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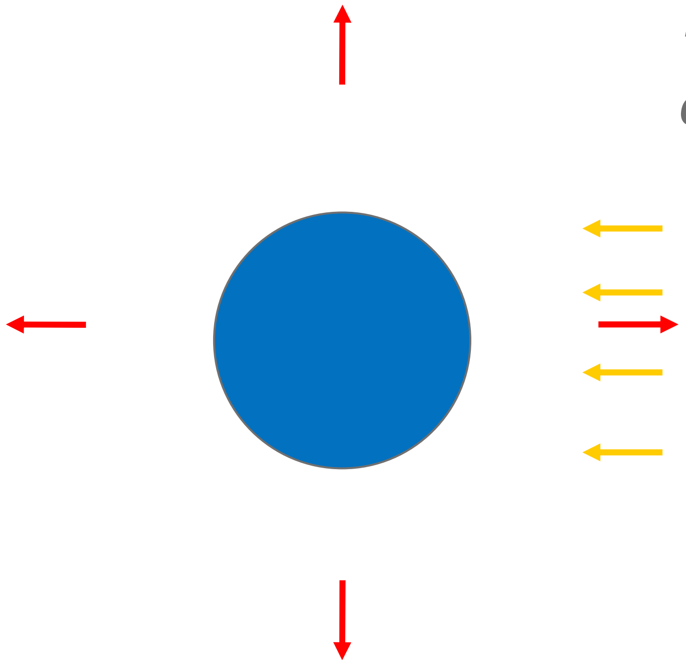
Climate Change in an Uncertain World

Brian Hoskins



“Greenhouse” gases determine height of layer from which heat escapes

More greenhouse gases:

higher level

colder temperature

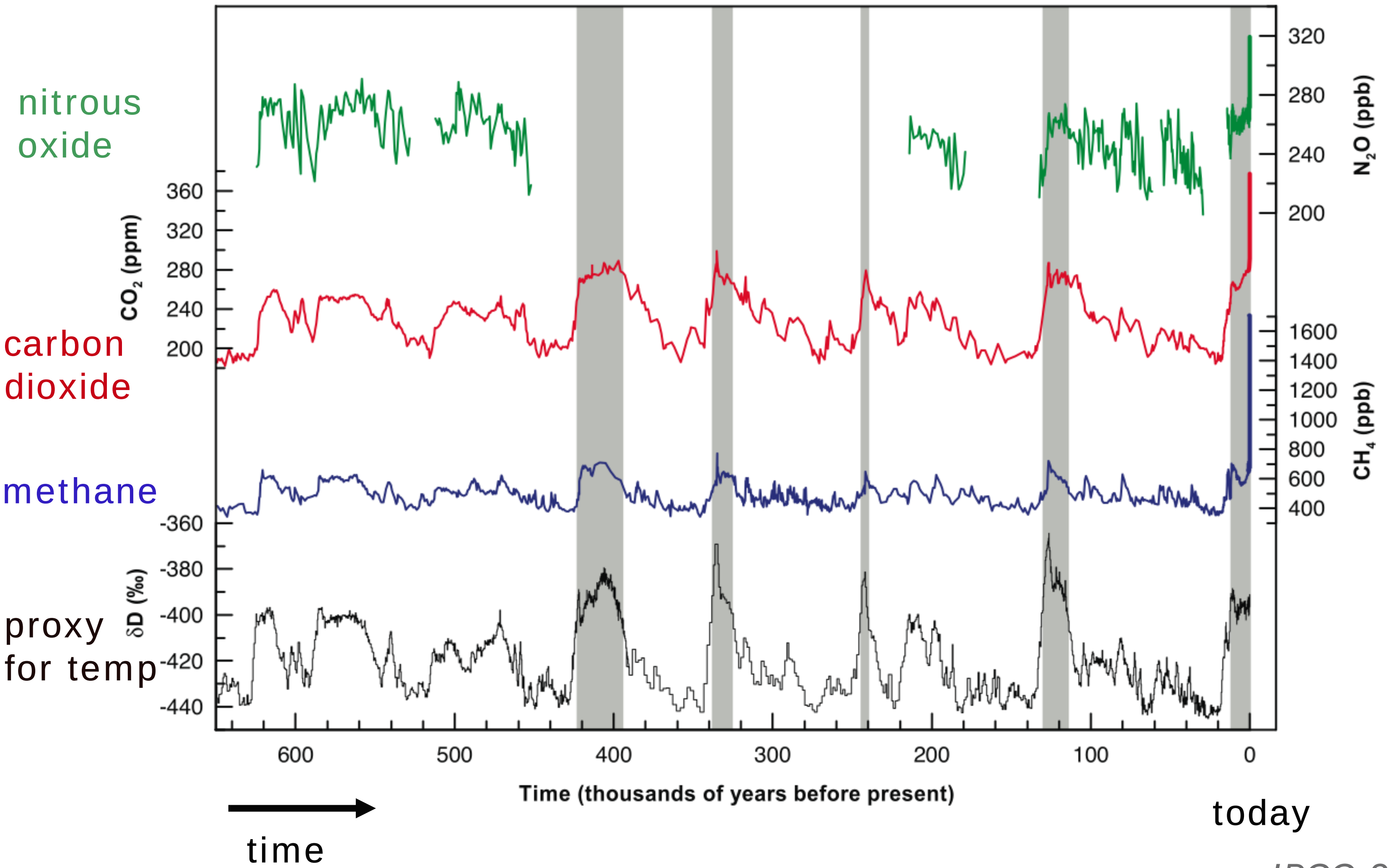
less heat lost

global warming

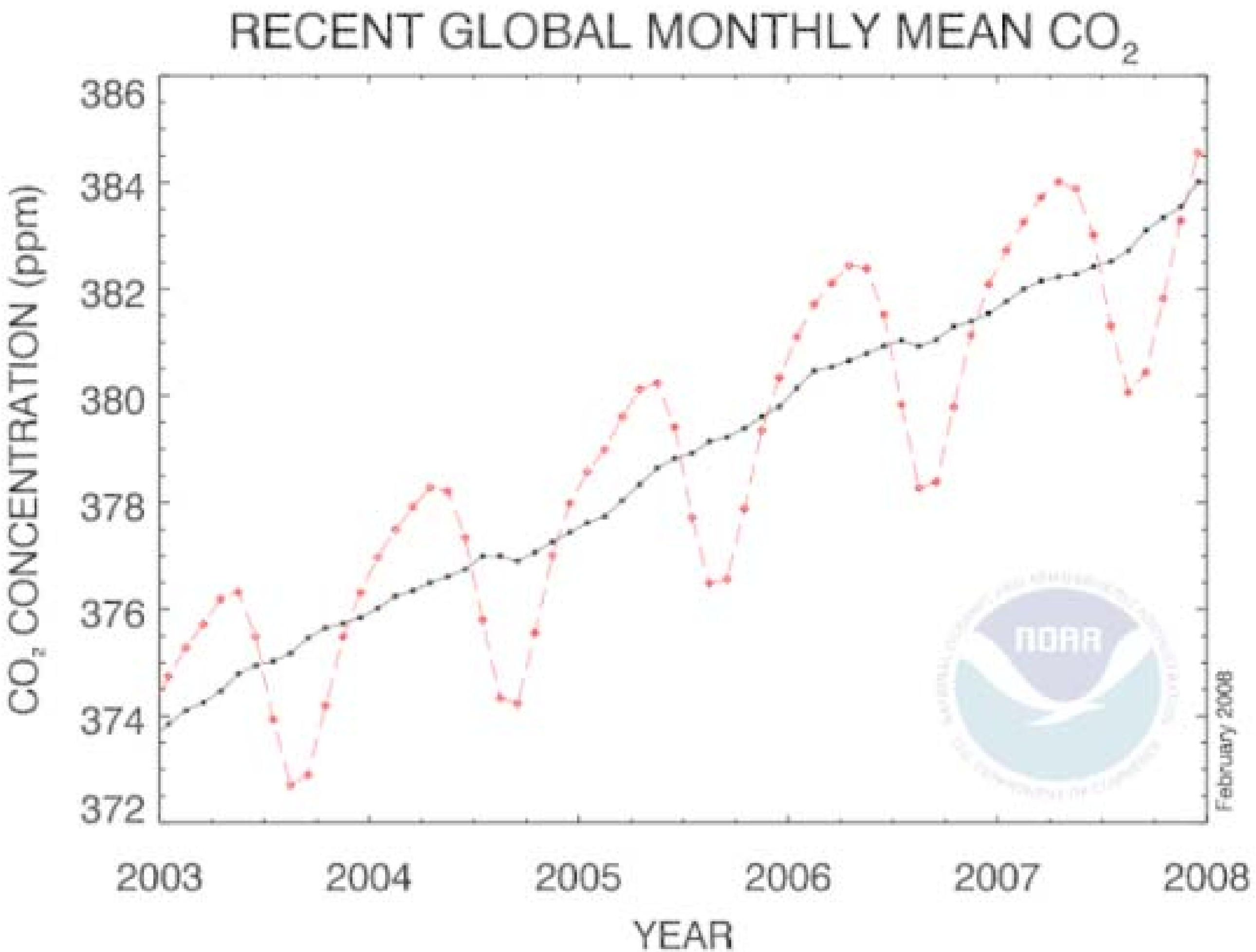
(water vapour) carbon dioxide, methane,...

Fourier (1827), Tyndall (1861)

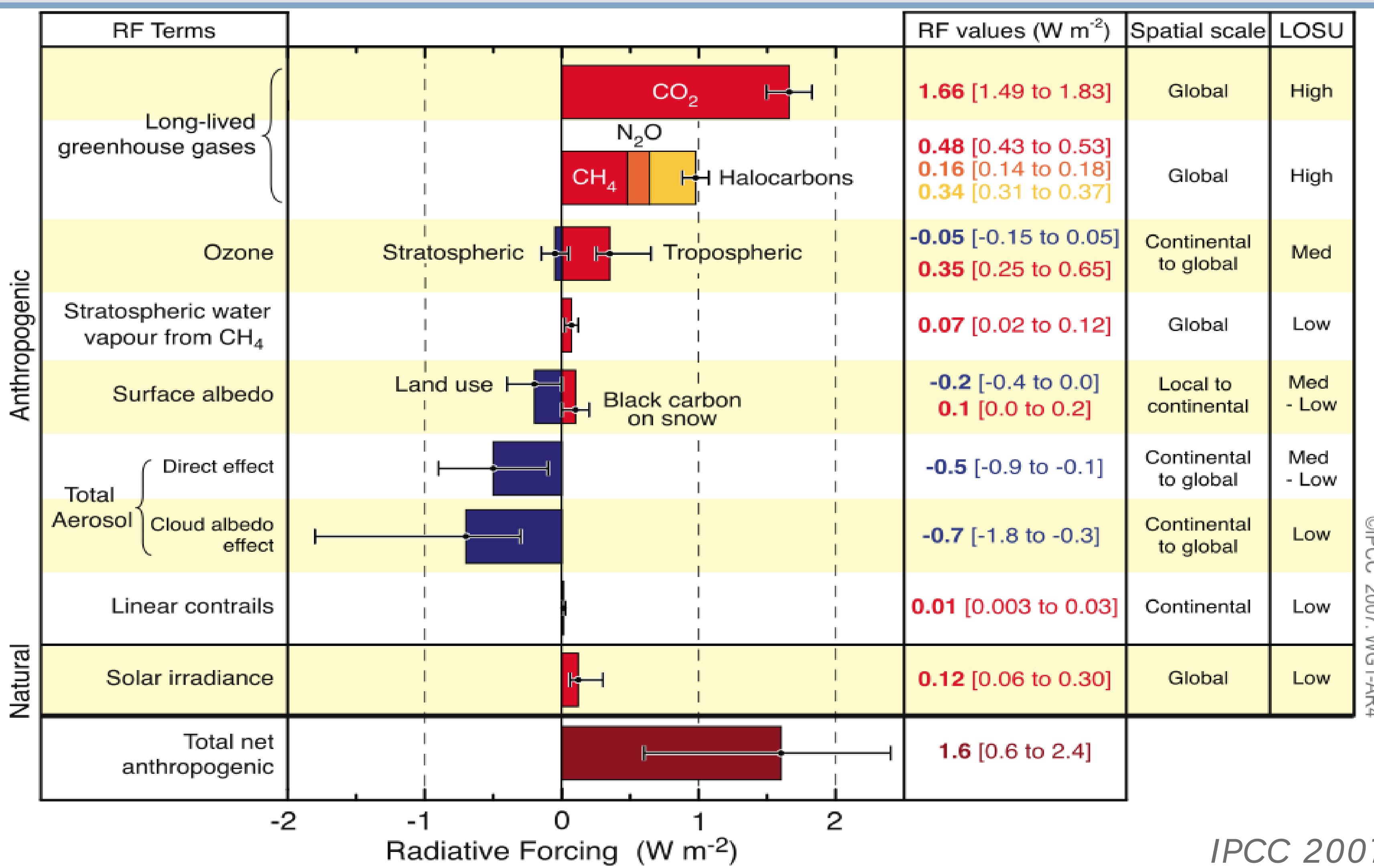
Temperature and greenhouse gases in past 650,000 y



IPCC 2007


RECENT GLOBAL MONTHLY MEAN CO2
386
384
382
380
378
376
374
372
CO2 CONCENTRATION (ppm)
2003
2004
2005
2006
2007
2008
YEAR
NOAA
February 2008

Causes of the current imbalance in the energy budget



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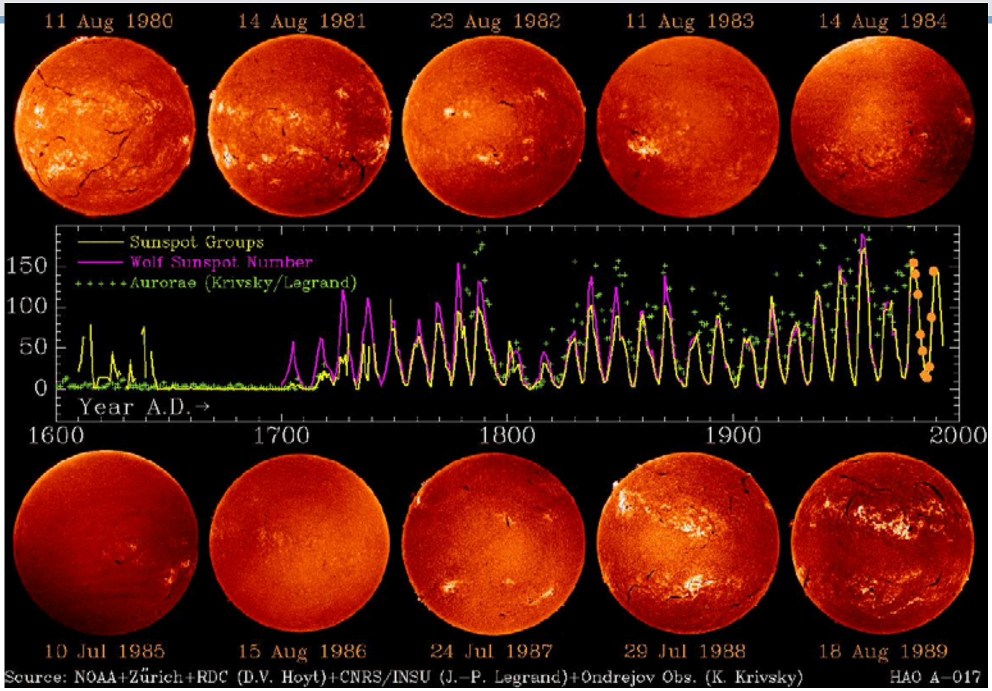
Natural causes of climate variability and change

Orbital parameters

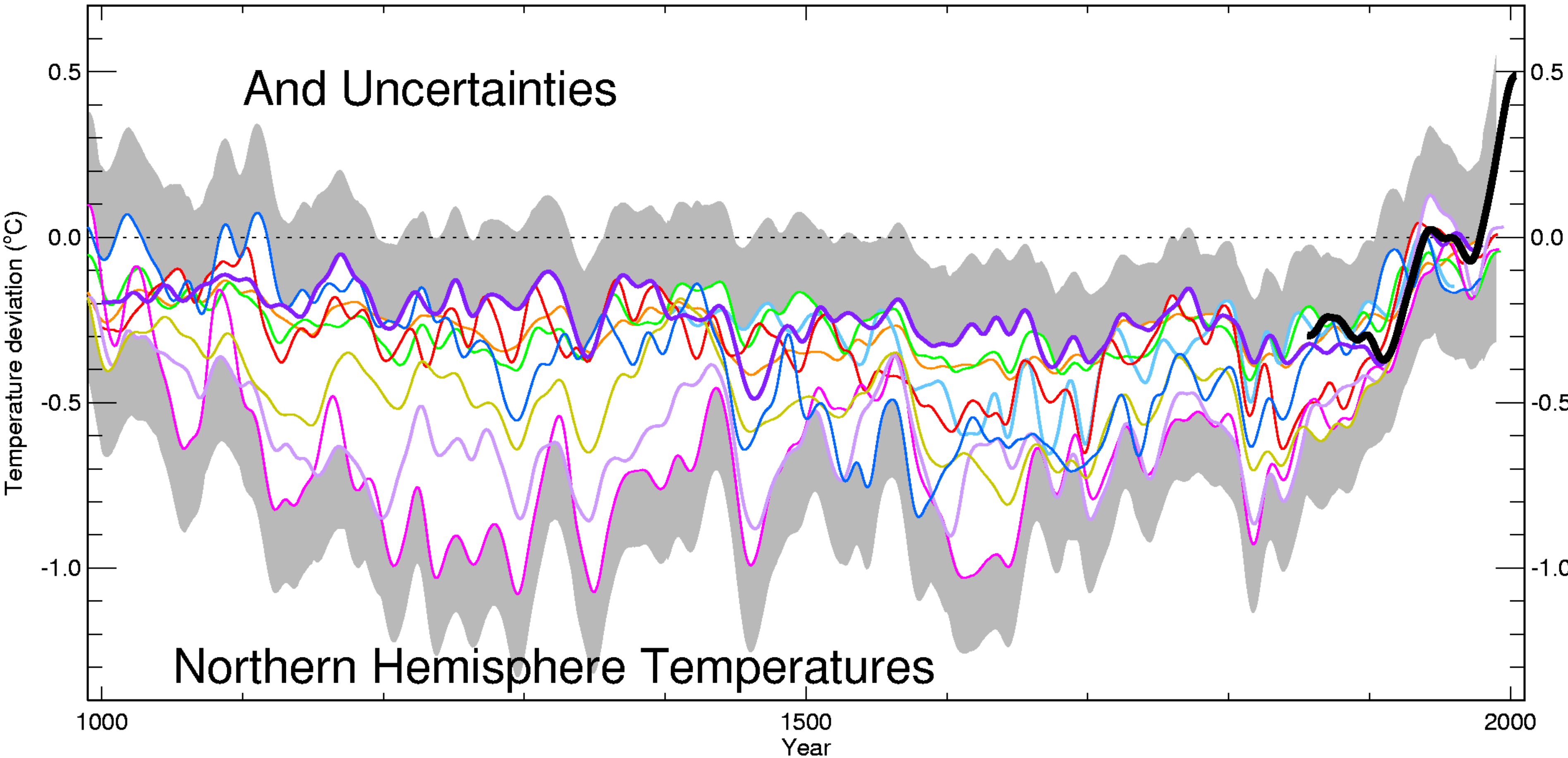
Explosive volcanoes



Solar activity

Plus natural internal variability

Published estimates of NH temperature in the past 1000 years



IPCC 2007

IPCC 2007 Fourth Assessment Report: "Global Warming is unequivocal"

Since 1970, rise in:

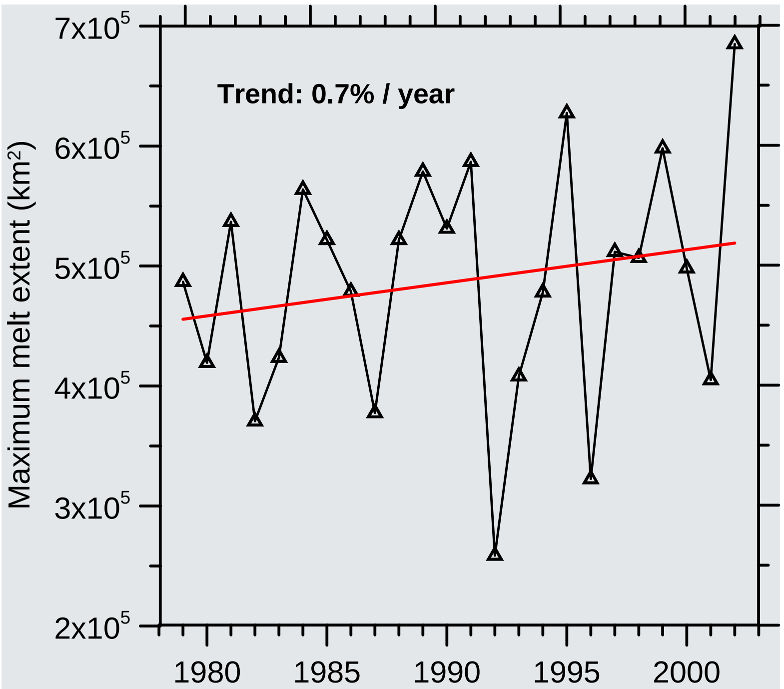
- Global surface temperatures
- Tropospheric temperatures
- Global ocean temperatures
- Global sea level
- Water vapour
- Rainfall intensity
- Precipitation in extratropics
- Drought
- Extreme high temperatures
- Summer Greenland ice sheet melt

Decrease in:

NH Snow extent
Arctic sea ice
Glaciers
Cold temperature extremes

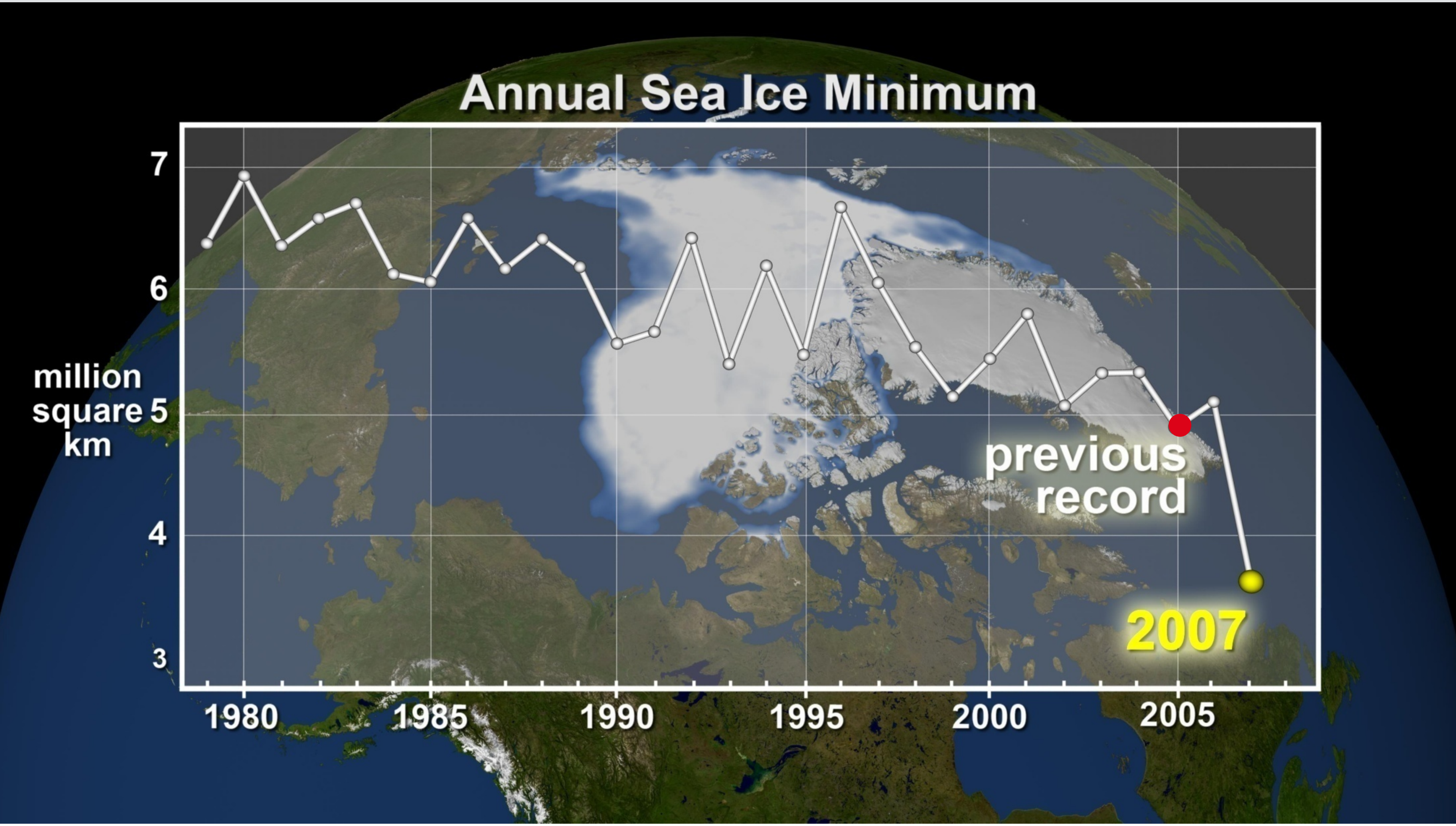
Surface Melt on Greenland

Maximum melt

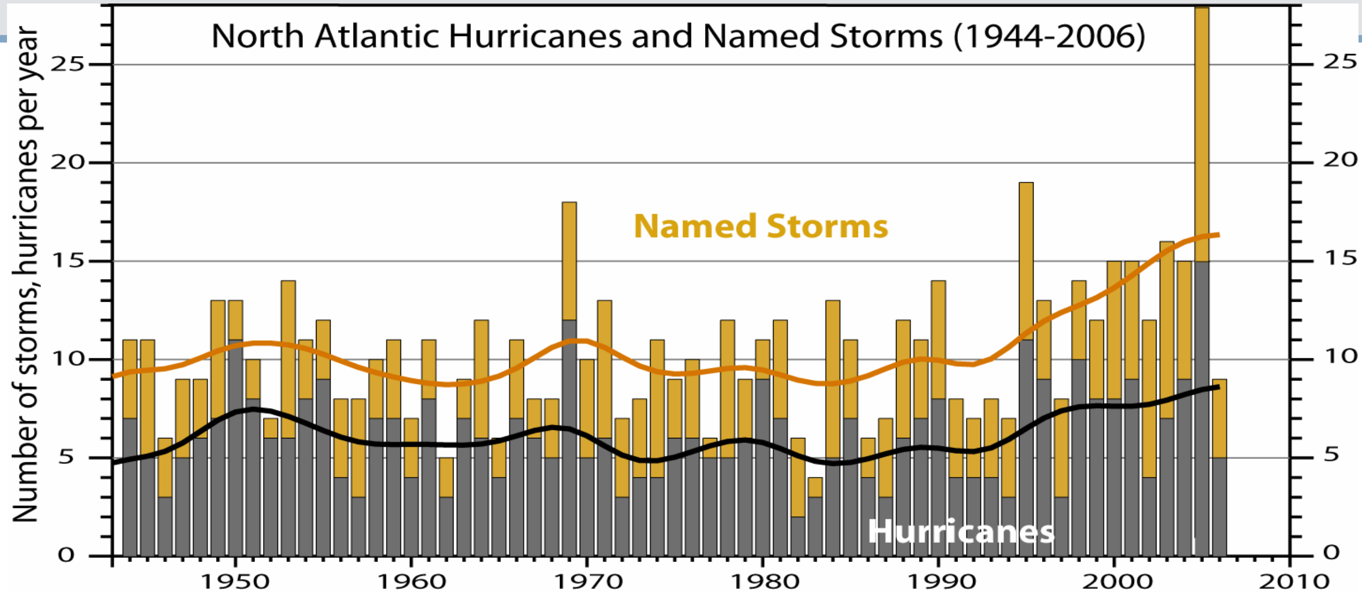


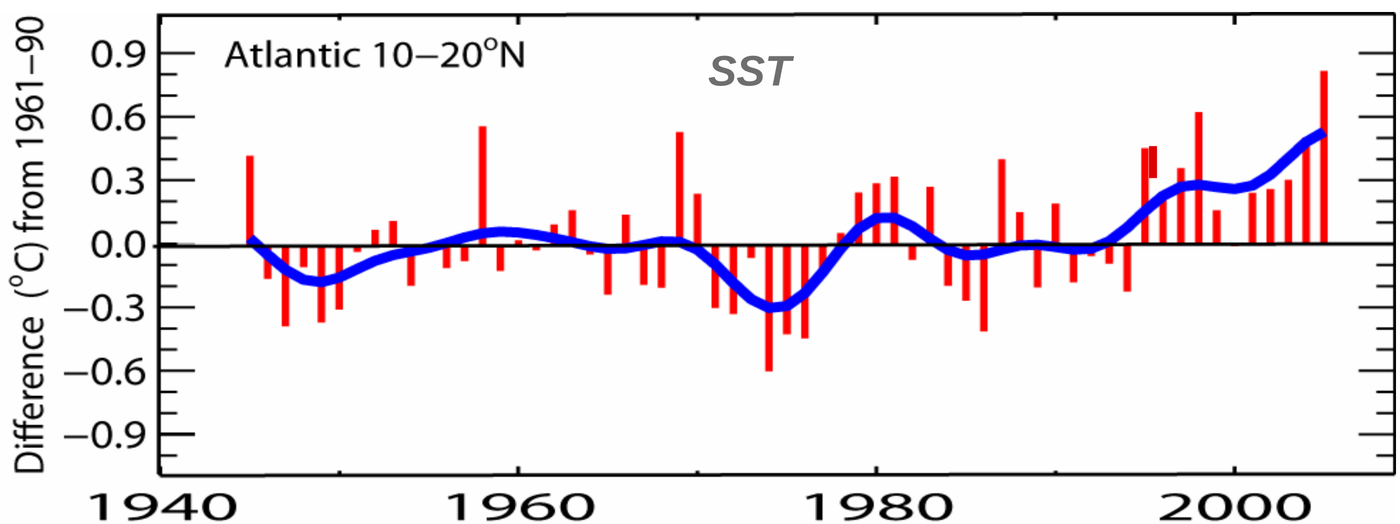
Melt descending into a moulin, a vertical shaft carrying water to ice sheet base.

Source: Roger Braithwaite, University of Manchester (UK)


Annual Sea Ice Minimum
million square km
7
6
5
4
3
1980
1985
1990
1995
2000
2005
previous record
2007

North Atlantic hurricanes and Sea Surface Temperatures since 1944

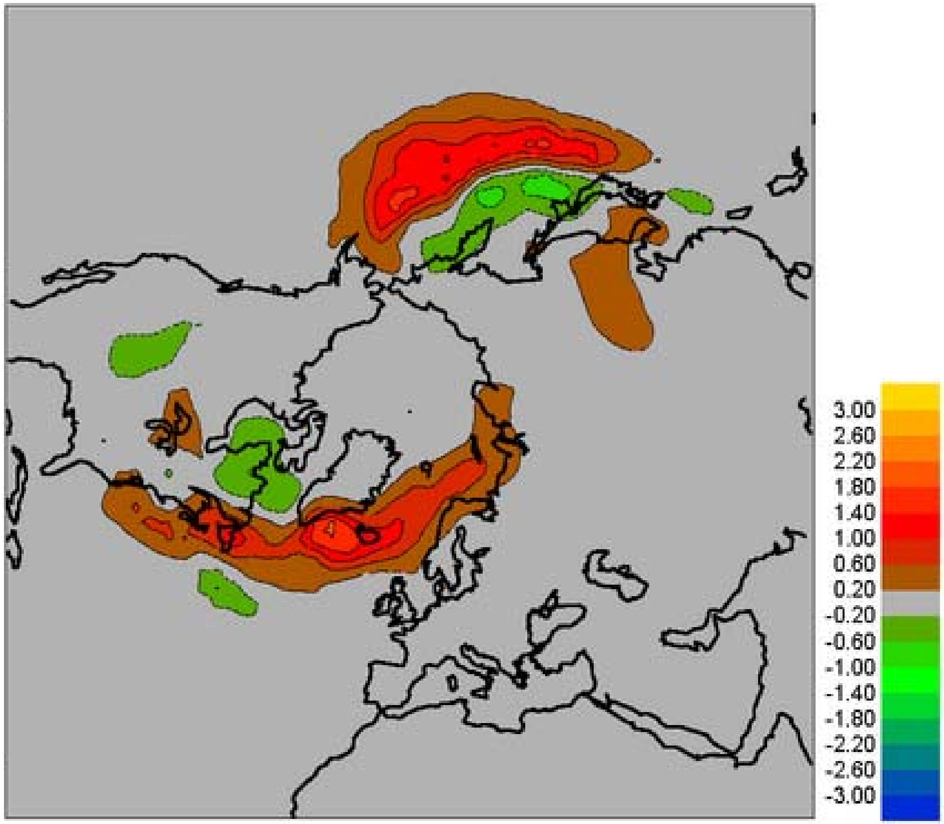




IPCC 2007

Changes in the track density of mid-latitude storms 1979/2003-1958/1978

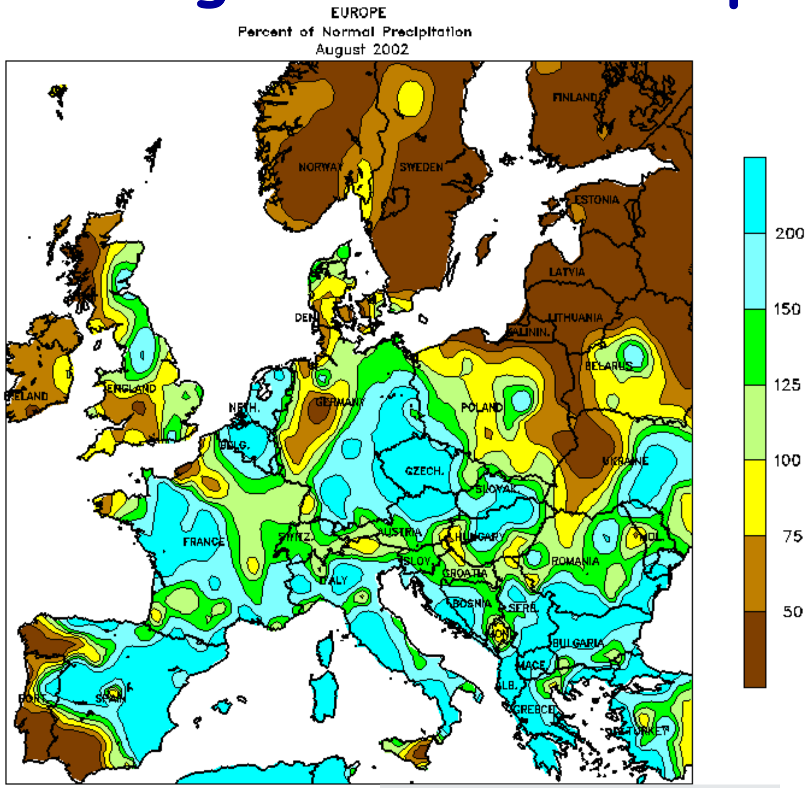
Central pressure at least 40mb below a background state



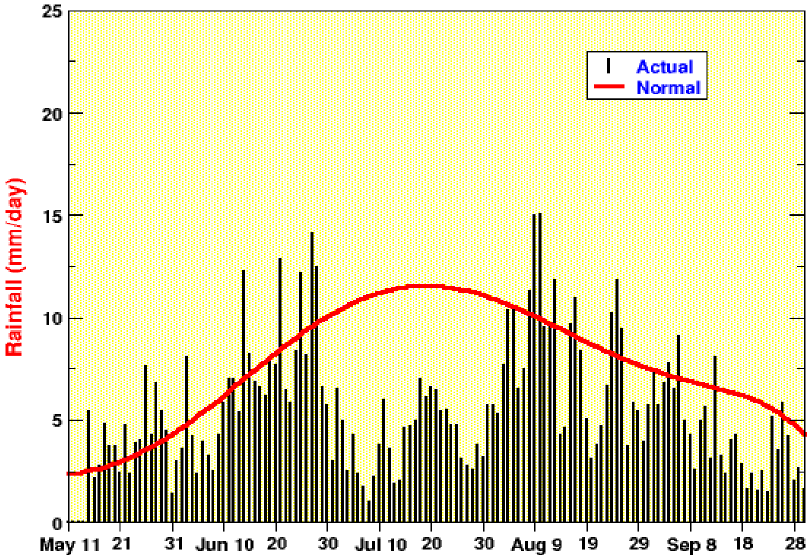
Hoskins & Hodges

Summer 2002

Flooding in Central Europe



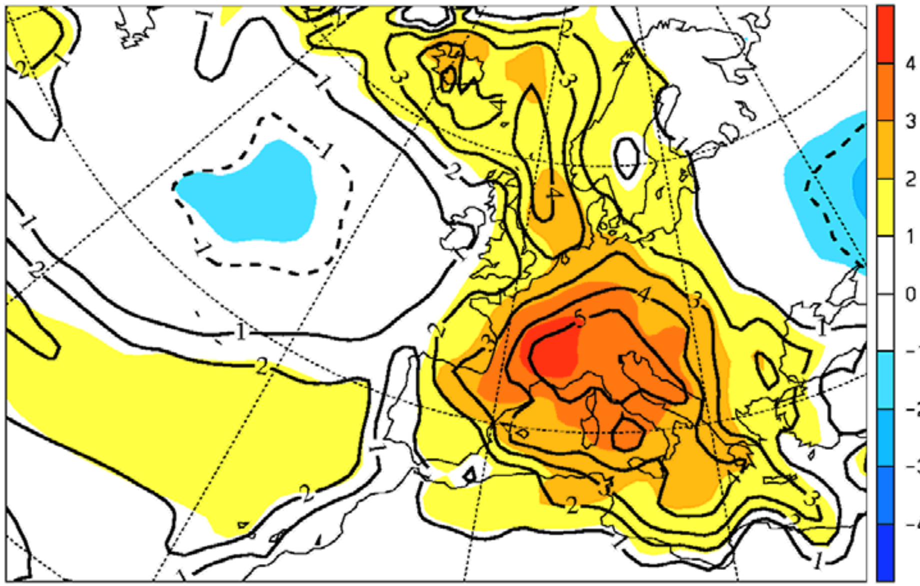
Drought in India



Blackburn & Hoskins (2006)

Summer 2003: record warmth in Europe

Temperature anomalies



Under clear skies the ground dried out and then all excess energy from the sun heated the ground

This was possible only because there were no weather systems coming in from the Atlantic

Schär et al (2004)

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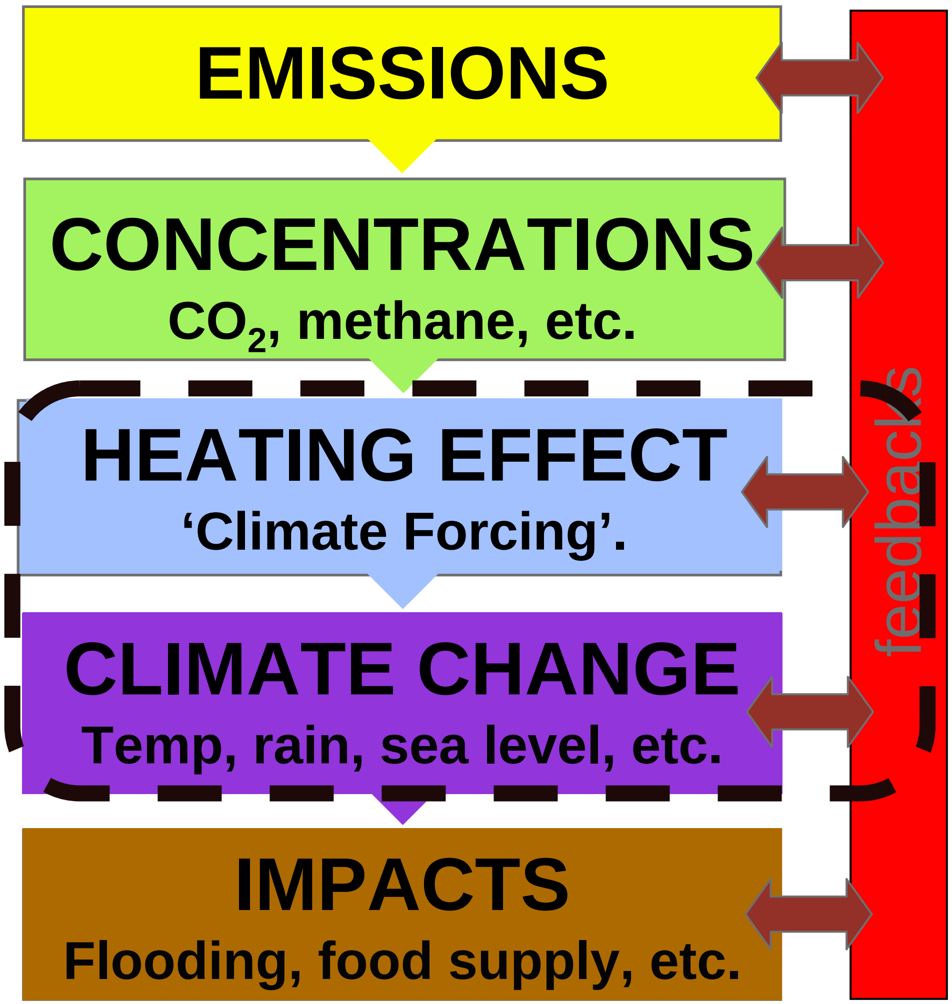
Making Projections of climate change & its impacts



Scenarios from population, energy, economics models

Carbon cycle and chemistry models

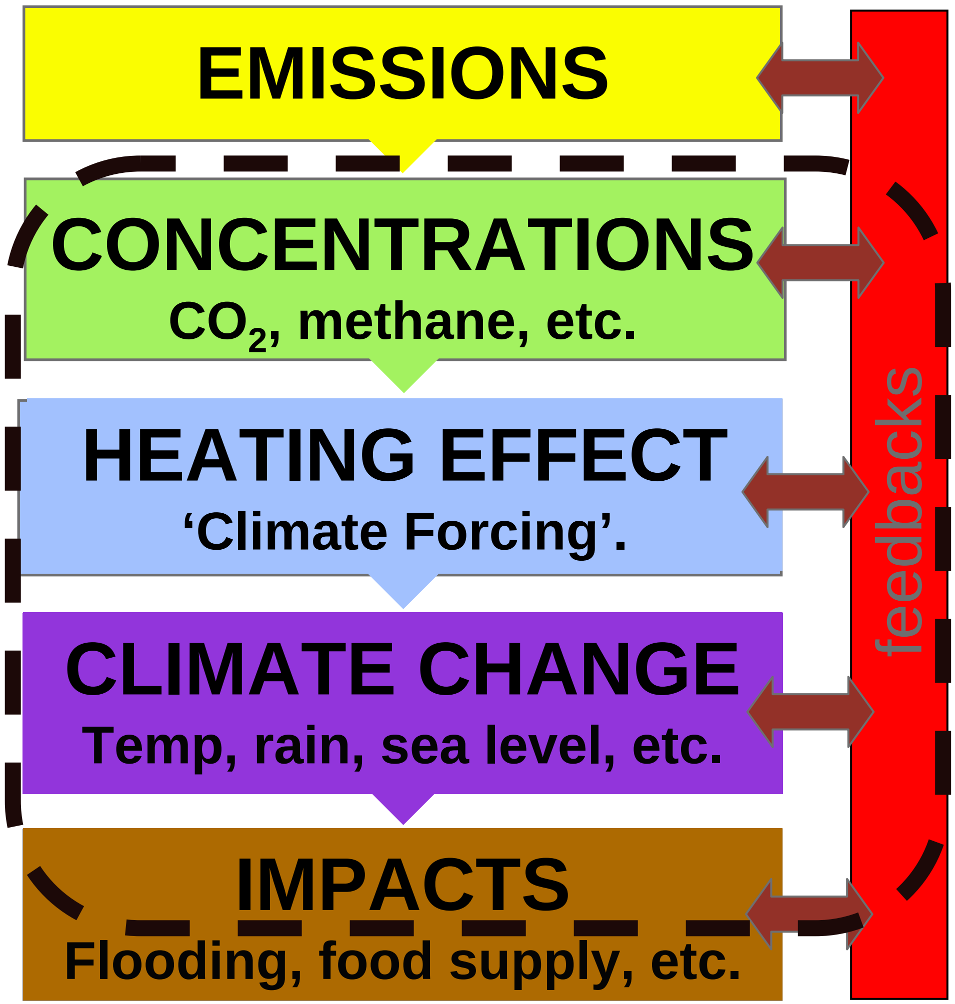
Gas properties

Coupled climate models

Impacts models

Making Projections of climate change & its impacts

Making quantitative projections (& hindcasts) of Climate Change



Scenarios from population, energy, economics models

Carbon cycle and chemistry models

Gas properties

Coupled climate models

Impacts models

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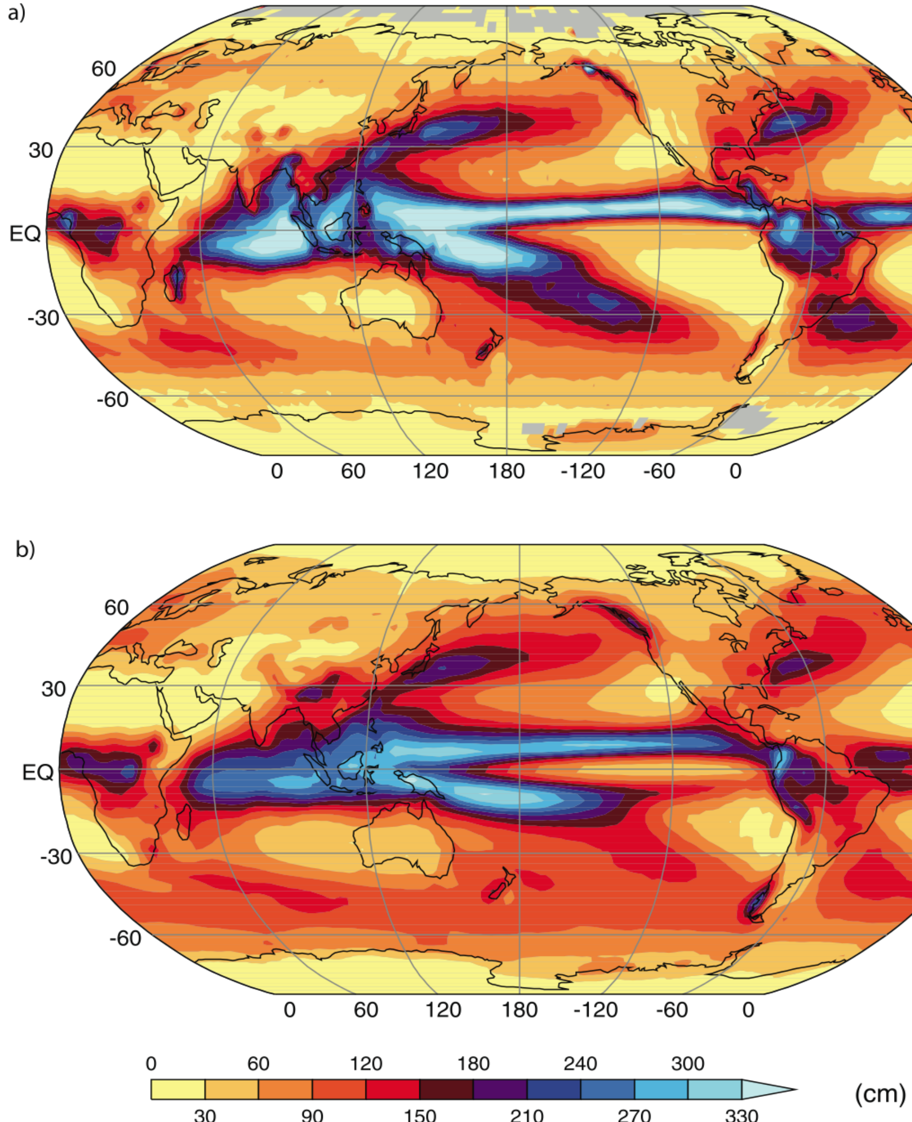
One test for models: Annual mean precipitation: 1980-1999

Observed

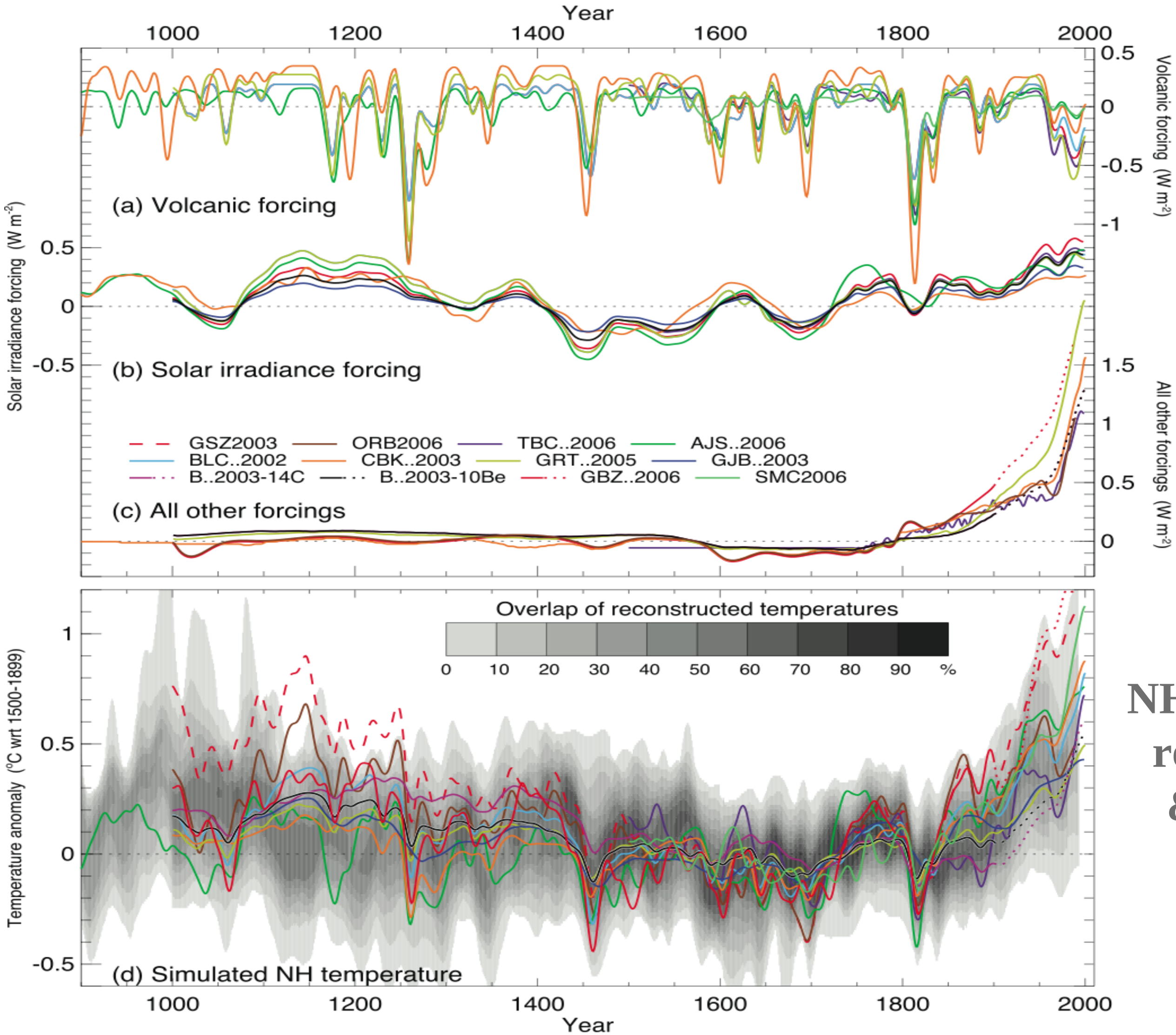
Climate model simulations



IPCC 2007

The past 1000 years: observation, forcings & simulation

Forcing of energy imbalance



Volcanic

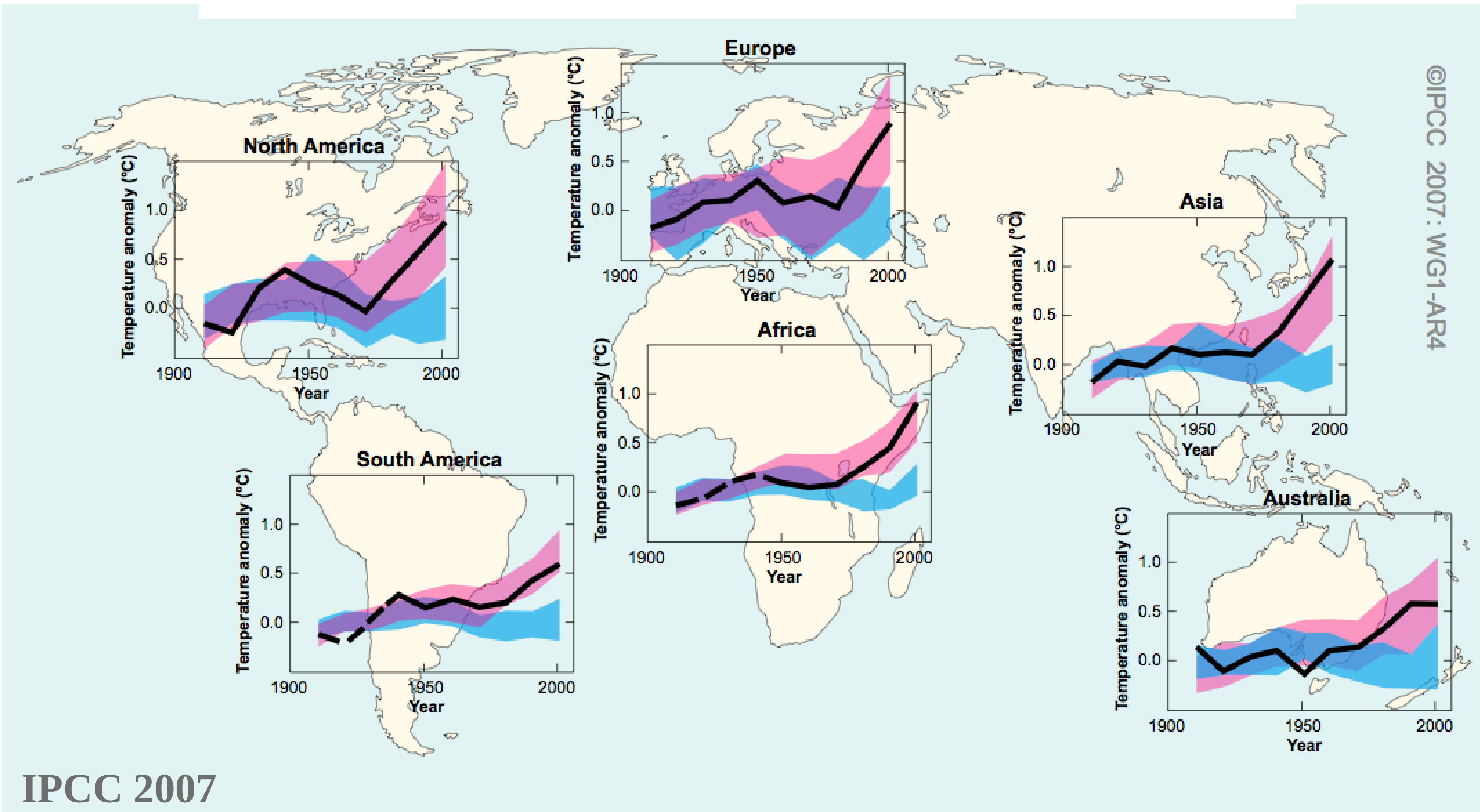
Solar

Other

NH Temperature: reconstructions & simulations

IPCC 2007

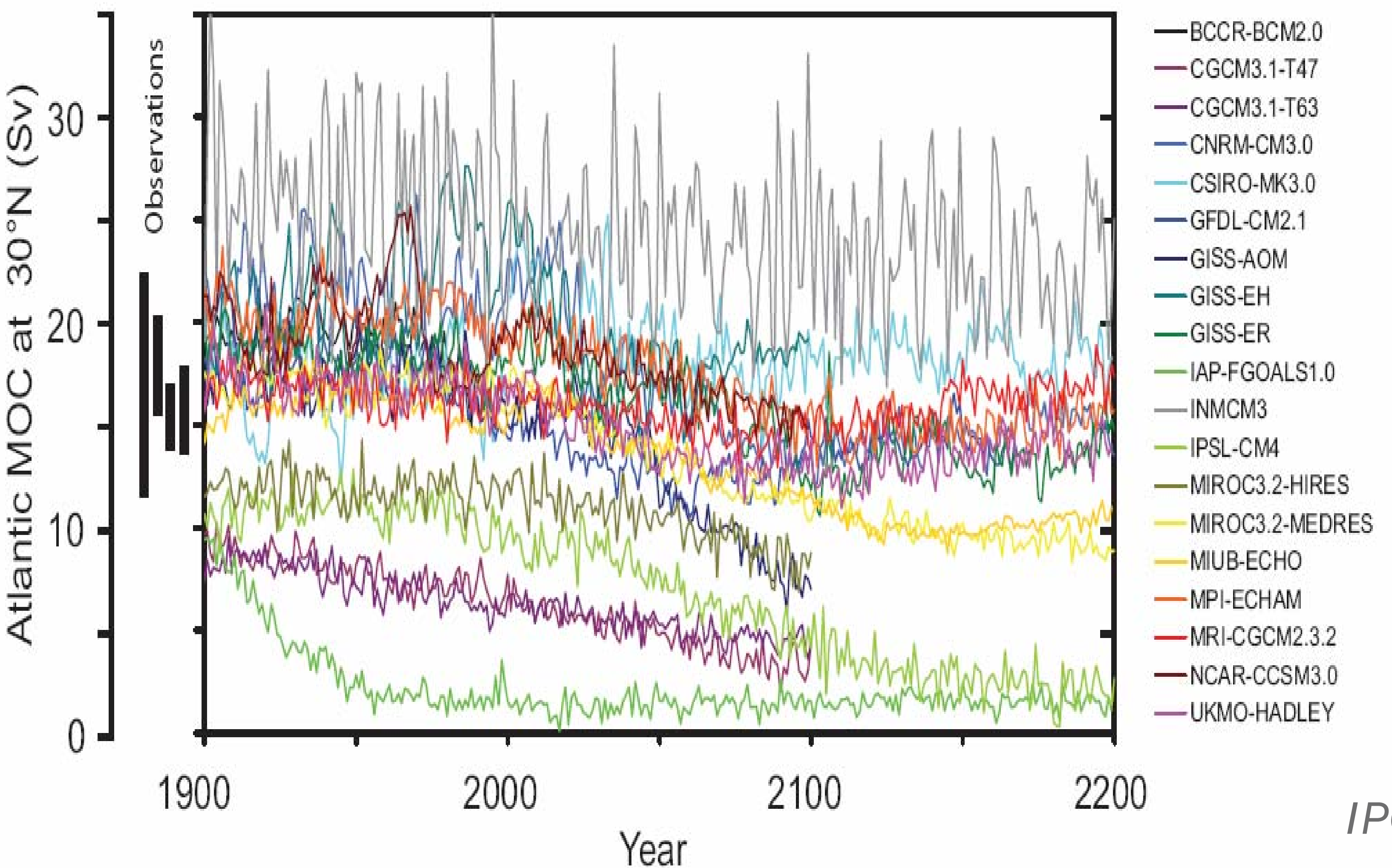
20th Century Continental Temperatures: Observed & Modelled with & without anthropogenic forcings



IPCC 2007

Strength of Atlantic ocean overturning at 30ºN

(A1B Scenario + constant emissions after year 2100)



IPCC

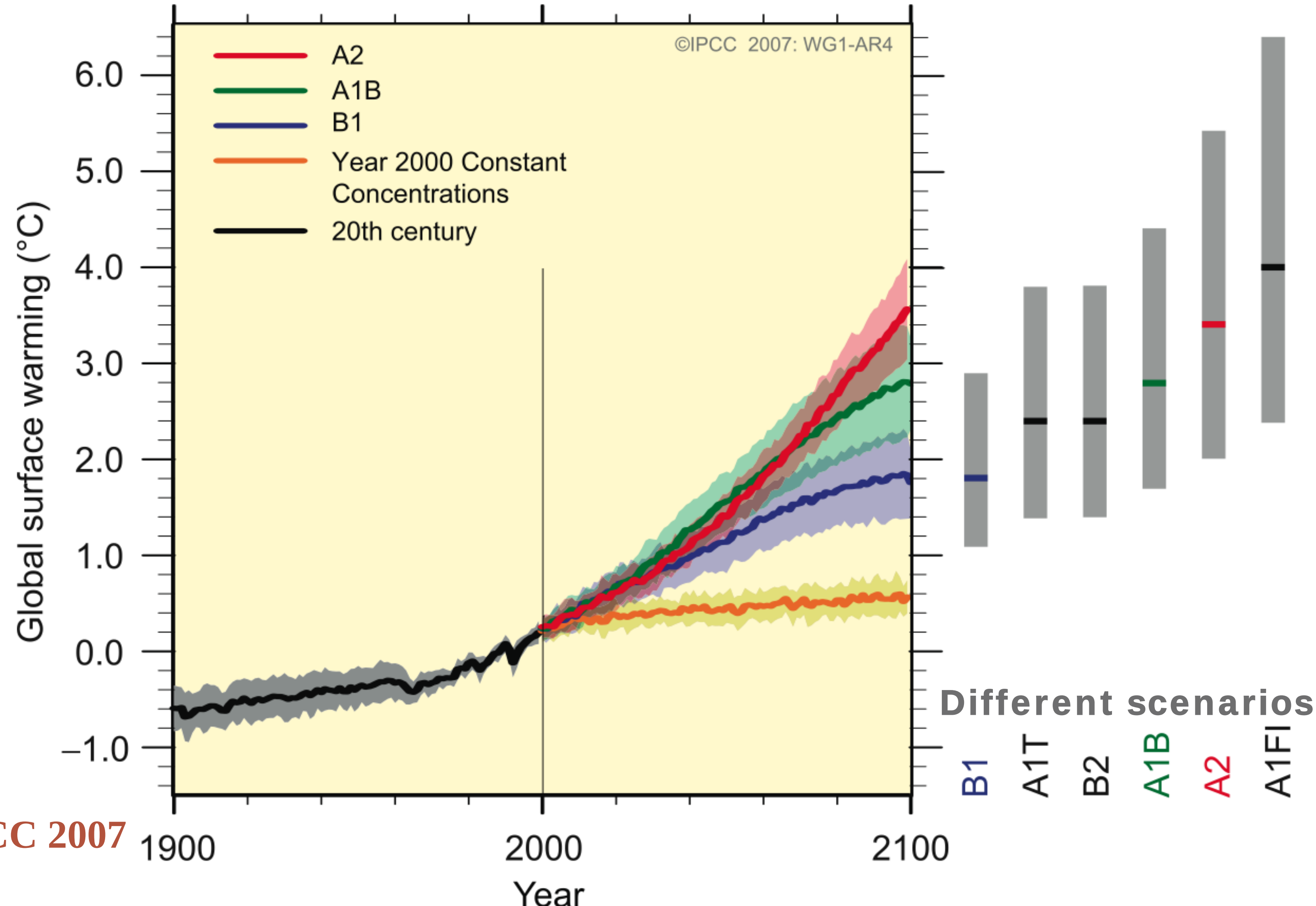
Reasons for Confidence in Model Projections

- Models built on basic physics
- General consistency of globally averaged T response from simplest to most complex
- Success in forecast/hindcast of weather, seasonal climate, impact of Pinatubo, past century
- Simulation of phenomena such as El Niño, storms

Reasons for Lack of Confidence in Model Projections

- Underestimation of natural variability? E.g. 1940s
- Uncertainty in forcing used for past century, e.g. solar, aerosols
- Only just starting to have interactive atmospheric chemistry & carbon cycle
- Uncertainty in cloud behaviour, aerosol effects, solar variability,...
- Poor representation of some phenomena particularly on smaller scales

Projections of globally averaged surface warming



IPCC 2007

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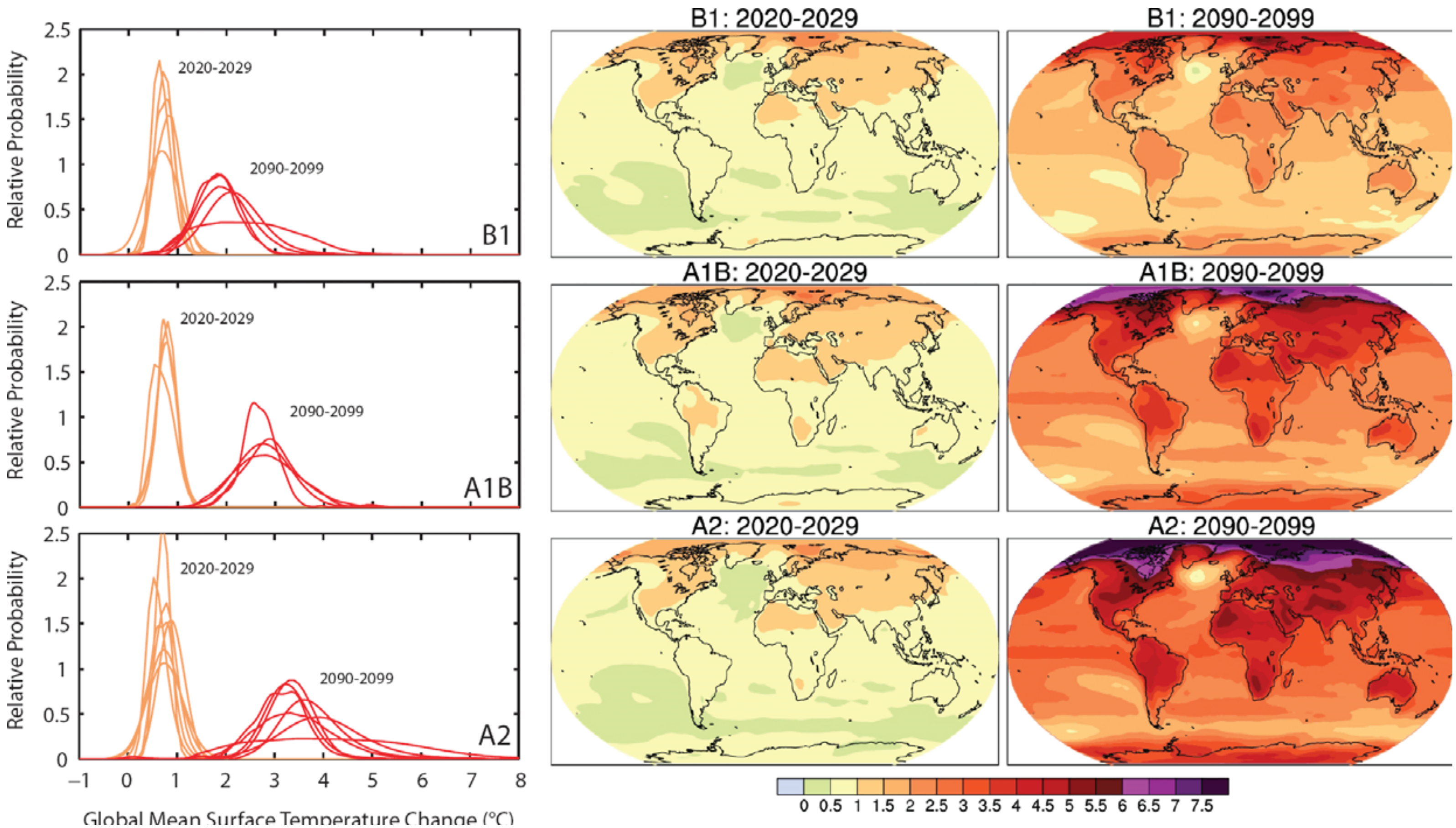
IPCC (2007) Surface Temperature Projections 2020s & 2090s relative to 1980-99



Global mean

2020s

2090s

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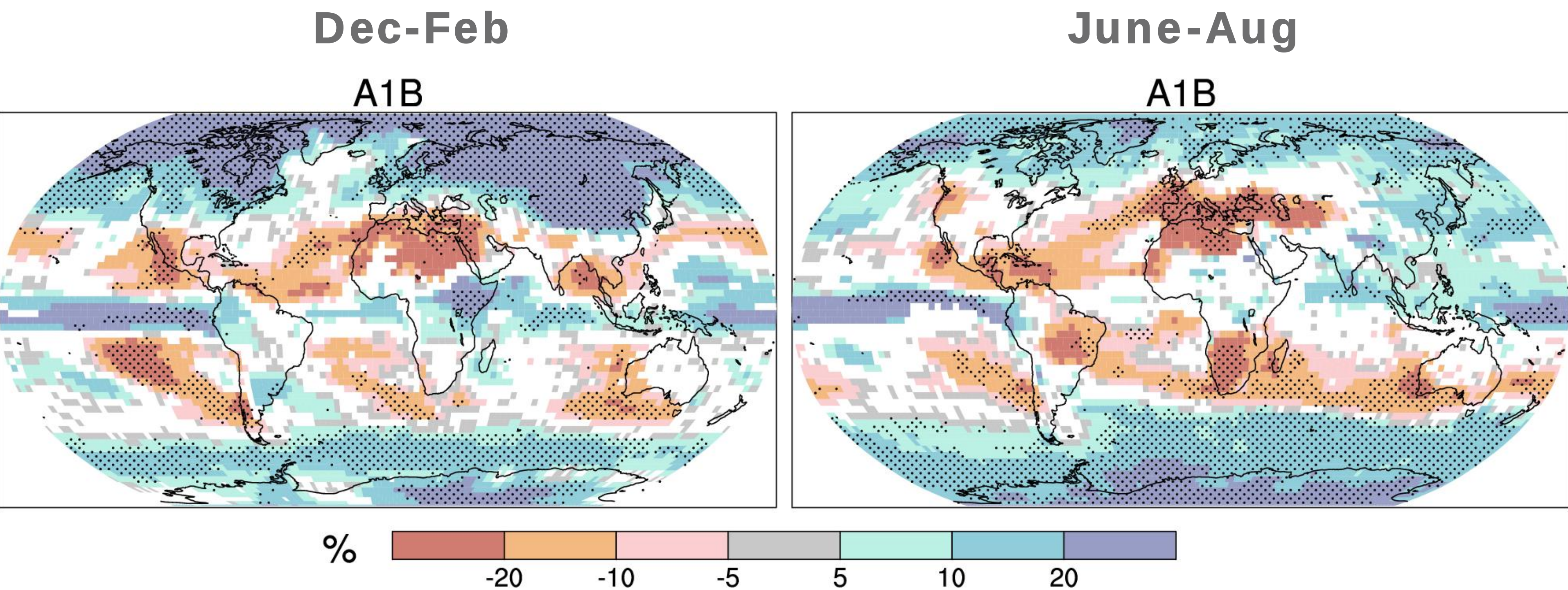
Projected patterns at end of 21st century: Change (%) in precipitation for one scenario



Stippled areas are where more than 90% of the models agree in the sign of the change

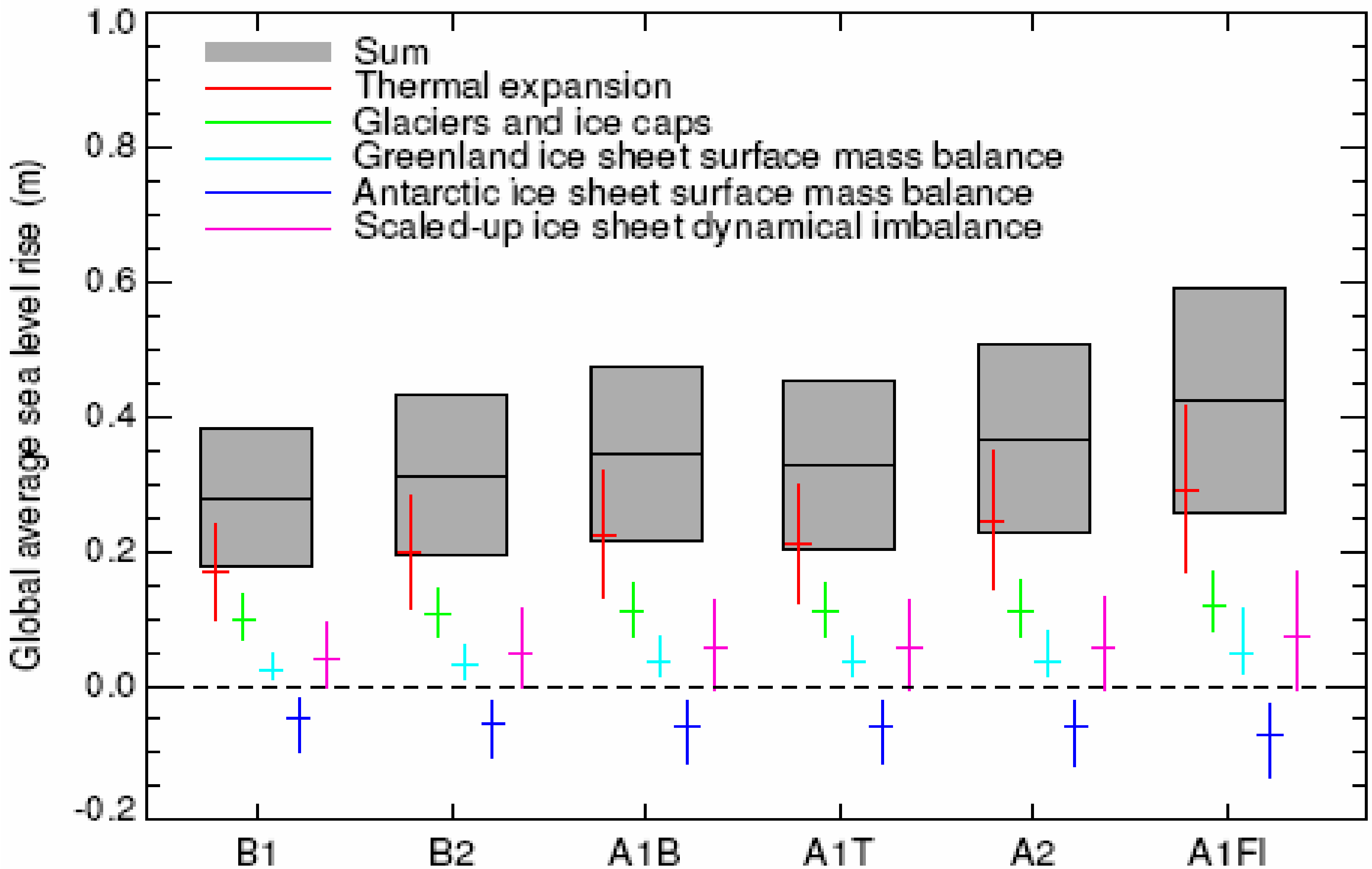
Precipitation increases very likely in high latitudes

Decreases likely in most subtropical land regions

This continues the observed patterns in recent trends

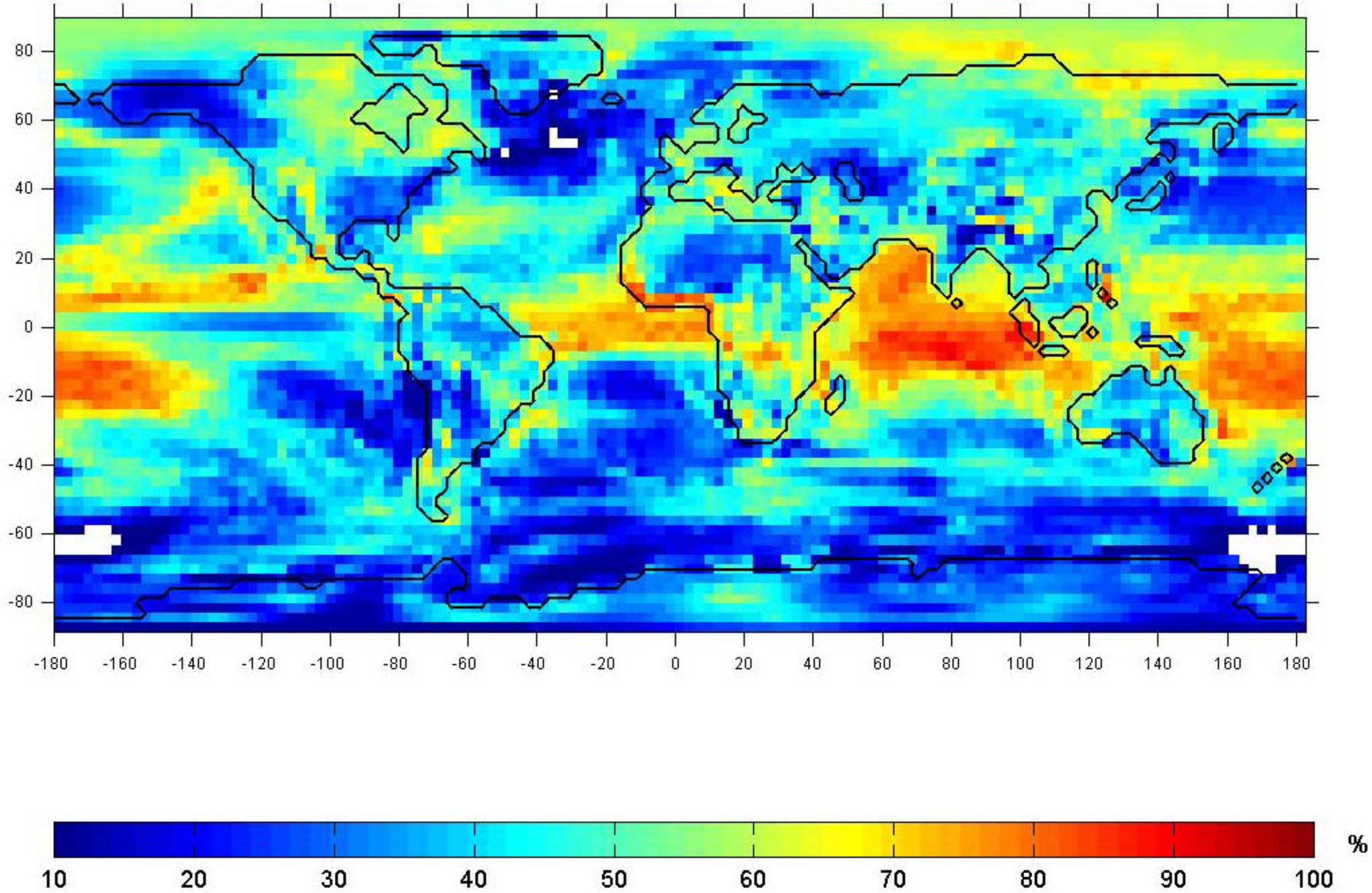
IPCC 2007

IPCC Projections of Sea Level Rise at 2100

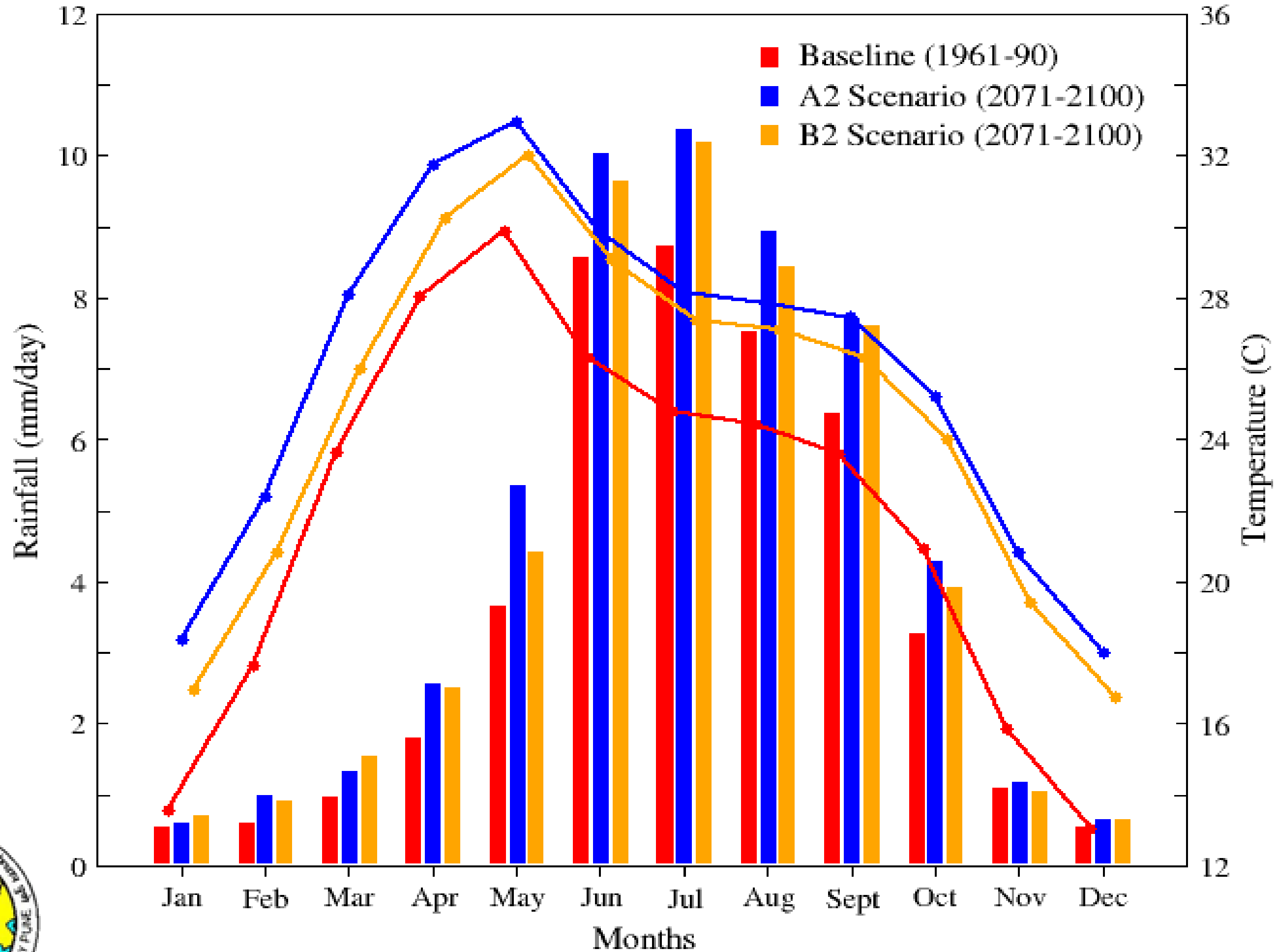


Extremely Warm Dec-Feb

Probability of exceeding 95% ile DJF temperature 2081-2100 (A1B, A2, B1)



Mean Annual Cycles of All-India Rainfall and Temperature for end of 21st century



A2: High Emissions

B2: Low Emissions

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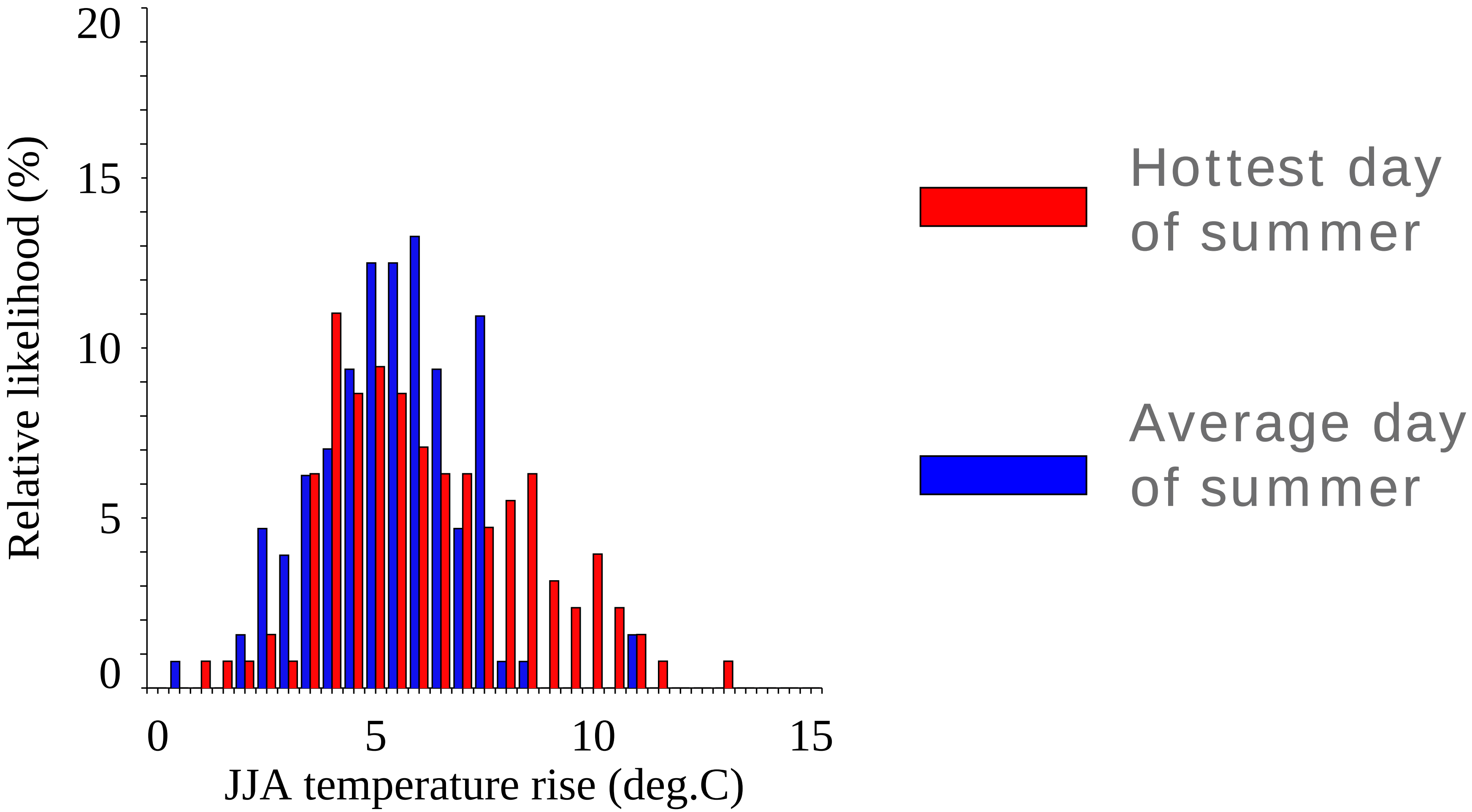
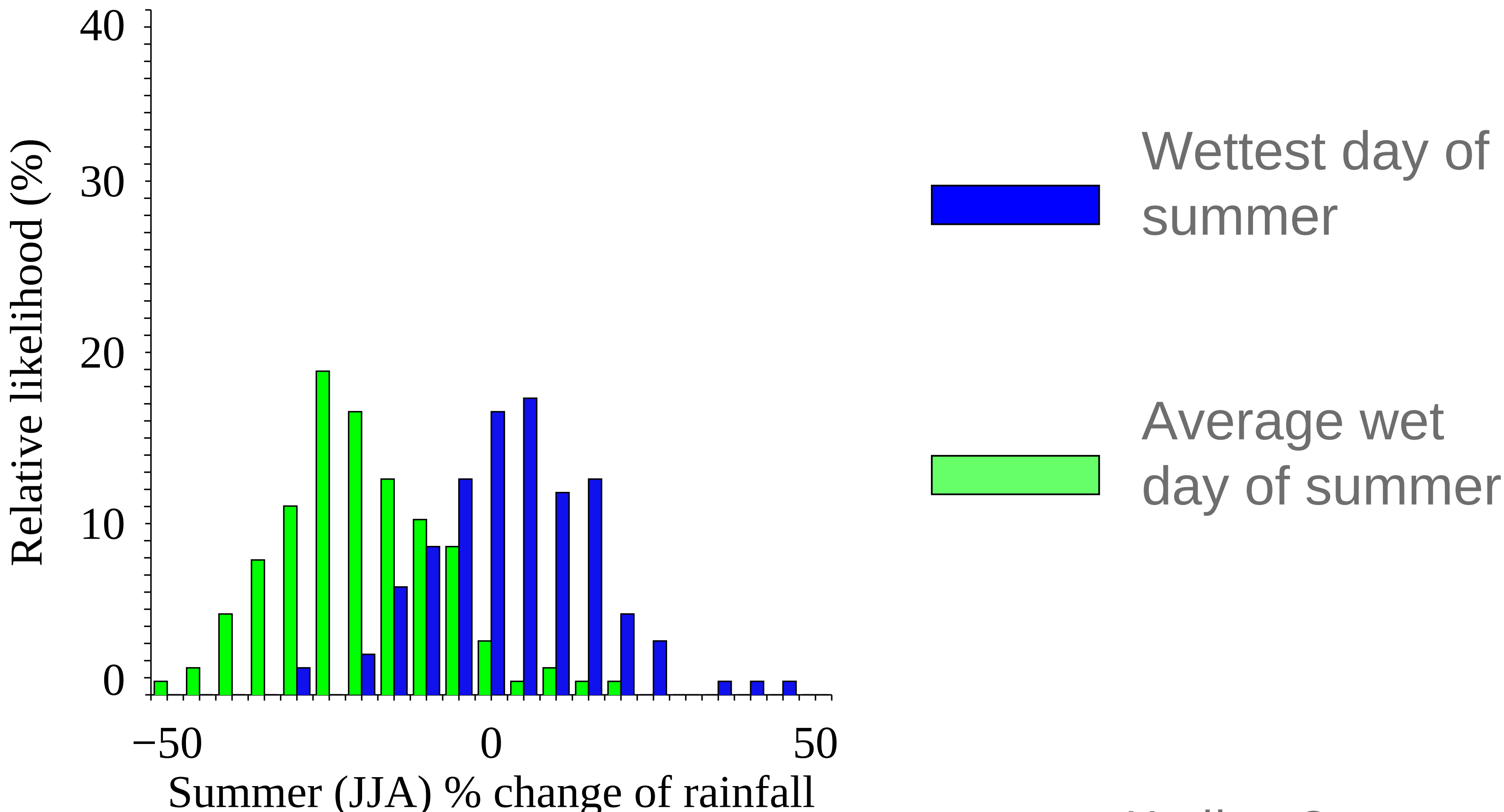
Doubled CO_2: Projected changes in probability distributions for summer day temperatures in Southern England



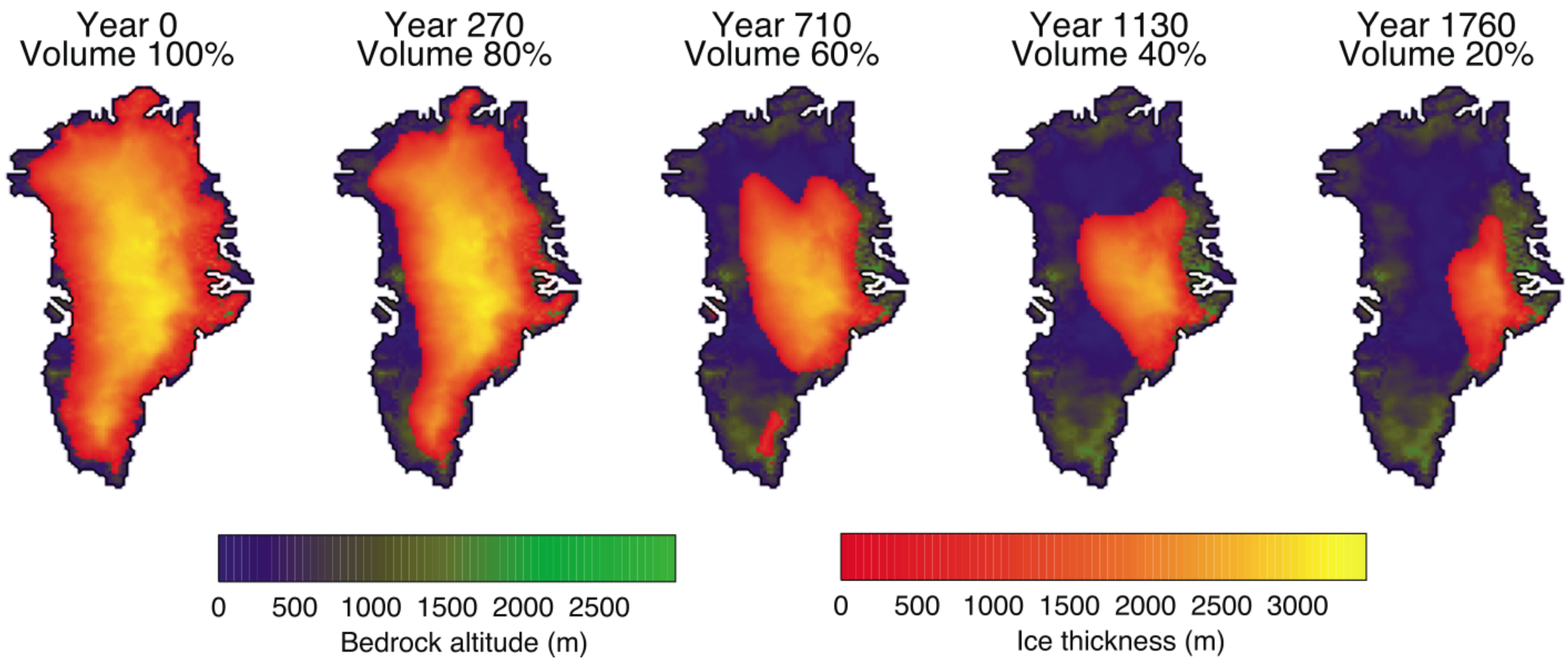
Hadley Centre

Doubled CO_2: Changes in probability distributions for summer wet days in Southern England



Hadley Centre

Greenland Ice Sheet Projections



Impacts of global warming in different sectors

•Water: increases & decreases; more exposed to water shortage

•Ecosystems: species shifts & extinctions

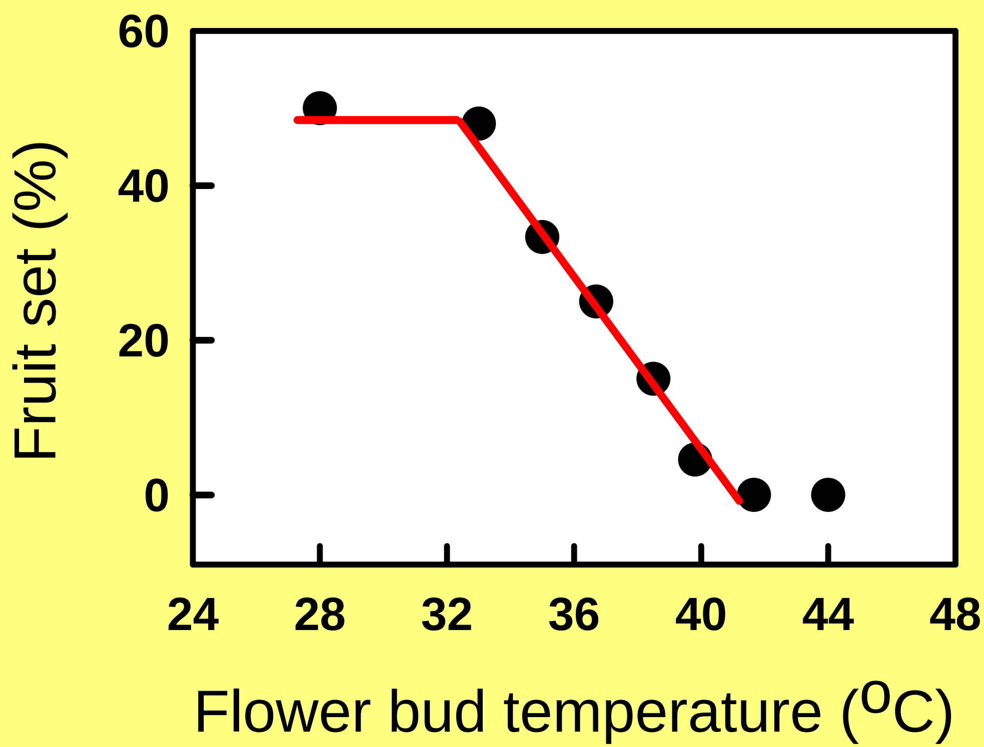
•Food: changes in possible crops; more reductions than increase in production

•Coasts: increases in coastal erosion & flooding

•Health: increases in malnutrition & infectious diseases; changes in e.g. malaria; increases in deaths from heat, floods & droughts, but decreases in deaths from cold

Food Production in a Changing Climate

Reduction in pod set in groundnuts



Warmer season
… or a few hot days?

Pollen sterility in rice

Under climate change, crops in many regions will be prone to environmental stresses not observed in today's climate.

T Wheeler, Reading

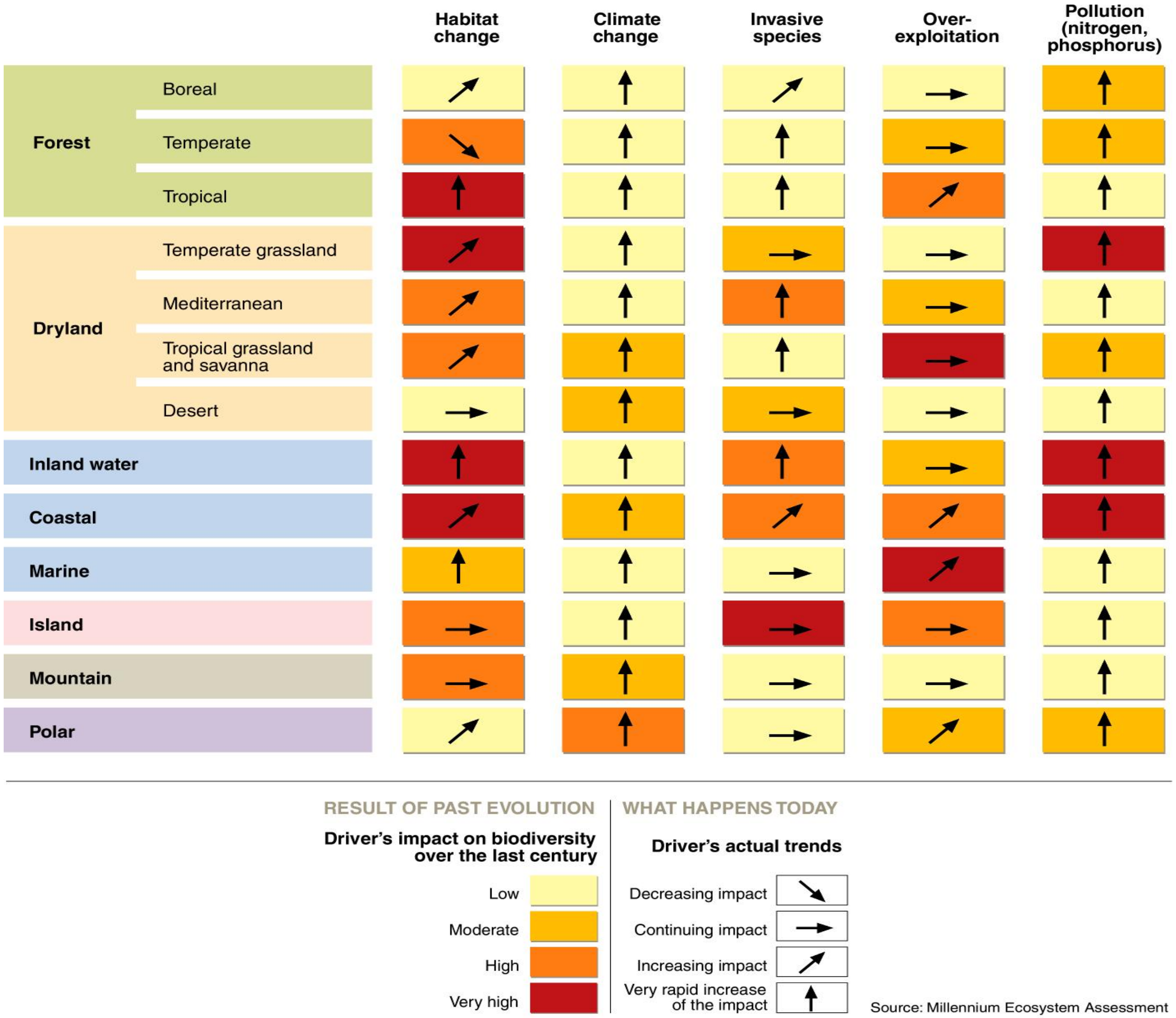
A health study in the delta region of Bangladesh

Rising sea levels are changing the salinity of its water

A strikingly high prevalence of hypertensive disorders among pregnant women in a coastal area, compared to those in non coastal areas

P Vineis
(E. Michael, Tanzania)

Millennium Ecosystem Assessment: Drivers of biodiversity loss



Source: Millennium Ecosystem Assessment

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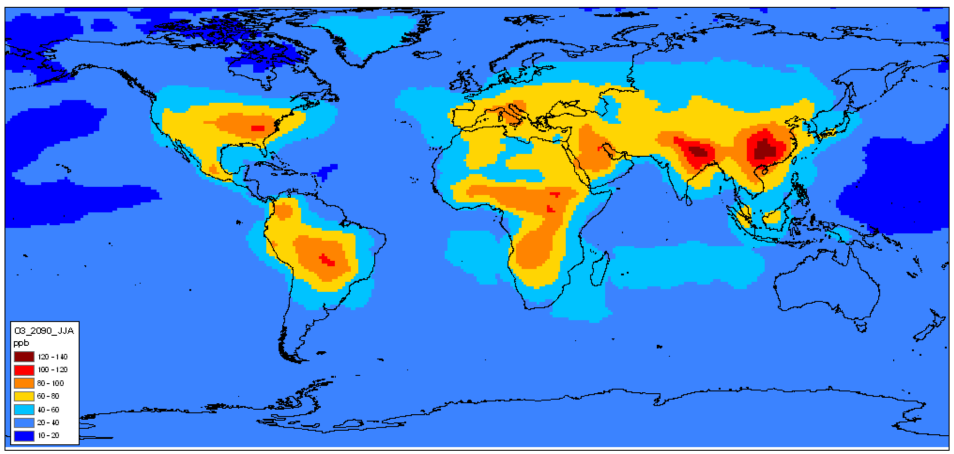
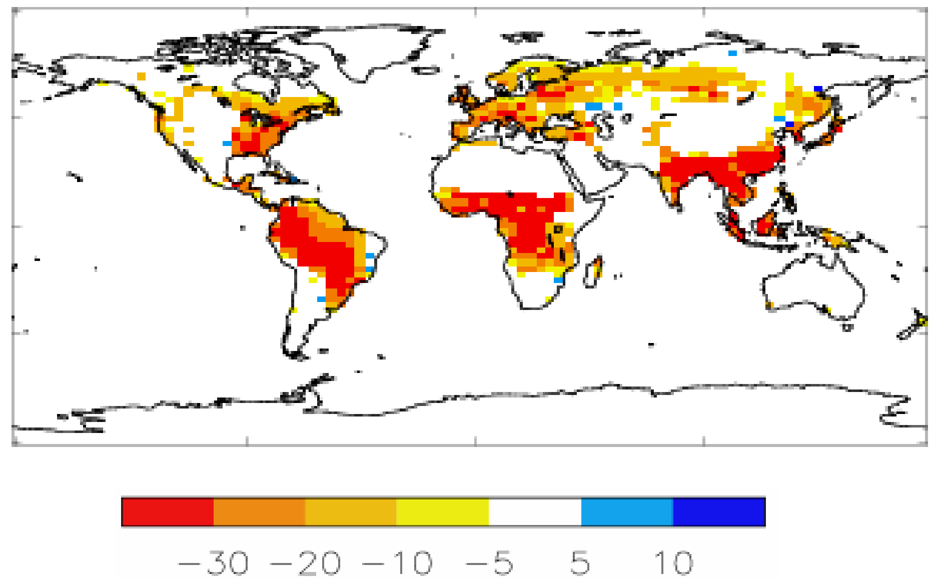
Projected impact on near surface ozone levels

Future low-level Ozone concentration – 2090s

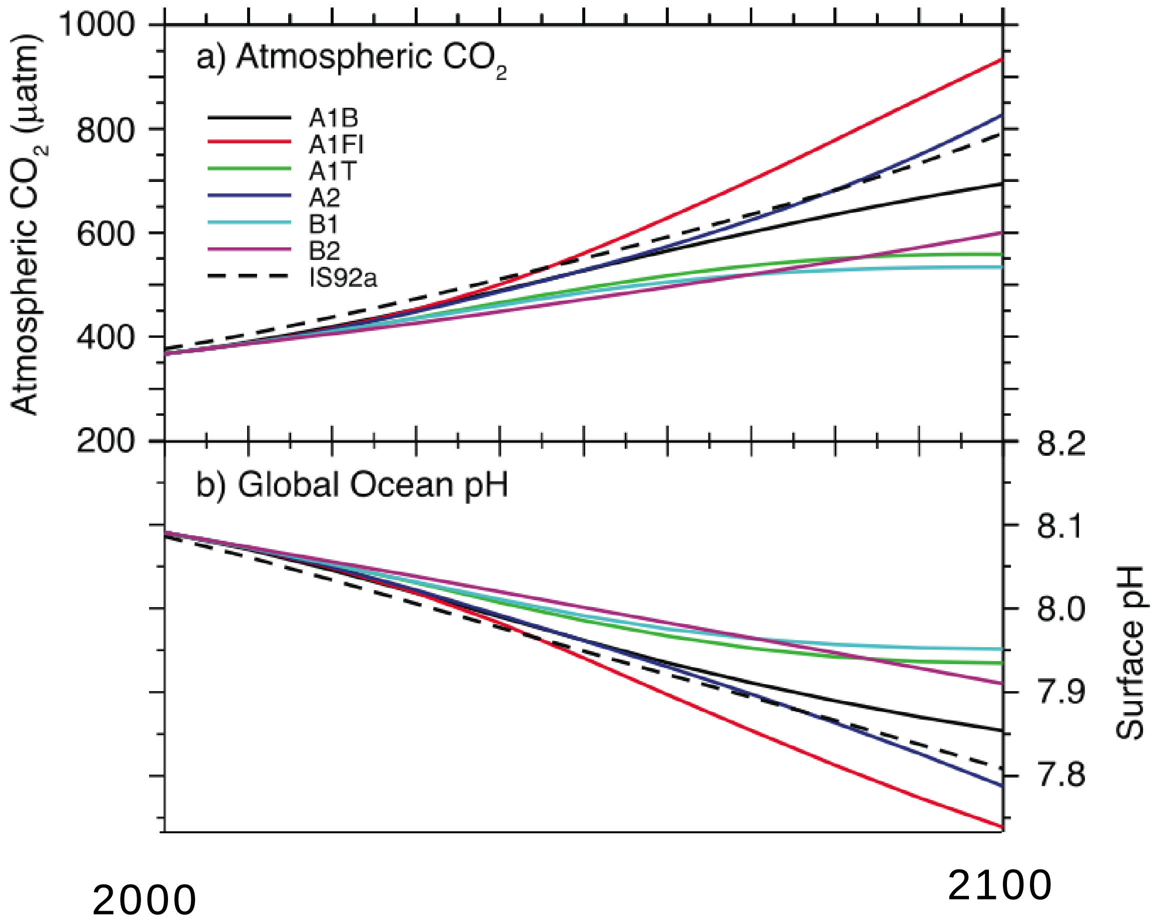


% changes in plant productivity due to higher ozone concentrations by 2100



MetO Hadley Centre & NERC

Acidification of the oceans



Mechanisms for extreme changes?

- Large dynamical ice sheet loss: Greenland & West Antarctic
- Reduced carbon absorption/emission: soil, vegetation, ocean
- Methane emission from melting tundra, peat, hydrates
- Rapid change in the circulation of the atmosphere/ocean:
  - reduction in the Atlantic northward heat transport
  - frequency or nature of ENSO
  - Asian monsoon circulation
  - summer European blocking
  - nature or location of winter storm-track
  - nature or location of tropical cyclones
- Complex dynamical system behaviour

Tackling the anthropogenic climate change problem

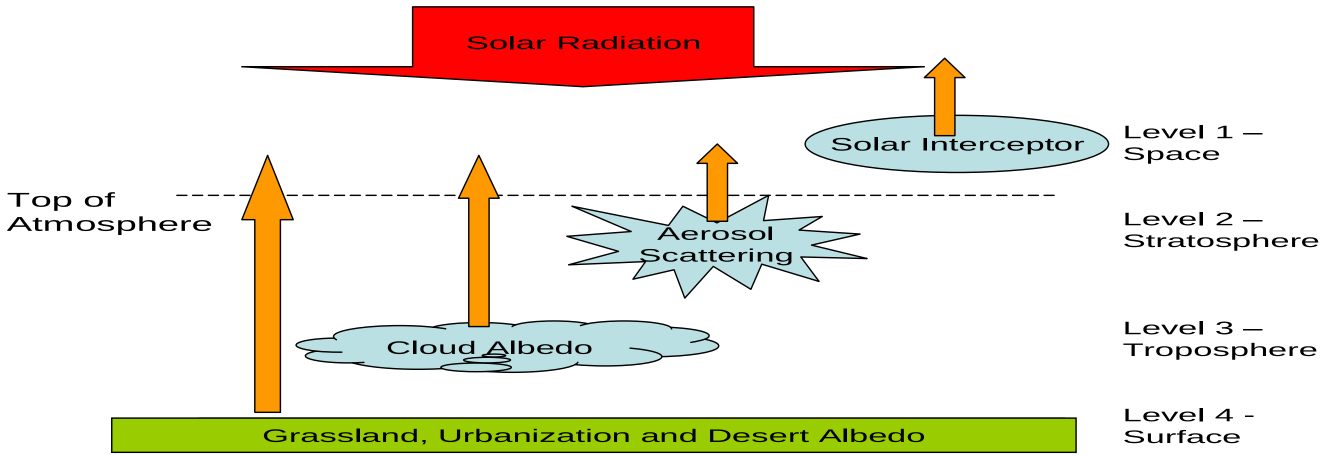
By emitting greenhouse gases to the atmosphere it is very likely we are perturbing the climate system in a dangerous way. What can we do?

1. Adapt to whatever happens: **adaptation**
2. Move towards a drastic reduction of the emissions of greenhouse gases: **mitigation**
3. Do something else to compensate: **geo-engineering**

Geo-engineering suggestions

1. Remove carbon dioxide from the atmosphere
   fertilise the ocean
   artificial trees, land surface treatment

2. Reduce amount of sun's energy absorbed



Actual climate impact; other impacts; feasibility?

Tackling the anthropogenic climate change problem

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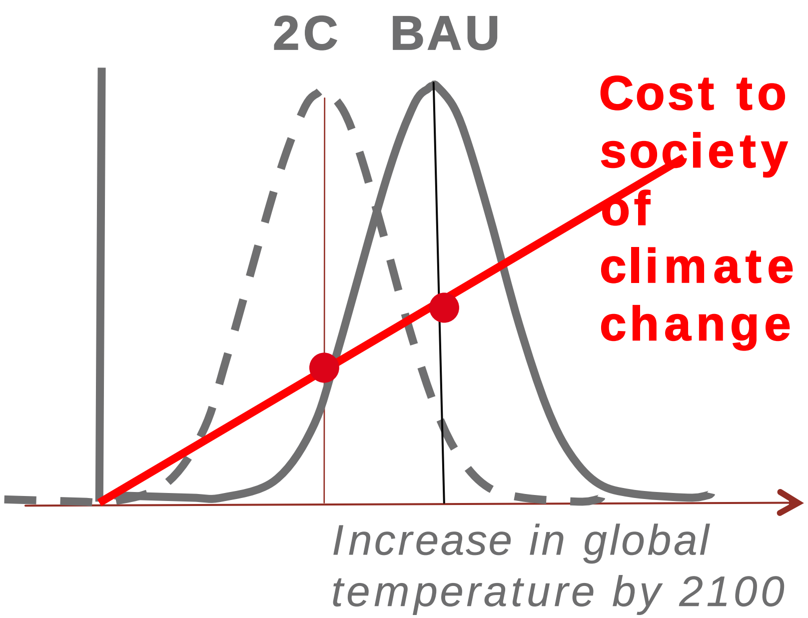
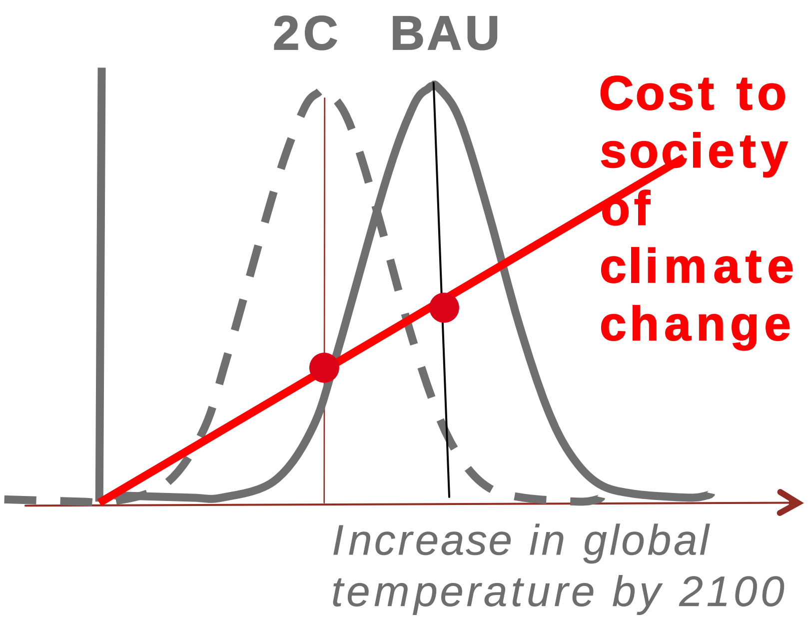
3. Do something else to compensate: **geo-engineering**

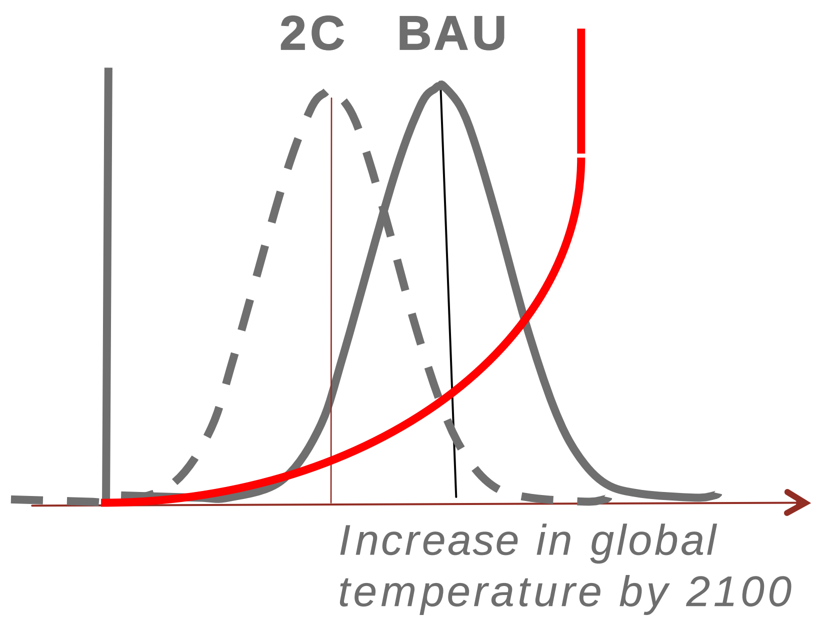
Economic evaluation of the cost/benefit of mitigation



Stern Review:
Benefit 5-10% GDP
Cost of action 1% GDP

“Greatest market failure”





Stern Review:
Benefit 5-10% GDP
Cost of action 1% GDP

Insurance to reduce the likelihood of an extreme outcome

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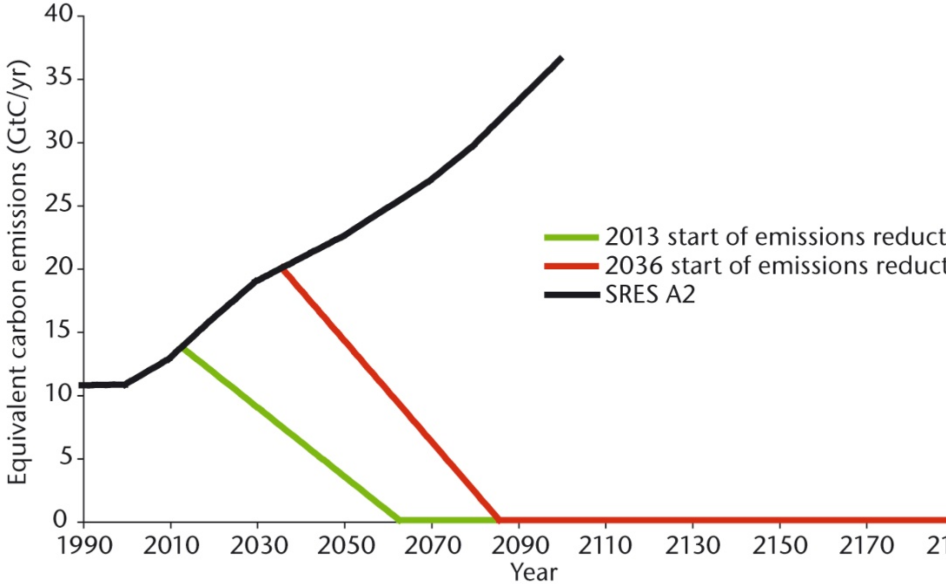
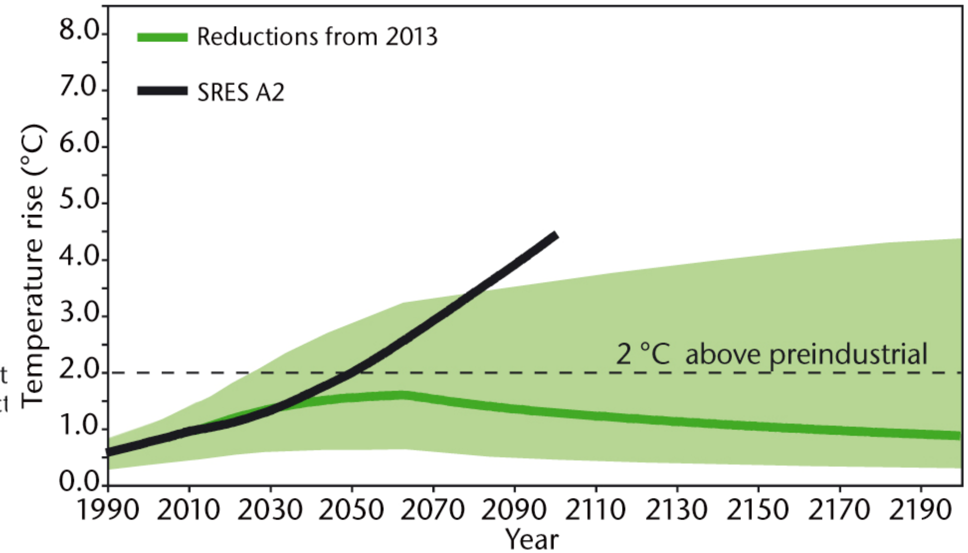
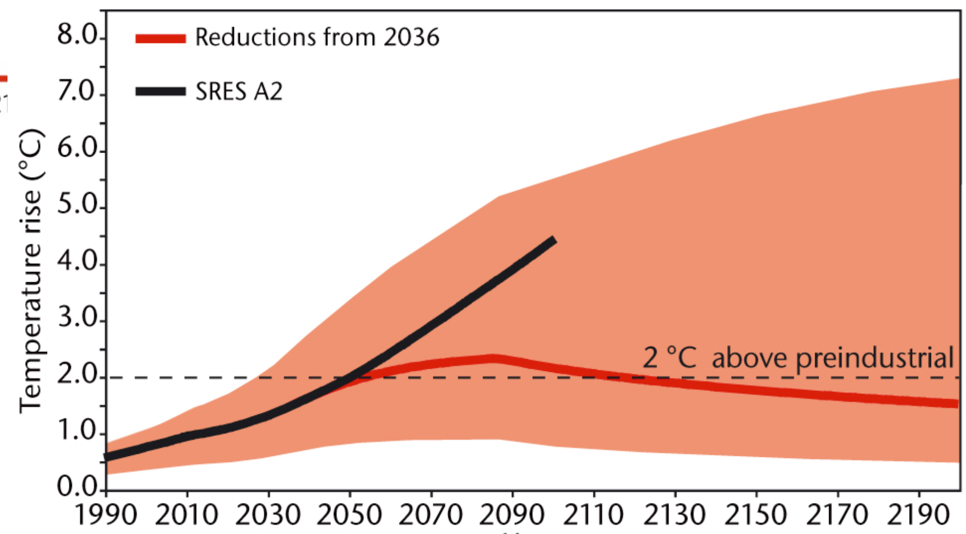
Idealised greenhouse gas emission reduction scenarios







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What sort of action is needed?

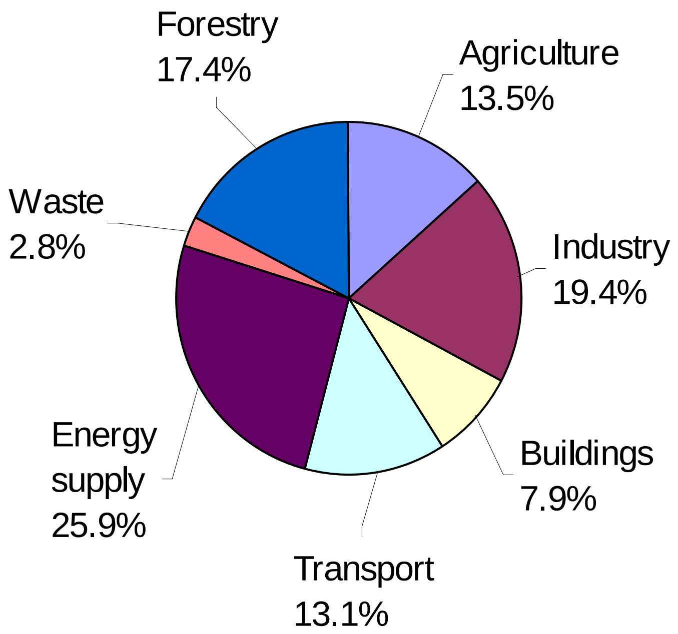
- Rapid mitigation to minimise risks of extreme outcomes e.g. 50% cut in global emissions by 2050

  - *Technological transformation – e.g. decarbonised electricity and transport*

  - *Action on deforestation and land use*

- Urgent start on adaptation to inevitable change

GHG emissions in 2004



Source: IPCC

Optimistic signs around the world

UK Climate Change Bill

At least 60% reduction in carbon dioxide emissions by 2050 – enshrined in law

Committee on Climate Change – independent

- Set actual target for 2050,
- Set targets for 2030 for 5, 10 & 15 years ahead.
- Consider targets for other greenhouse gases.
- Monitor progress towards targets & report to Parliament

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The Grantham Institute for Climate Change

Department of Meteorology

The University of Reading

Climate Change in an Uncertain World

There are many uncertainties
but this should not obscure the imperative for urgent action towards significant mitigation of likely climate change & adapting to changes we cannot avoid

Such action is possible and would have many other benefits