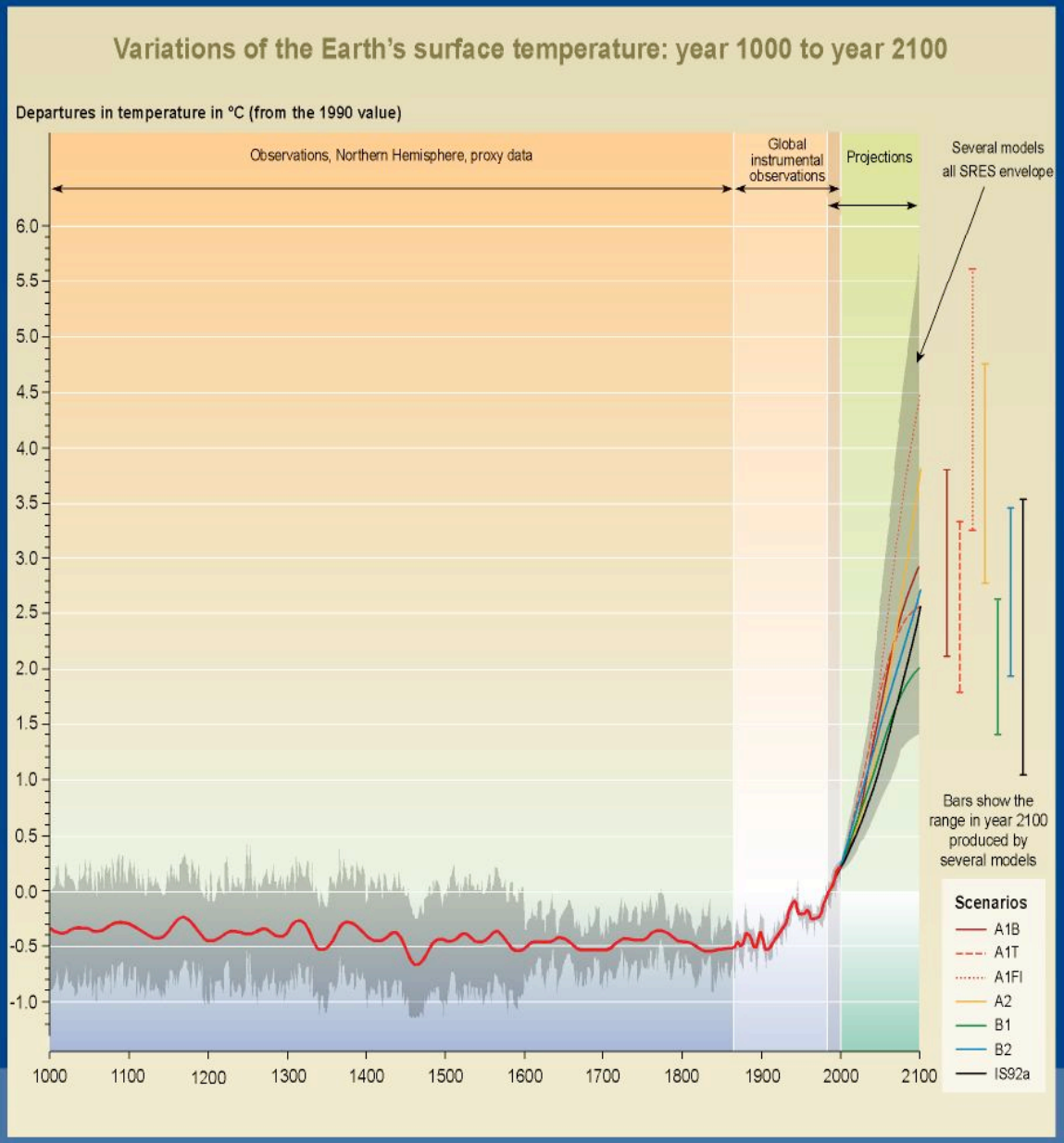
Carbon Dioxide in the Atmosphere



Global Average Temperature Change

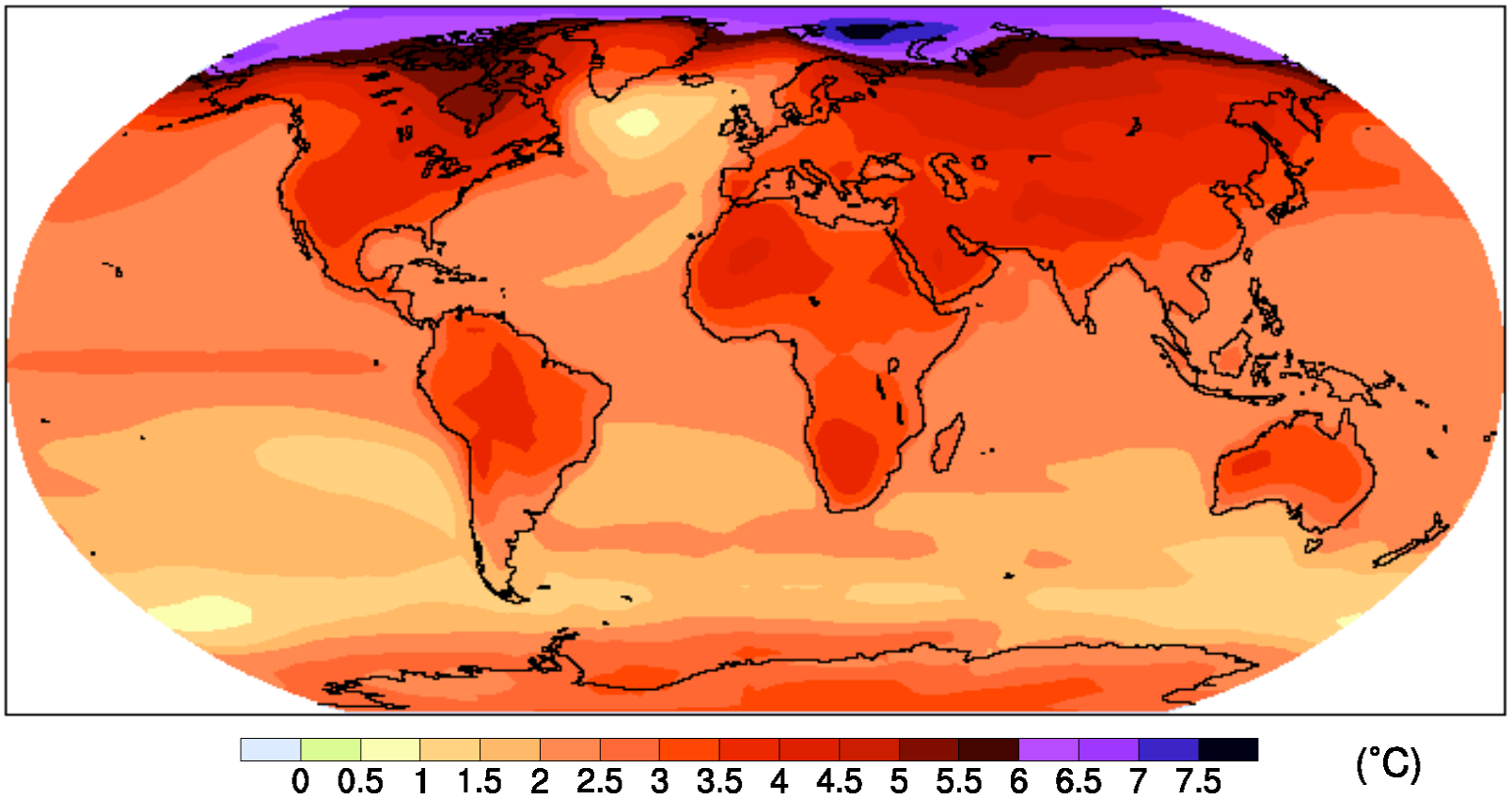


For a mid-range emission scenario, model project an global average warming over the next 100 years of 2.8 ºC: 3 to 4 times the warming over the past century.



SYR - FIGURE 9-1b

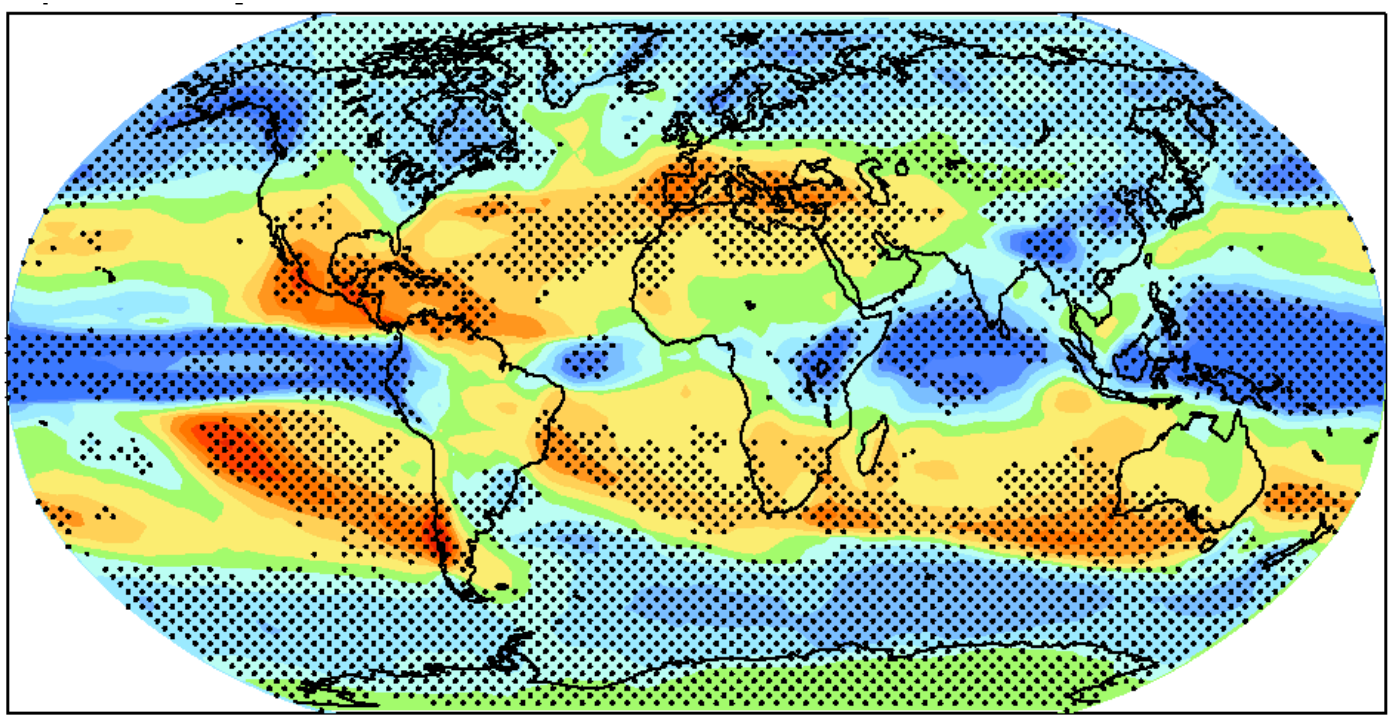
Projected Annual Average Surface Temperature Change: "2080-2099" minus "1980-1999"

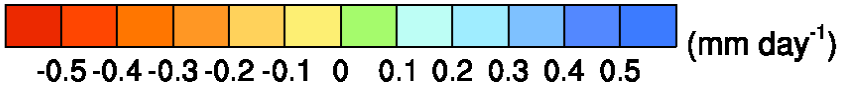


Average of 21 climate models forced by Scenario A1B.

(Multiply by ~1.2 for A2 and ~0.7 for B1)

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



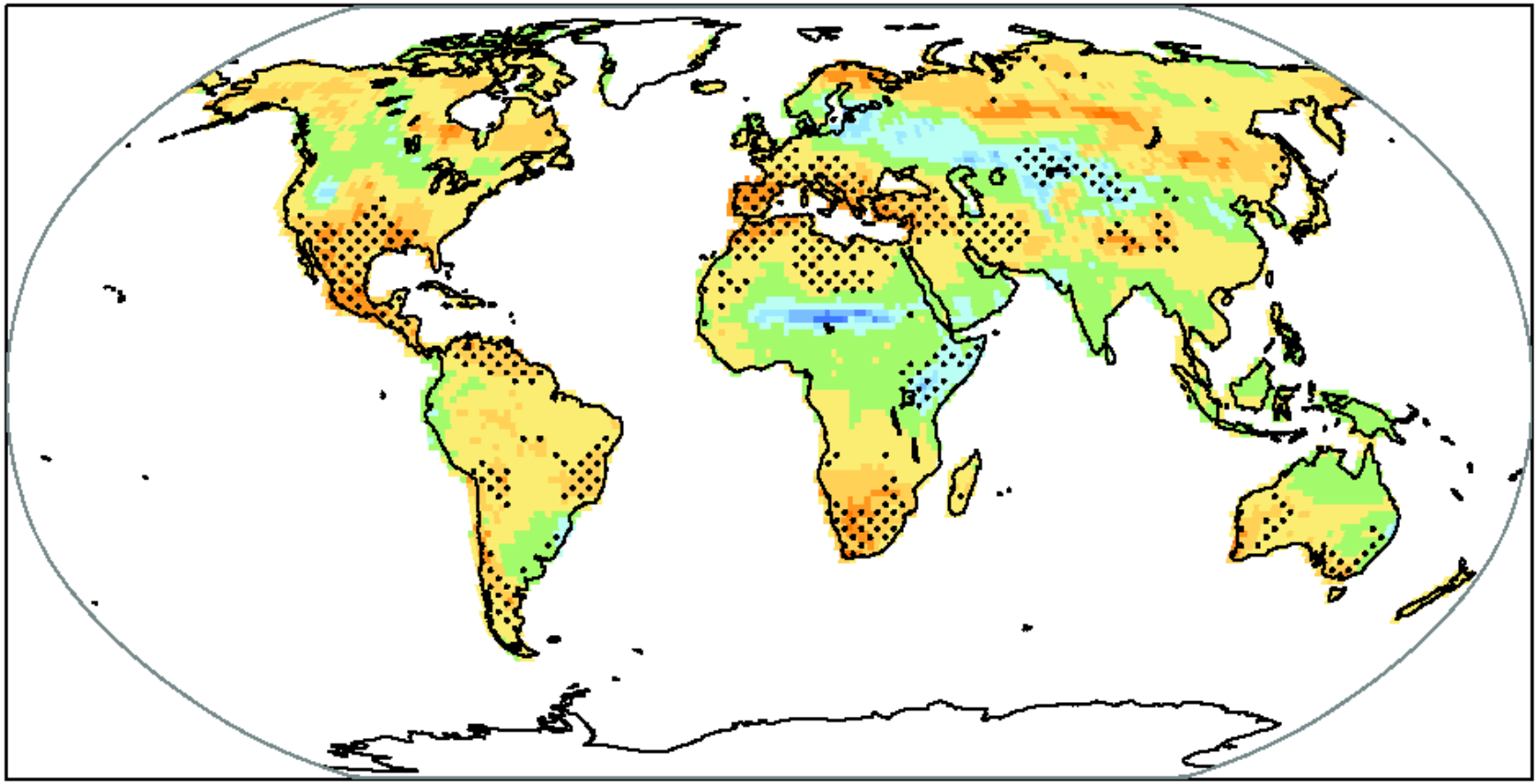


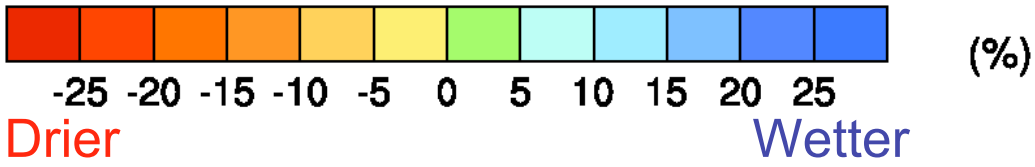
Scenario A1B

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

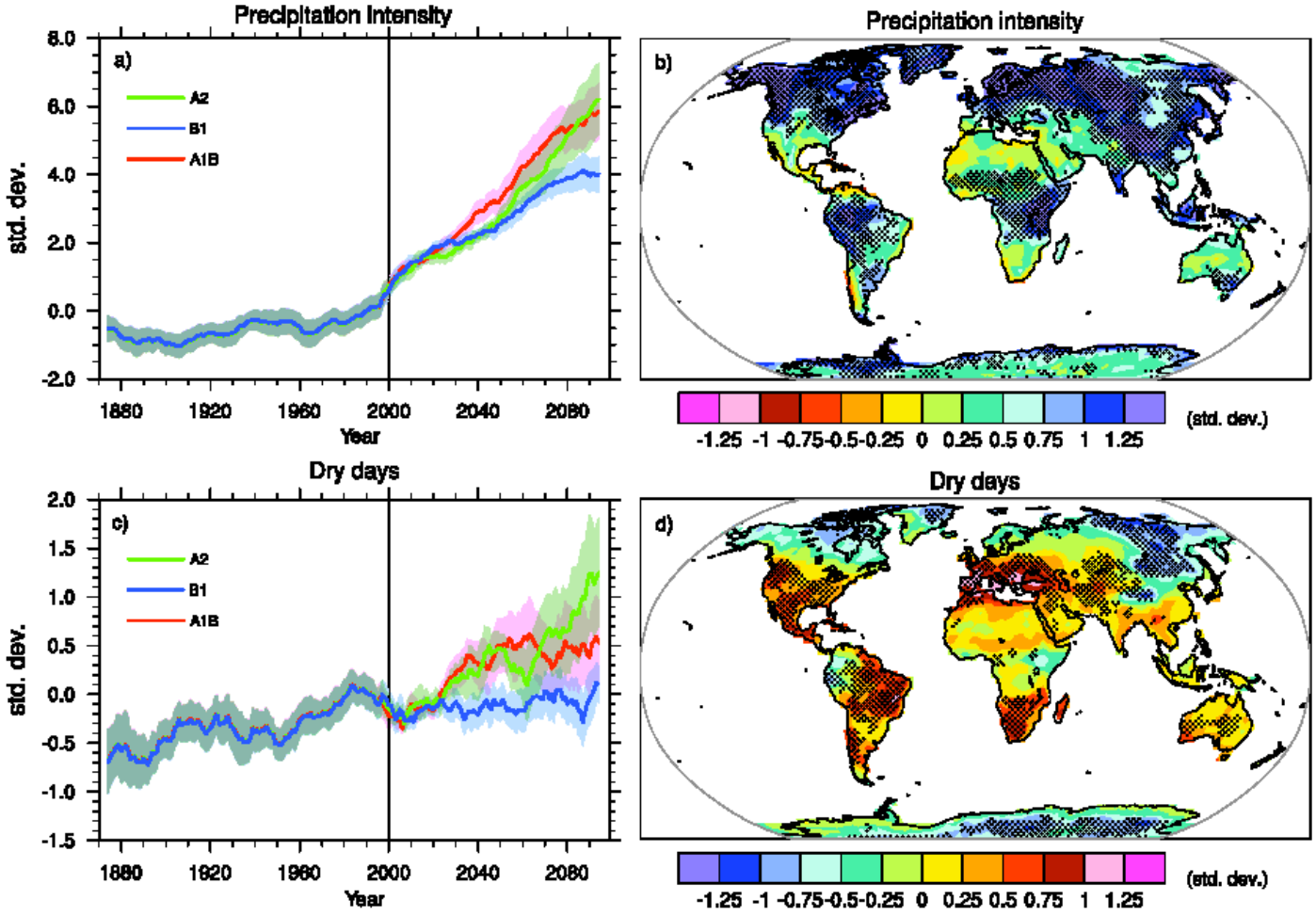
Projected Soil Moisture Change: “2080-2099” minus “1980-1999”





Scenario A1B Drier Wetter

Projected Hydrologic Changes: “2080-2099” minus “1980-1999”



Scenario A1B

Climate changes due to human activity

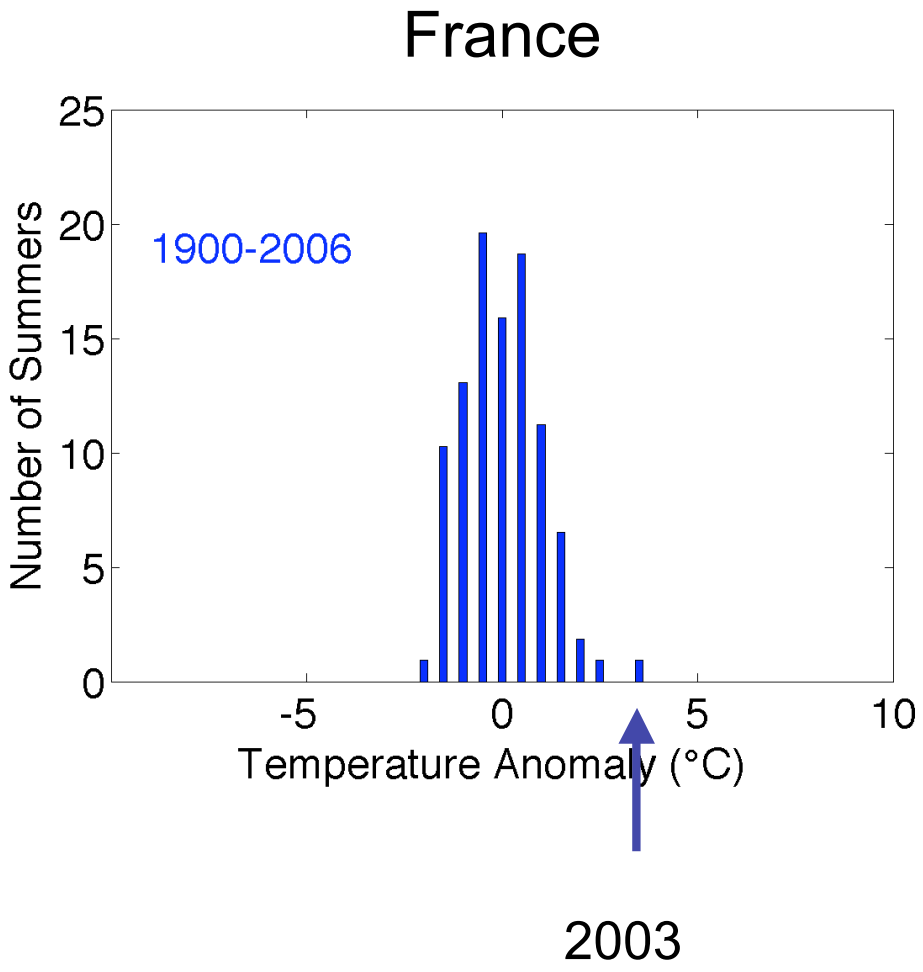
Phenomenon[a] and direction of trend	Likelihood of future trends based on projections for 21st century using SRES scenarios
Warmer and fewer cold days and nights over most land areas	*Virtually certain*[d]
Warmer and more frequent hot days and nights over most land areas	*Virtually certain*[d]
Warm spells/heat waves. Frequency increases over most land areas	*Very likely*
Heavy precipitation events. Frequency (or proportion of total rainfall from heavy falls) increases over most areas	*Very likely*

Virtually certain > 99%

Very likely >90%

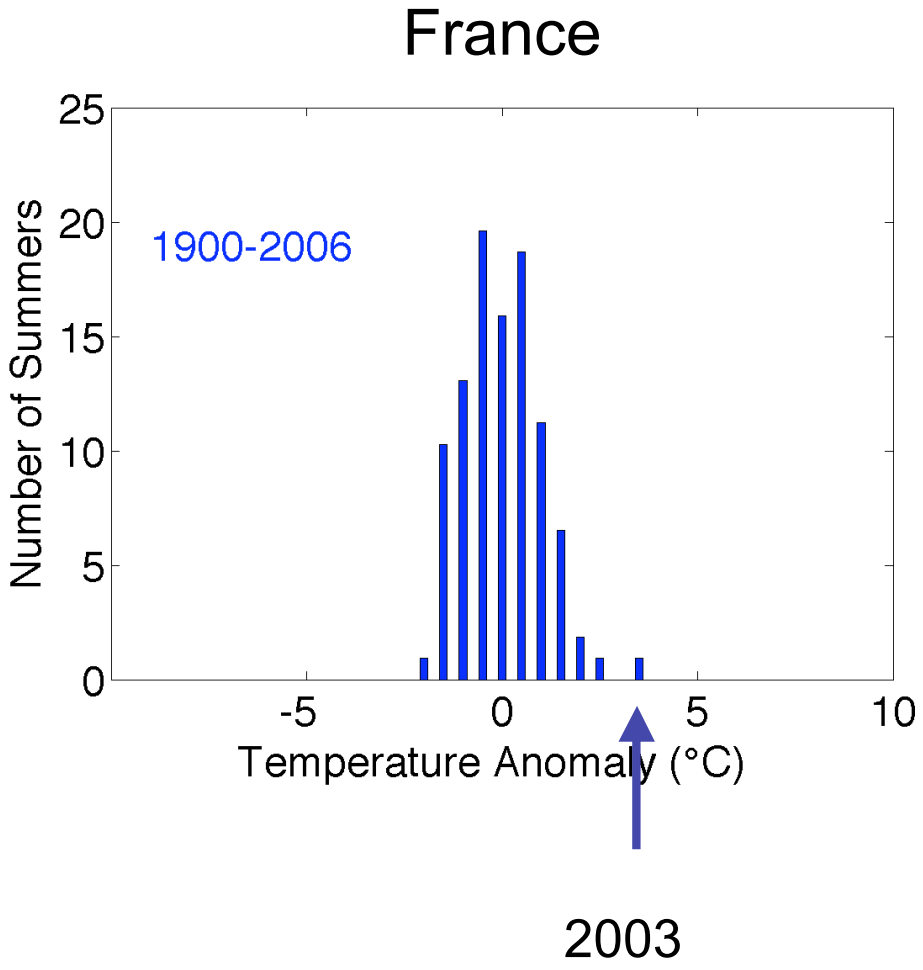
IPCC 2007

Growing Season Temperature



Observed JJA Temp
(1900-2007)

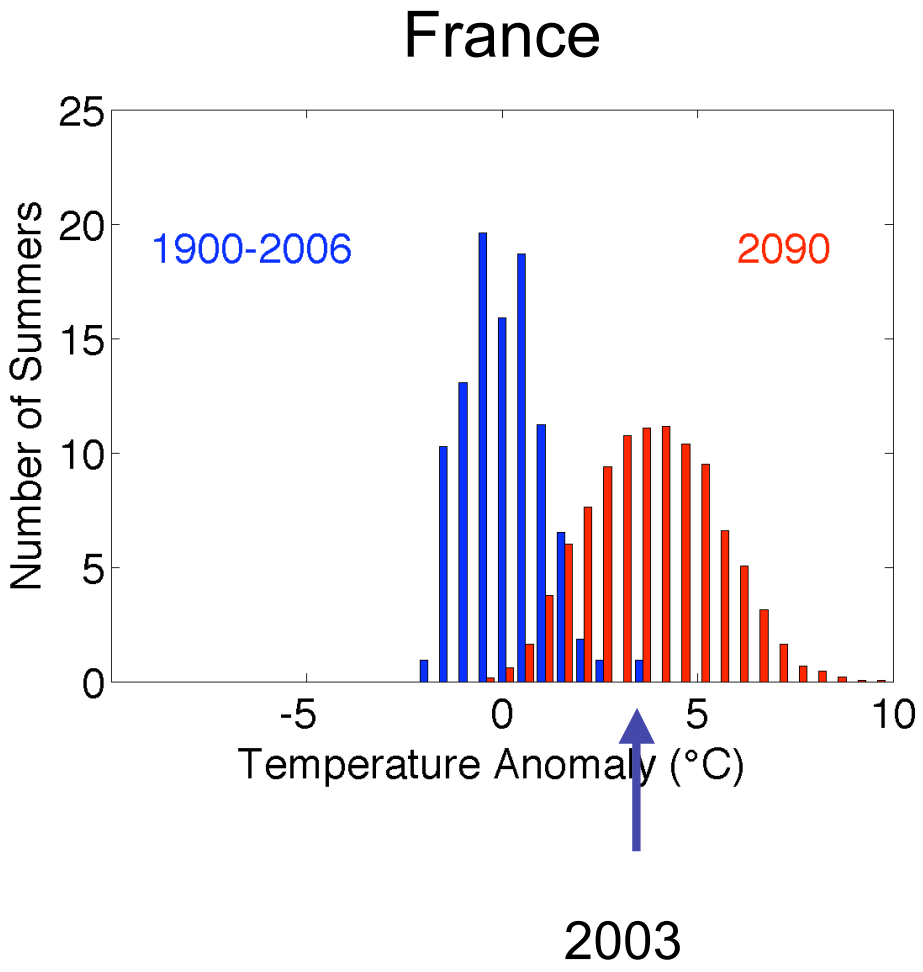
Growing Season Temperature



Observed JJA Temp (1900-2007)

- *France/Italy in 2003*
  - 30 to 36% drop in maize yields
  - 24% drop in fruit harvest
  - 21% reduction in wheat yields
  - 30,000 to 50,000 dead of heat stress

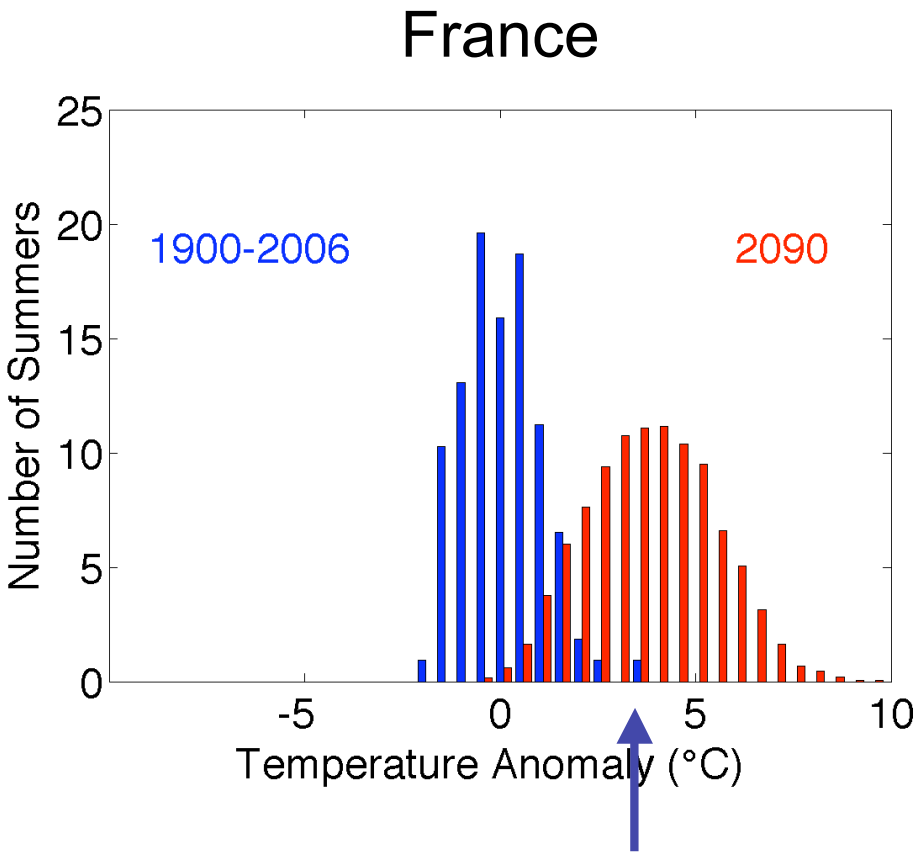
Projections of Growing Season Temperature



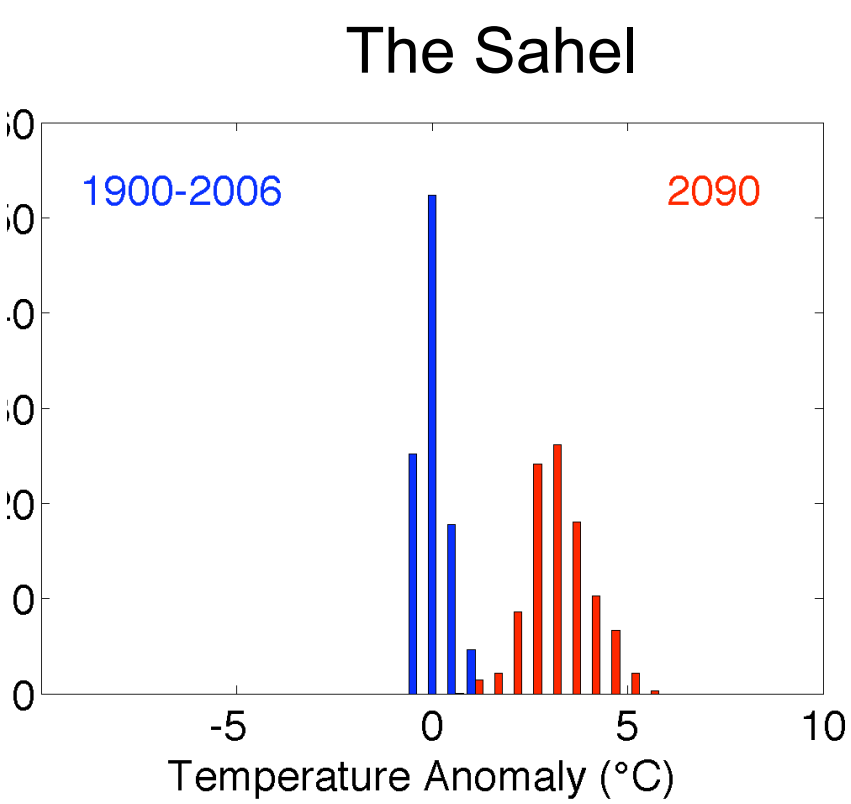
Observed JJA Temp (1900-2007)

Projections use 22 climate models (IPCC AR4) forced by A1B Emission scenario. Variability taken from observations

Projections of Growing Season Temperature

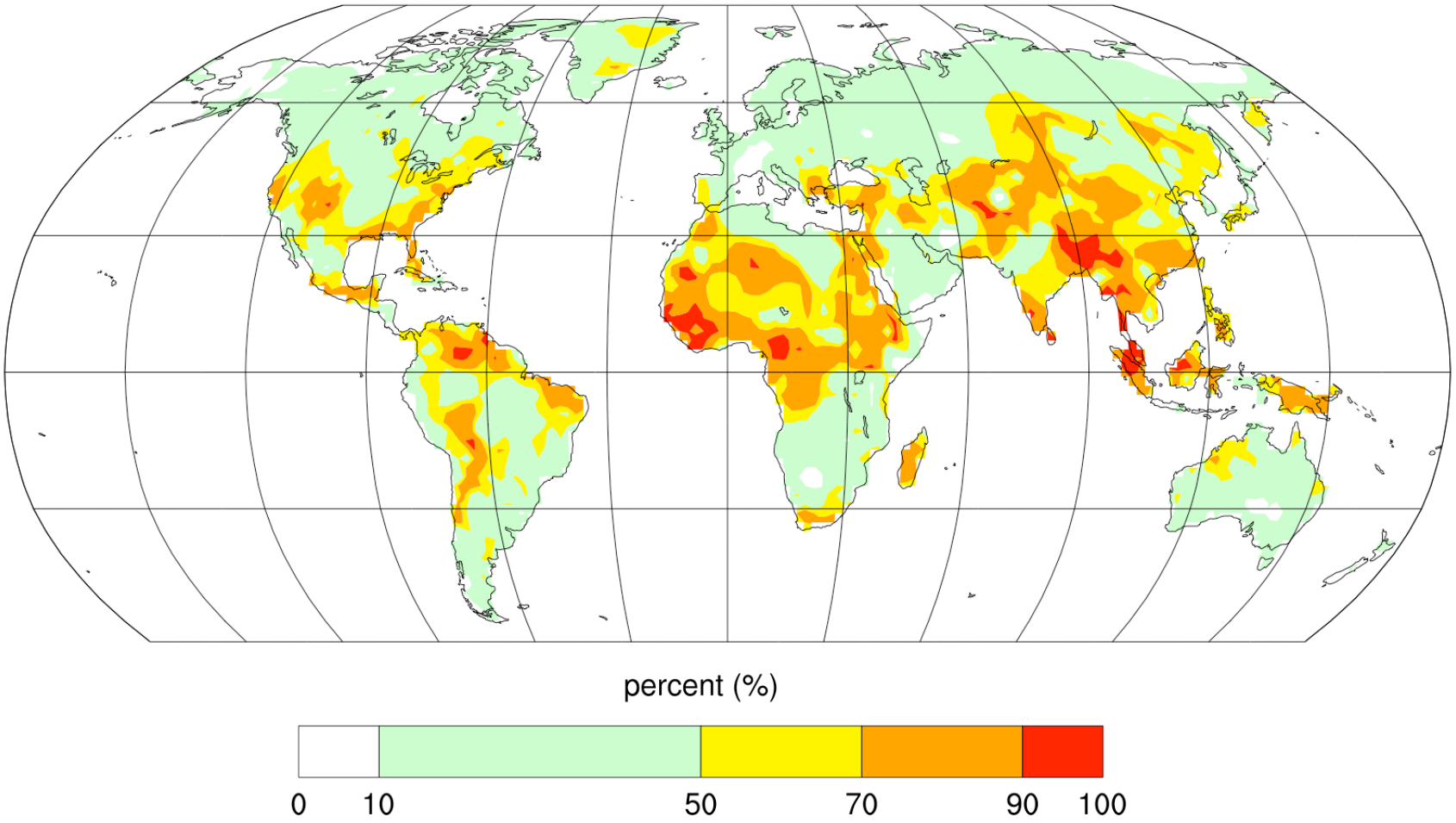


2003



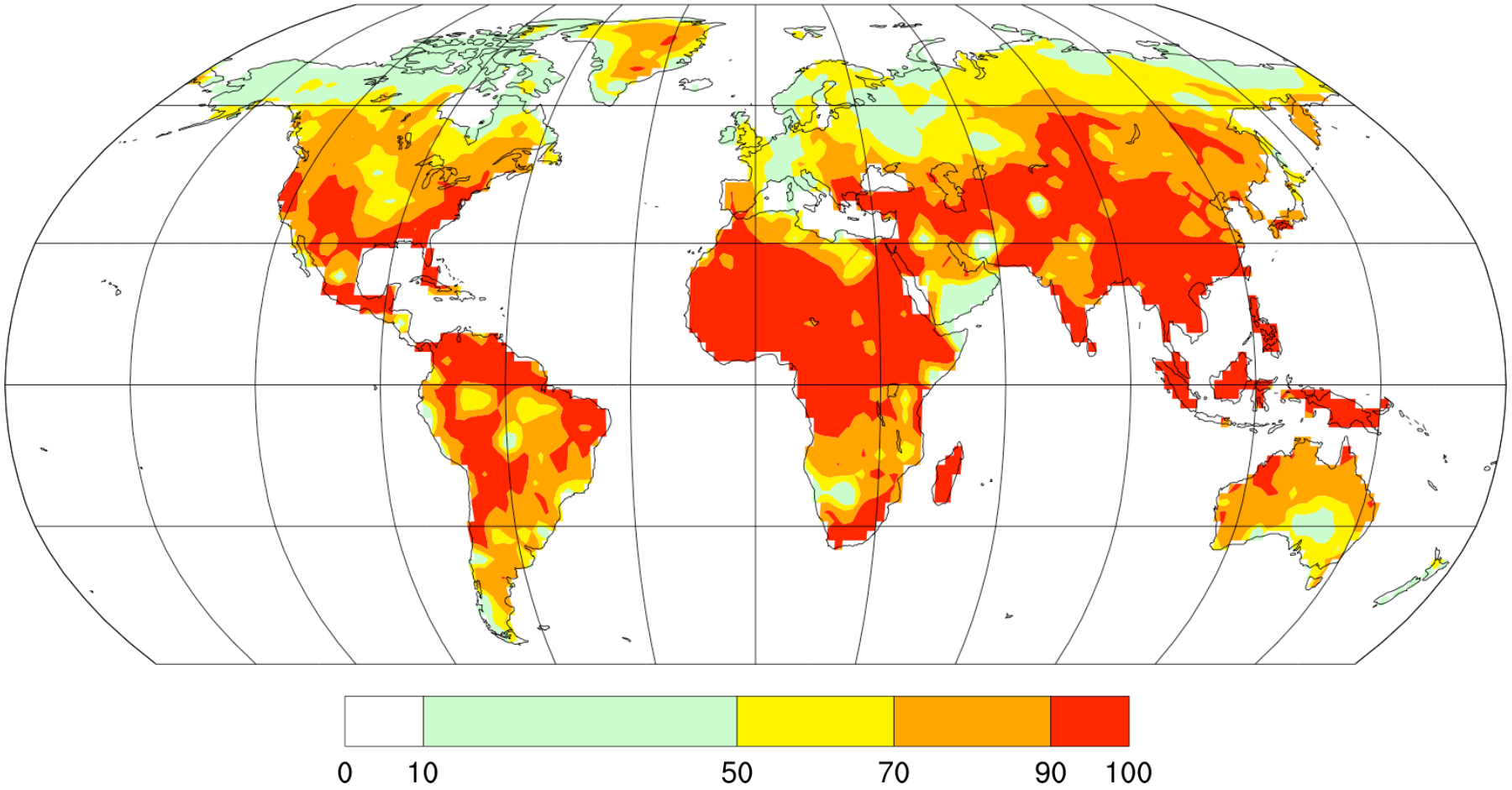
Projections of Growing Season Temperature

Percent of Summers in 2050 Warmer than Warmest on record



Battisti and Naylor 2009

Percent of Summers in 2090 Warmer than Warmest on record



By the end of the 21st Century it will be much hotter everywhere

In most of the tropics/subtropics, the seasonal average temperature will *very likely* exceed the warmest year on record

Battisti and Naylor 2009

Summary: Climate in the 21st Century

- The climate will change because of human-induced changes in greenhouse gases (CO_2, CH_4, N_2O, etc)
- The global, annual averaged temperature will likely increase by 2.4 to 6.4ºC
  - Uncertainty in projections due in ~ equal parts to uncertainty in emissions uncertainty and models
  - Changes over the next 100 years will be much, much greater than the changes seen over the past 150 years
  - The rate of change is 100 - 1000 times faster than nature
- It is *very likely* that warming will be
  - More over continents than oceans; more in high latitudes than in tropics; more in winter than summer, more at night than day
  - More extreme warm days and nights; fewer frost days per year

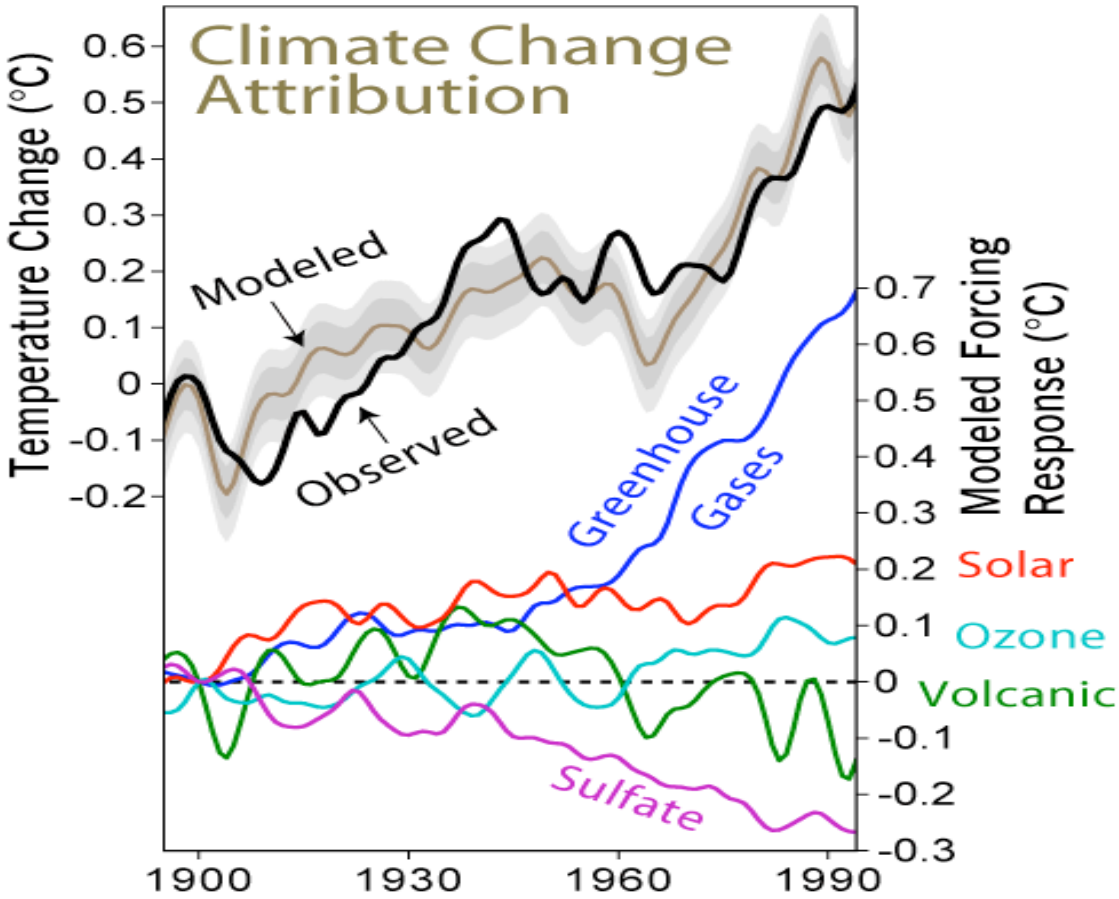
Summary: Climate in the 21st Century

- It is very likely that the growing season will be hotter than the hottest ever observed, throughout the tropics and subtropics

- Other climate changes that are *very likely* over the next 100 years include:
  - the hydrologic cycle will speed up
  - the area covered by snow and sea ice will decrease
  - the subtropics will be drier (less precip/more evaporation)
  - the sea level will rise
  - the ocean will become more acidic
- These changes in climate will have a significant and increasing effect on temperature, precipitation, snow pack, river flows (amount and timing), and soil moisture
  - Impacts on **agriculture**, fisheries, forestry, aquaculture, ecosystems and biodiversity, flood control policy, hydropower, vector borne diseases, …

Attribution of the 20th Century Temperature Trends

The warming trend can only be explained (and is consistent with) human induced increases in greenhouse gases.



The pause in warming from ~1950-1980 is consistent with the natural (volcanoes and solar) and human (sulfate) forcing.