# Scientific Aspects of Climate Change: the latest IPCC assessment

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**NB: The support of the Belgian Science Policy Office is gratefully acknowledged**

# Outline

- Introduction:
  - Climate Change
  - What is the IPCC?

- What does IPCC tell us about the challenge and opportunities of climate change?
  - IPCC Group 1: climatology
  - IPCC Group 2: impacts, vulnerability, & adaptation
  - IPCC Group 3: mitigation

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# Introduction

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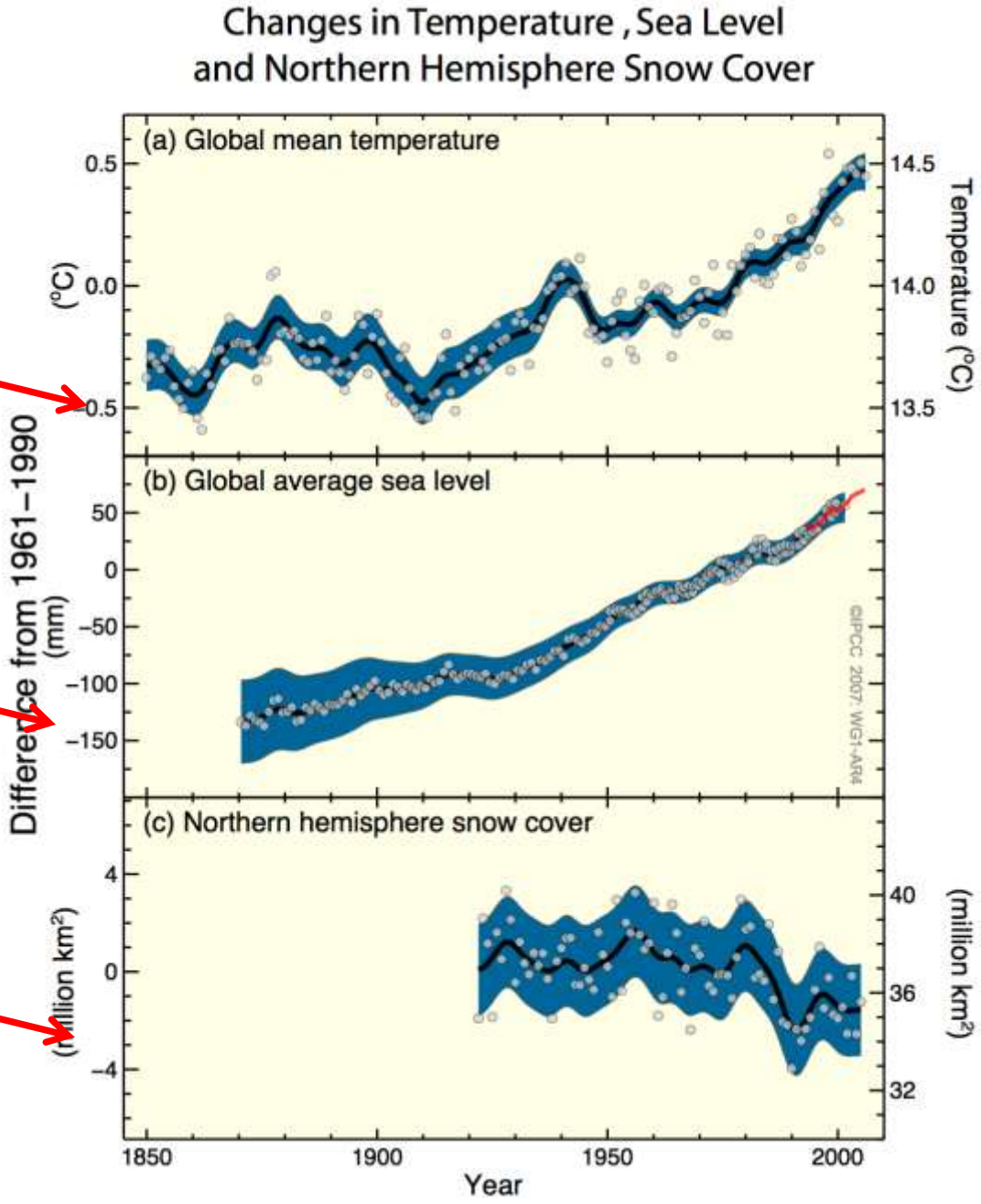
# Warming is Unequivocal

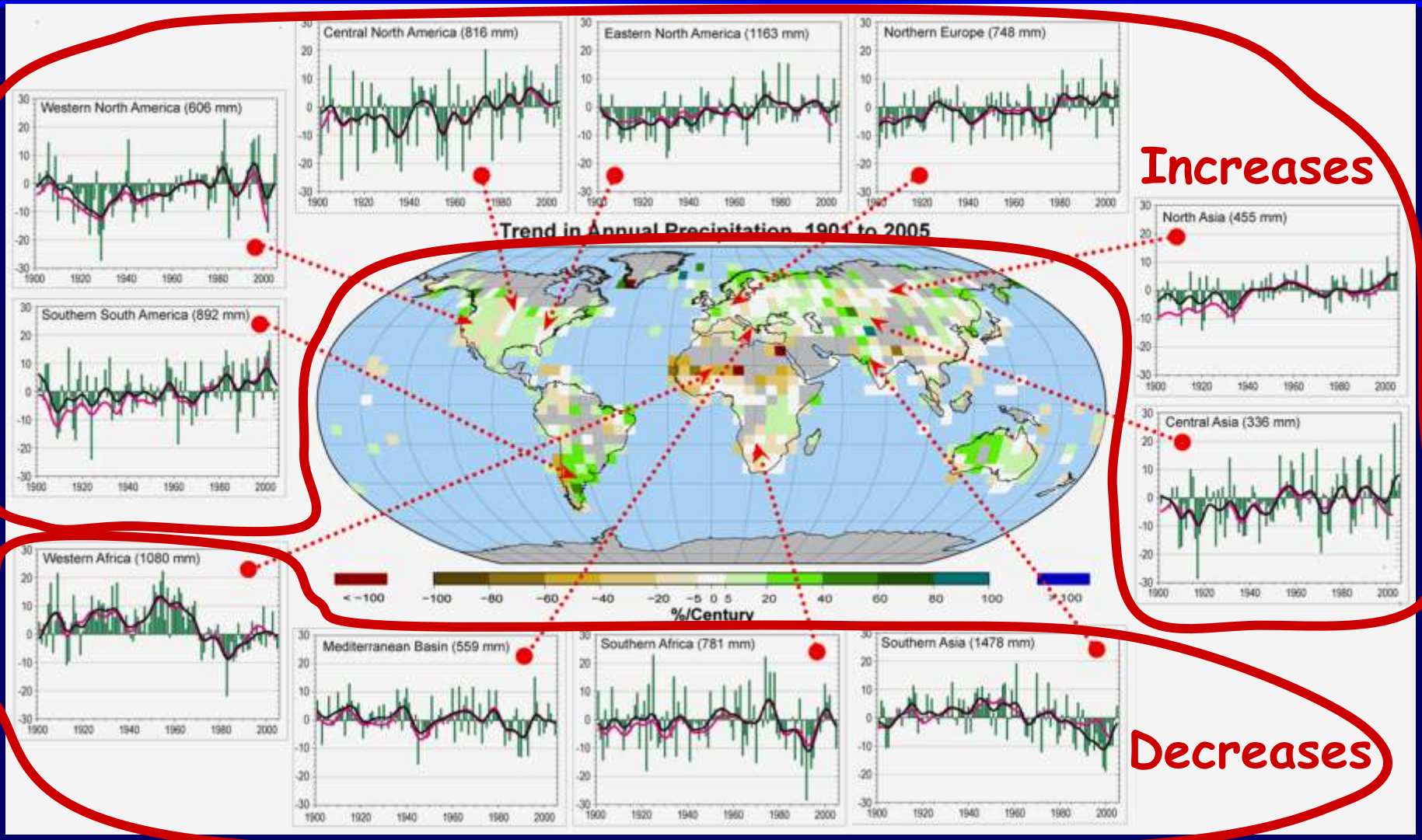
Rising atmospheric temperature

Rising sea level

Reductions in NH snow cover

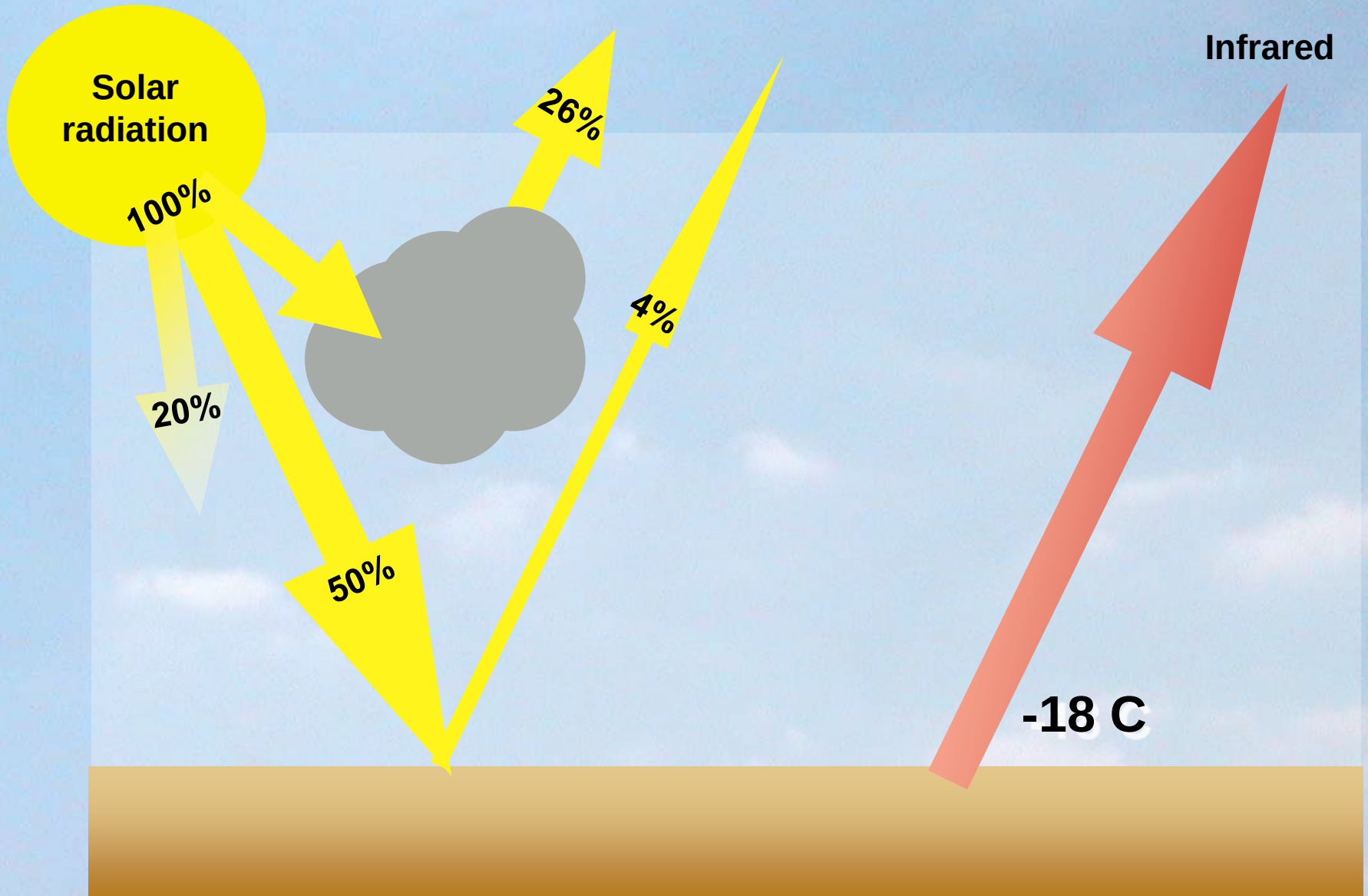


# Land precipitation is changing significantly over broad areas

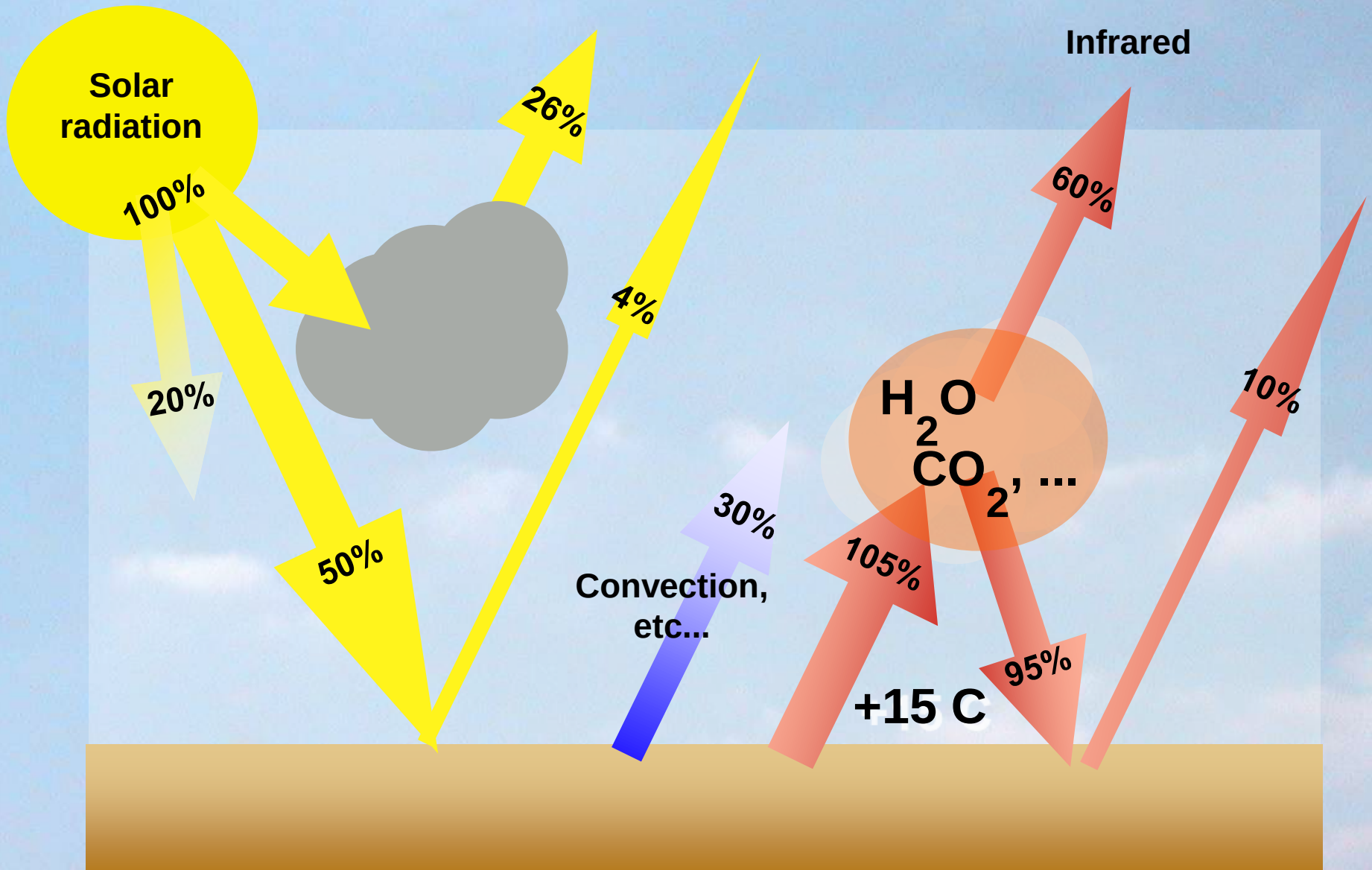



Smoothed annual anomalies for precipitation (%) over land from 1900 to 2005; other regions are dominated by variability.

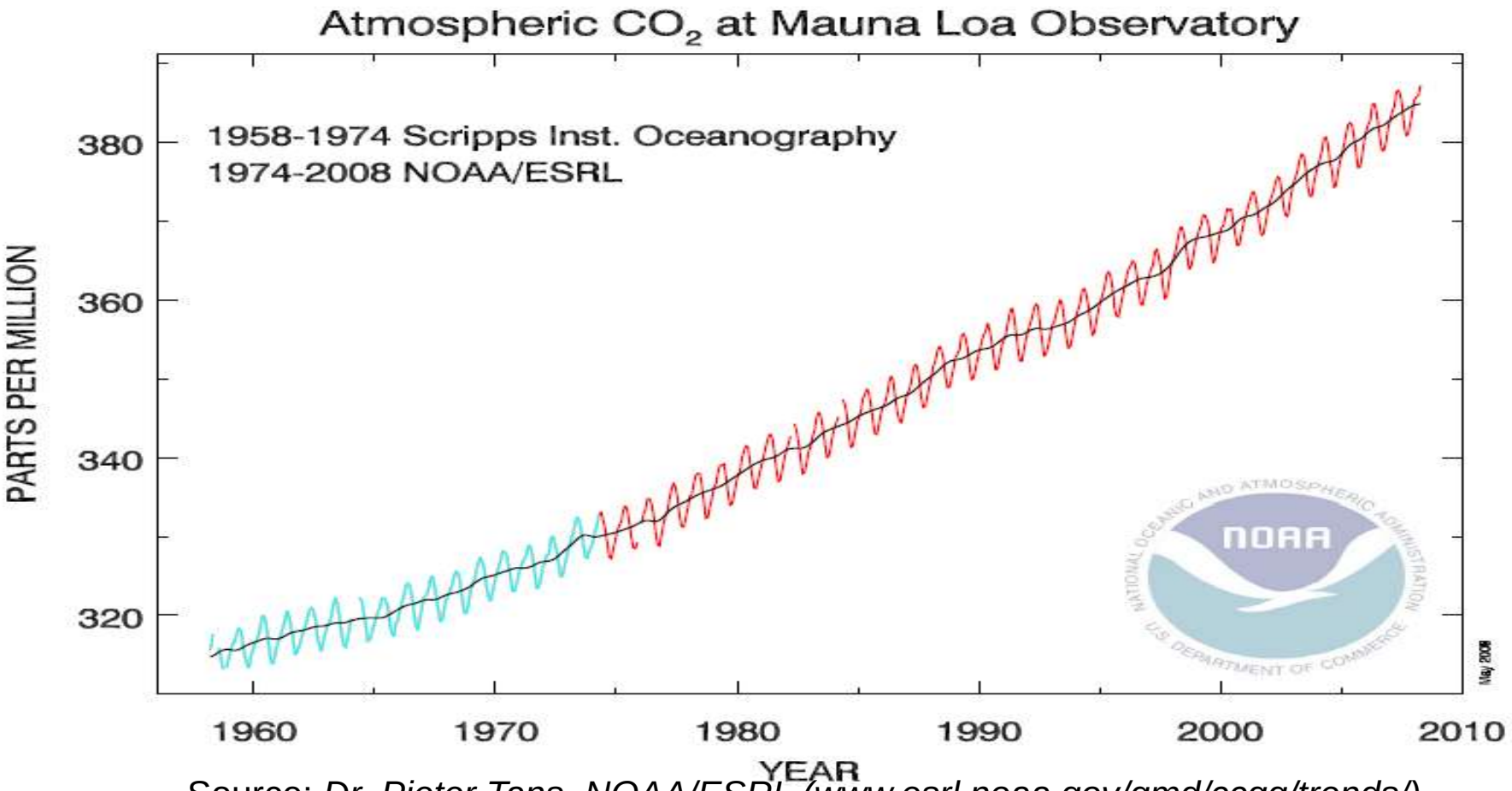
# Energy cycle without greenhouse effect



# Energy cycle *with* greenhouse effect



# $CO_2$ concentration measured at Mauna Loa (3400 m)




Source: *Dr. Pieter Tans, NOAA/ESRL (www.esrl.noaa.gov/gmd/ccgg/trends/)*

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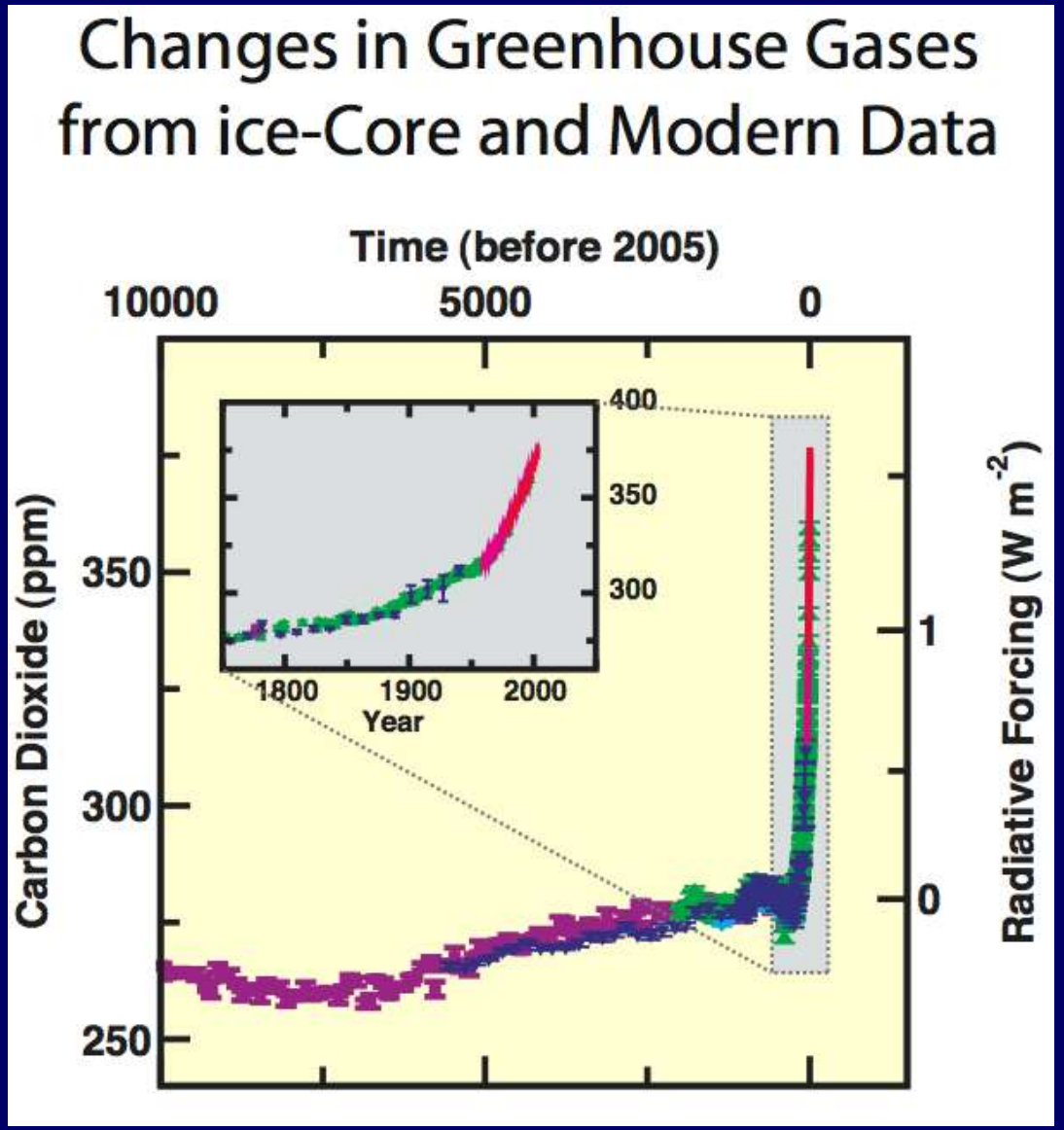
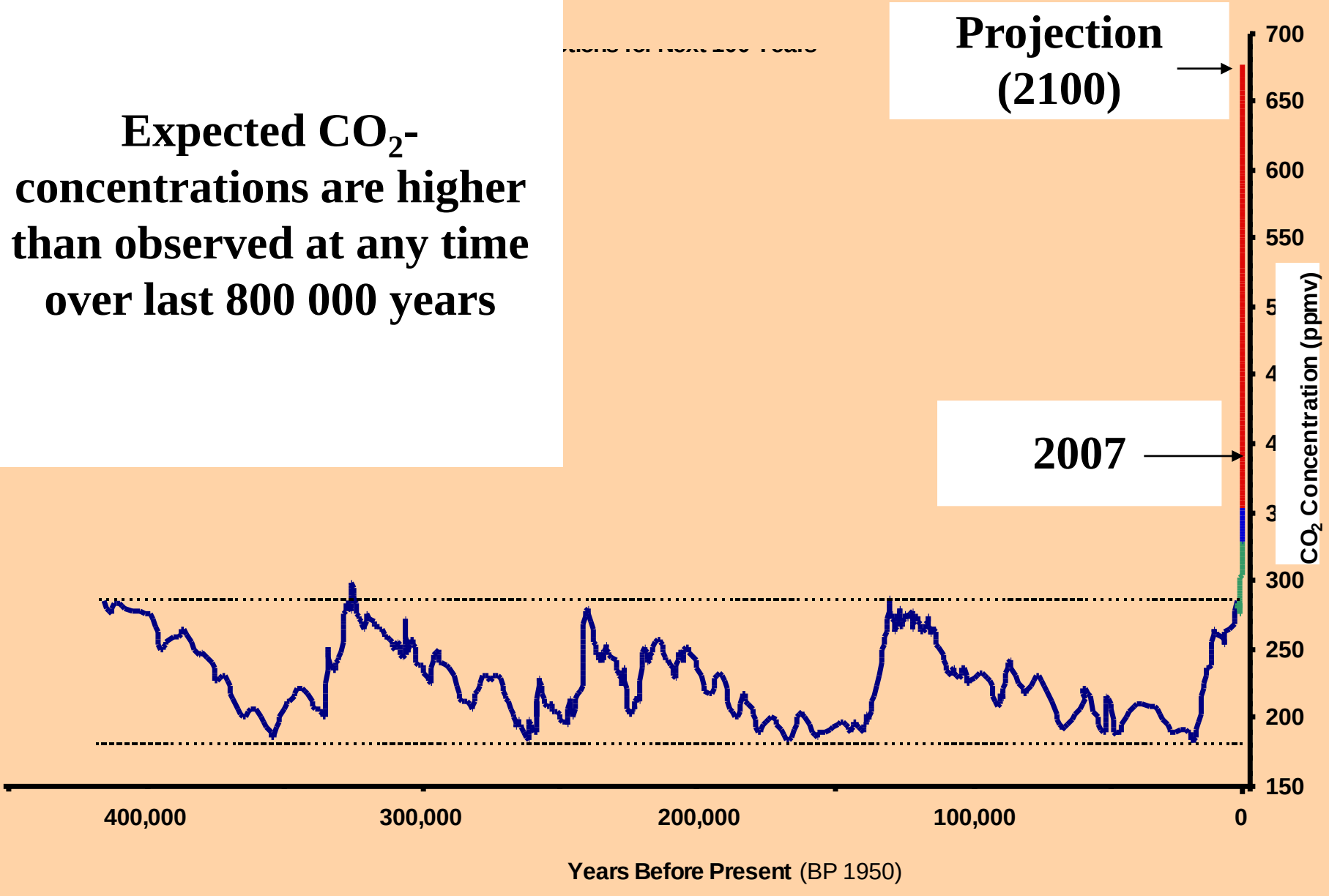
# Human and Natural Drivers of Climate Change: Unprecedented

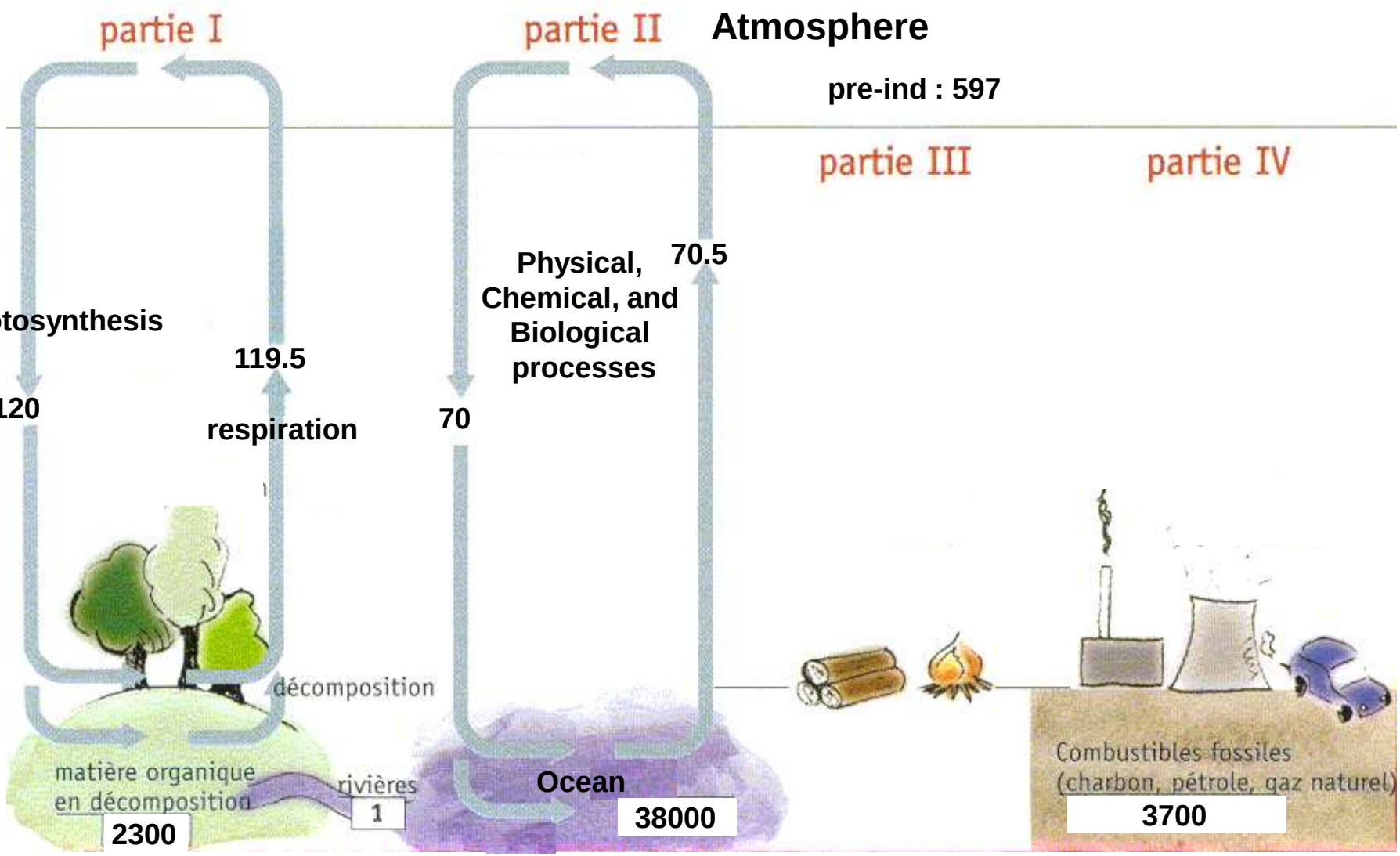
- Dramatic rise in the industrial era
- Largest growth rate of CO2 seen over the last ten years (1995-2005) than in any decade at least since direct measurements began (1960).



**Expected $CO_2$-concentrations are higher than observed at any time over last 800 000 years**



# Carbon cycle




Units: GtC (billions tons of carbon) or GtC/year

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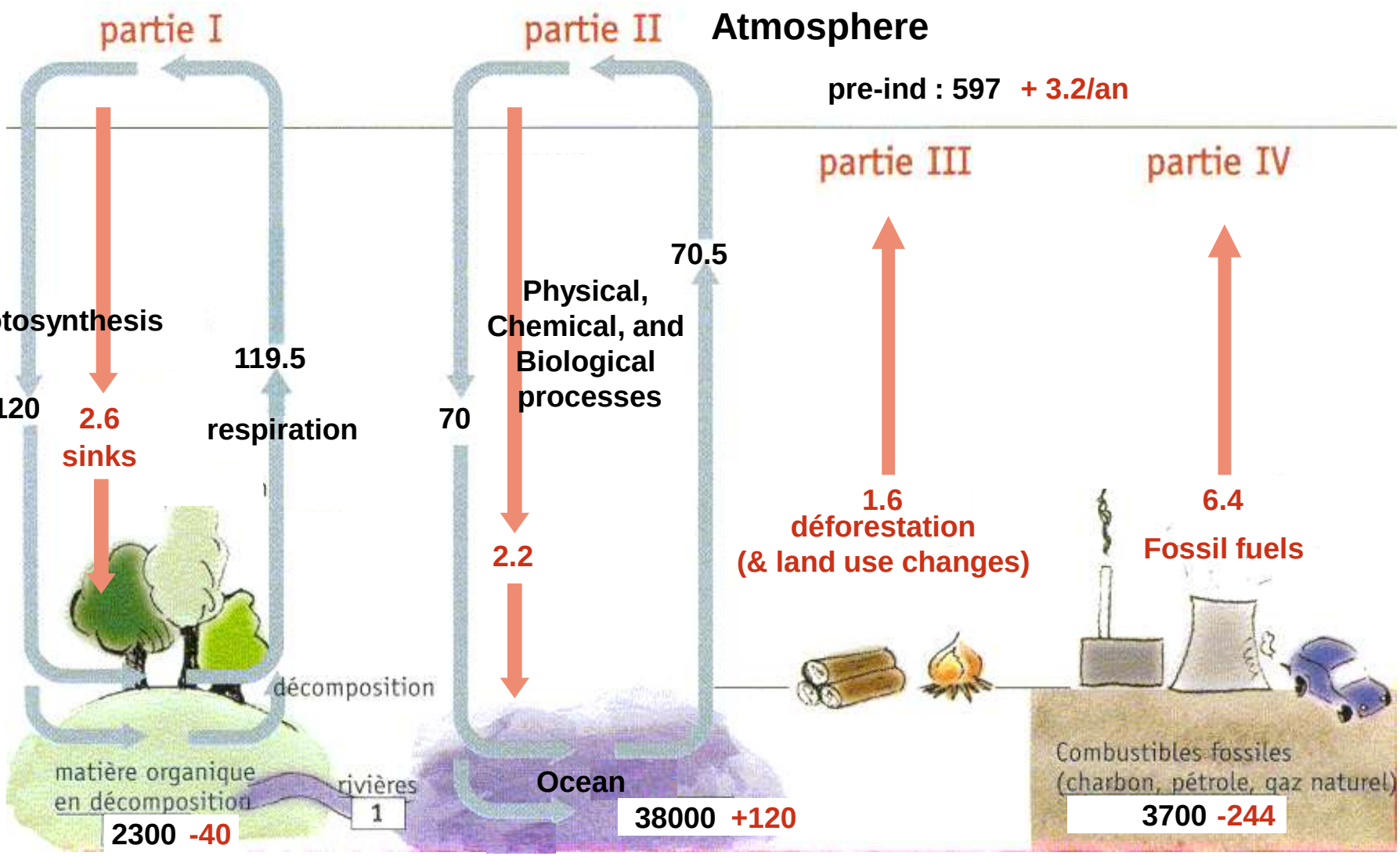
# Carbon cycle




Units: GtC (billions tons of carbon) or GtC/year

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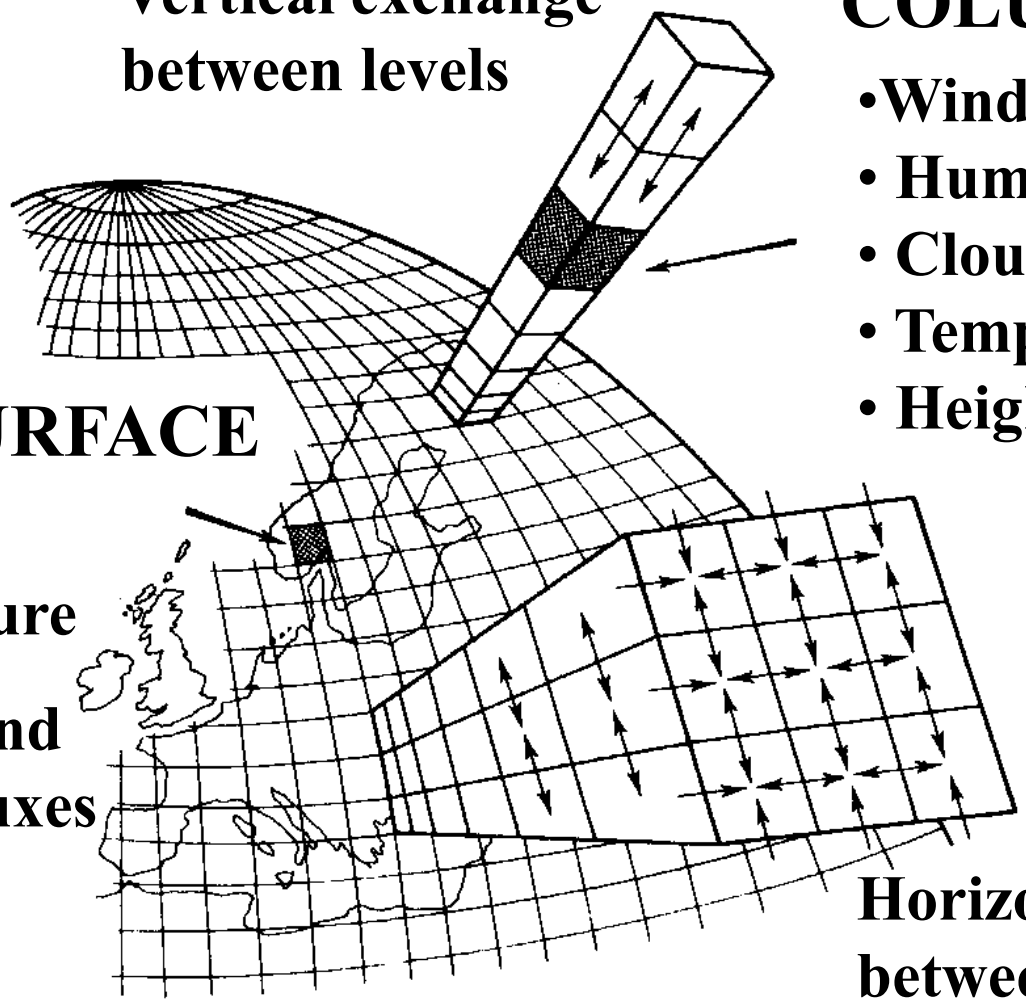
# A climate model:

## IN THE ATMOSPHERIC COLUMN

- Wind vectors
- Humidity
- Clouds
- Temperature
- Height

Vertical exchange between levels



## AT THE SURFACE

- Ground temperature
- Water and energy fluxes

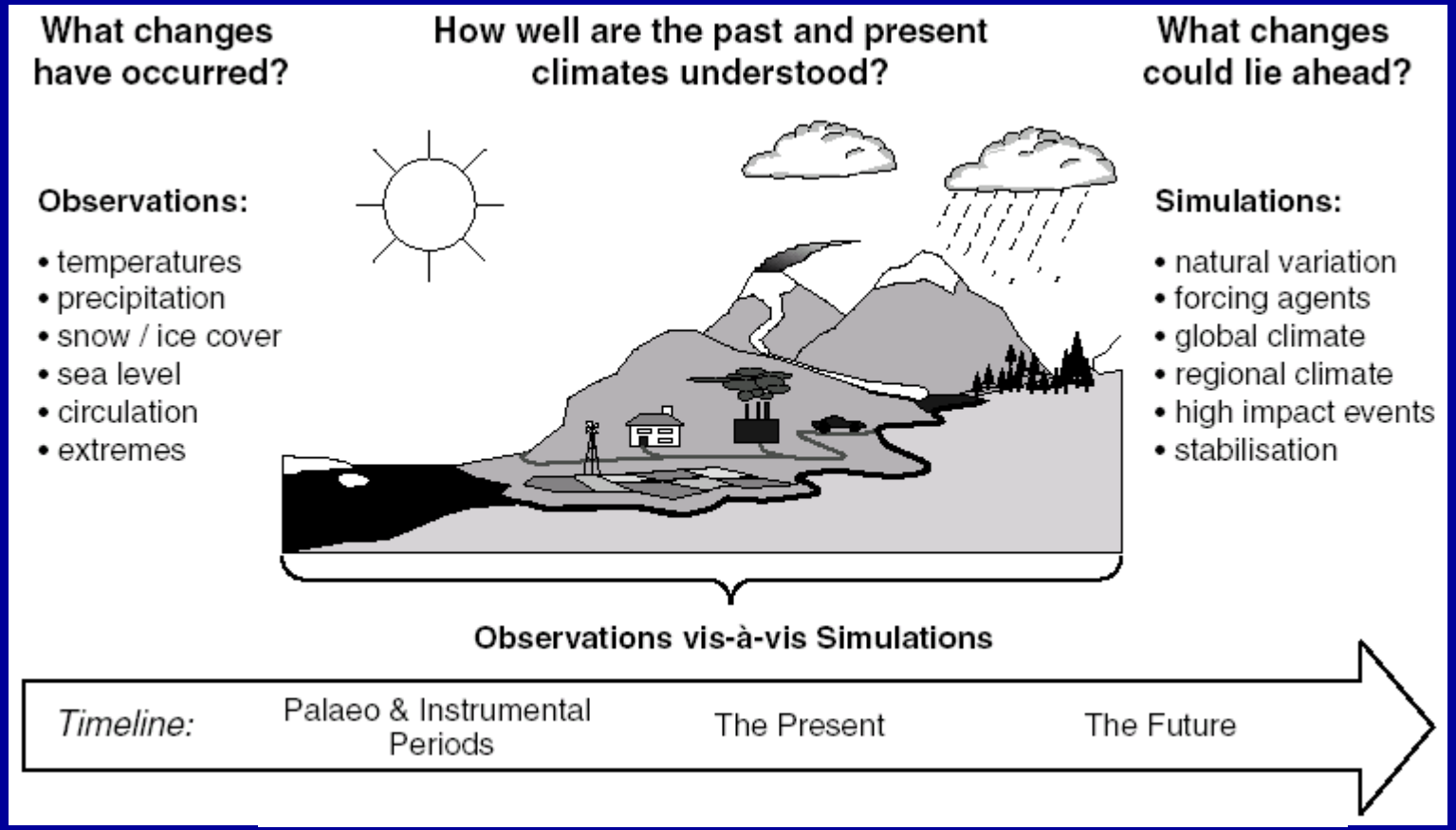
Horizontal exchange between columns

Time step ~ 30 minutes

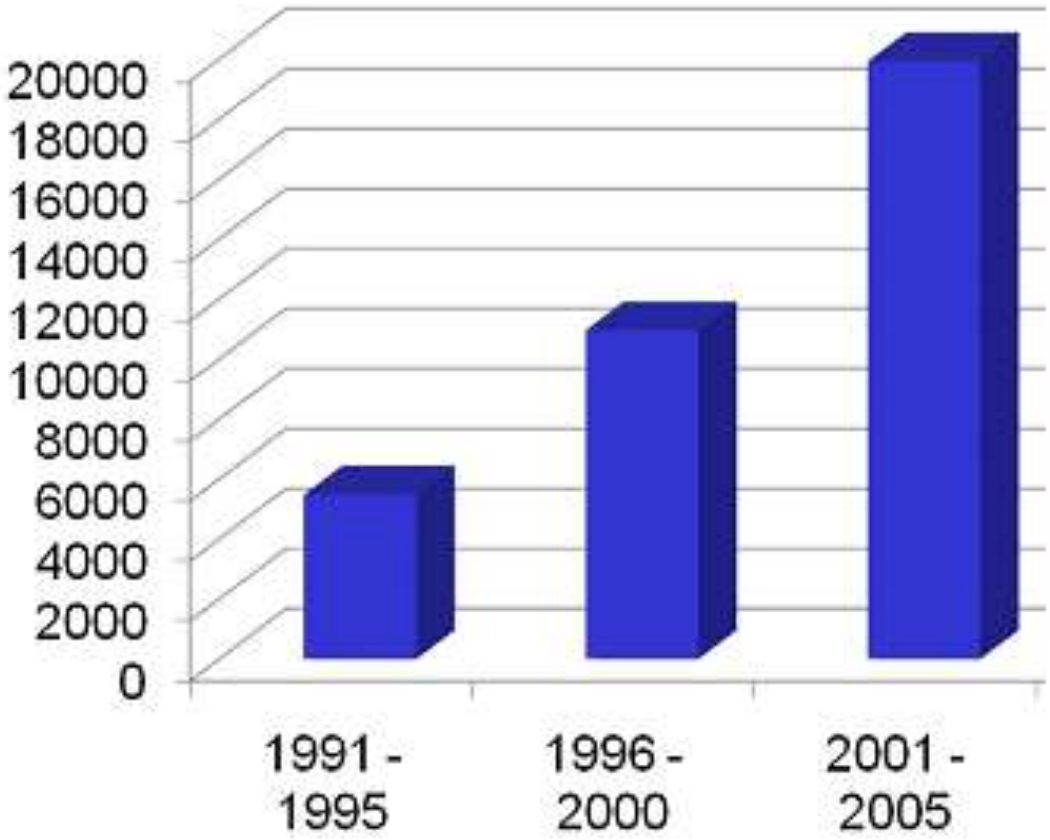
Grid spacing ~ 3°x 3°

Source: McGuffie & Henderson-Sellers (1997)

# Purpose of climate modelling



# Number of papers published on climate change



# How does IPCC work?

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# What is the IPCC (GIEC in French) ?

- **IPCC : Intergovernmental Panel on Climate Change**
- **Created by World Meteorological Organisation (WMO) & United Nations Environment Programme (UNEP) in 1988**
- **Mandate : assess the science of climate change, impacts and adaptation, mitigation options**
- **Publishes consensus reports (1990, 1996, 2001, 2007) (Cambridge University Press)**
  **Advises Climate Change Convention**
- **Nobel Peace prize (2007)**
- **Web : http://www.ipcc.ch**

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# Mandate of the IPCC

"The General Assembly […] endorses action of the World Meteorological Organisation and the United Nations Environment Programme in jointly establishing an Intergovernmental Panel on Climate Change to provide **international coordinated scientific assessments** of the magnitude, timing and potential environmental and socio-economic impact of climate change and realistic response strategies […]."

United Nations General Assembly
43rd session resolution, 6th December 1988

# Role of IPCC

"The IPCC does not carry out research nor does it monitor climate related data or other relevant parameters. It bases its assessment mainly on peer reviewed and published scientific/technical literature."

(source: www.ipcc.ch)

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# IPCC Reports are policy-relevant, NOT policy-prescriptive

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# IPCC Structure

- **3 Working Groups, 1 Task Force**
- WG1: Physical basis for climate change
- WG2: Impacts, adaptation & vulnerability
- WG3: Mitigation (emission reductions)
- TF: Emission inventories (methodologies)

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# IPCC writing cycle (4 years, 2500 scientists)

- Plenary decides table of content of reports
- Bureau appoints world-class scientists as authors, based on publication record
- Authors assess all scientific literature
- *Draft* – Expert review (+ Review editors)
- *Draft 2 (+ Draft 1 Summary for Policy Makers (SPM)* – Combined expert/government review
- *Draft 3 (+ Draft 2 SPM)*– Government review of SPM
- Approval Plenary (interaction authors – governments) – *SPM and full report*

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# The IPCC Fourth Assessment Report (2007)

**+130** countries

**around 450** lead authors

**around 800** contributing authors

**+2500** scientific expert reviewers

**+18000** peer-reviewed publications cited

**+90000** comments from experts and Governments

# Completed IPCC Reports

4 Assessment Reports *(1990,1995, 2001, 2007)*

1992 Supplementary Report and 1994 Special Report

7 Special Reports *(1997,1999, 2000, 2005)*

Guidelines for National GHG Inventories, Good Practice Guidance *(1995-2006)*

6 Technical Papers *(1996-2008)*

# ⌘IPCC Working Group I: climatology

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# Key points from the WG1 IPCC AR4 Report

- Warming of the climate system is unequivocal
- Very high confidence that net effect of human activities since 1750 = warming
- Last 50 years likely to be highest temperature in at least last 1300 yrs
- Most of this warming is very likely due to increase in human greenhouse gases
- Without emission reduction policies, global temperature could increase by 1.1 to 6.4°C, or even higher in 2100 compared to 1990
- Sea level could increase by 18 to 59 cm, or more
- Frequency/intensity of several extreme phenomena due to increase (ex: heat waves, droughts, floods, …)

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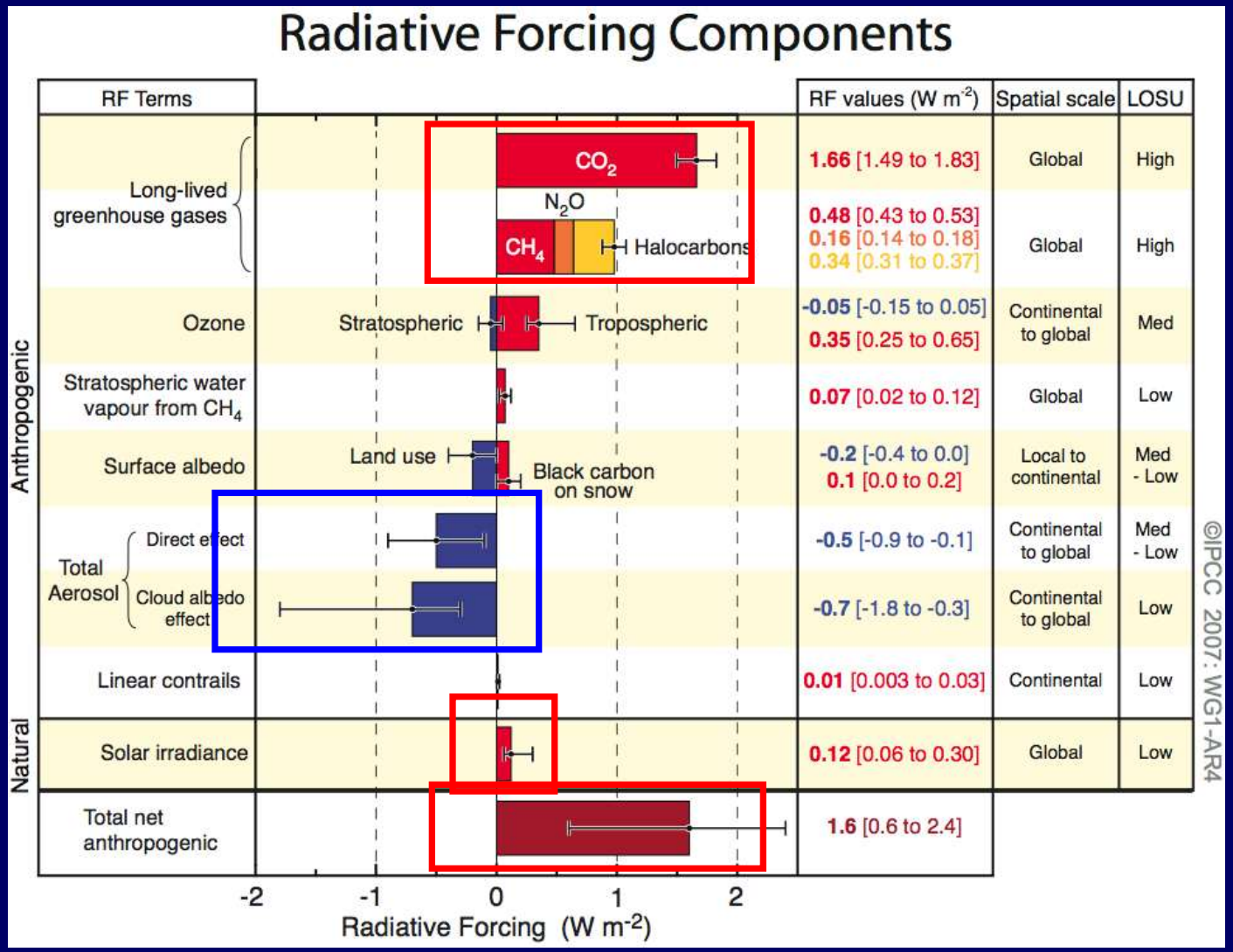
# Human and Natural Drivers of Climate Change

Major improvements in understanding forcing compared to IPCC (2001).

Now we have more confidence about “drivers”.

1.6 W m$^{-2}$ warms like 1.6 Christmas tree lights over every m$^2$ on Earth.



# The IPCC WG1 Sequence (1)……

IPCC (1990) “The size of this warming is broadly consistent with predictions of climate models, but it is also of the same magnitude as natural climate variability (…) The unequivocal detection of the enhanced greenhouse effect from observations is not likely for a decade or more”

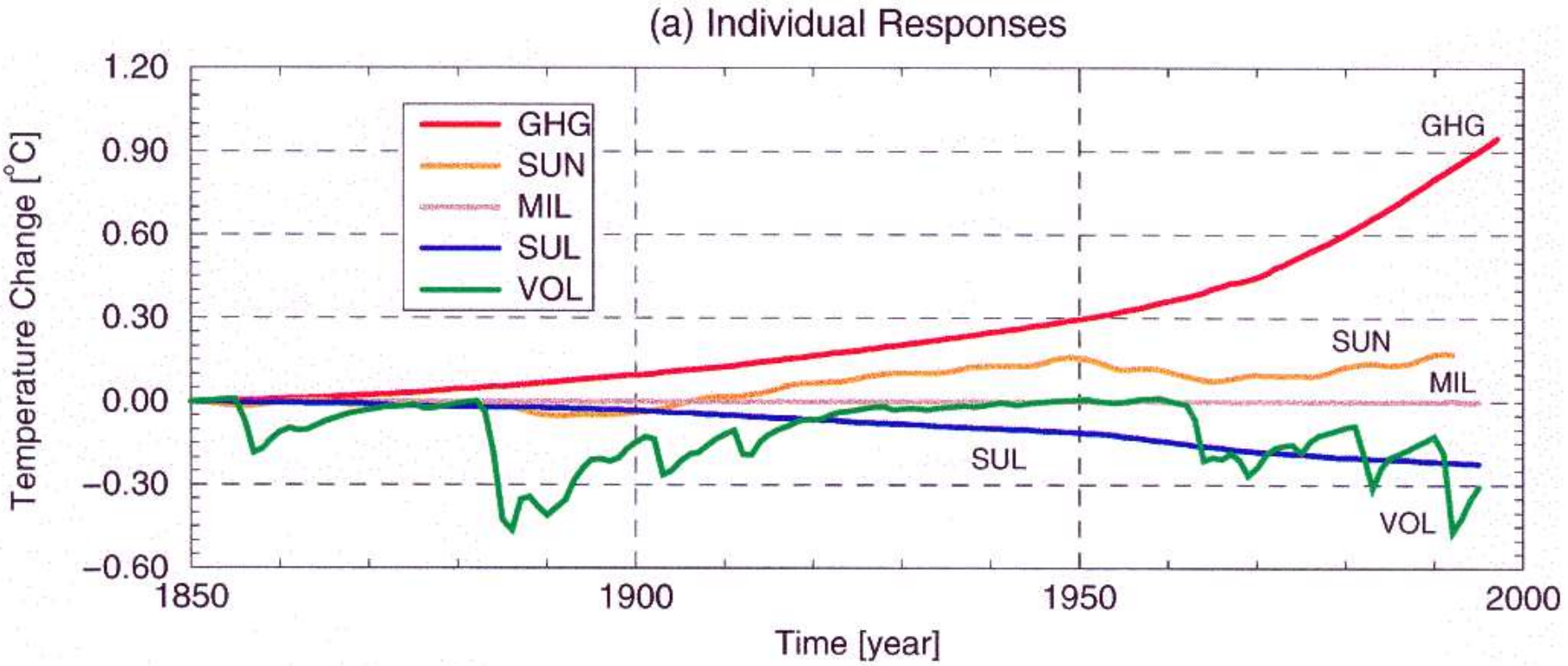
IPCC (1995) “The balance of evidence suggests a discernible human influence on global climate”

# The IPCC WG1 Sequence (2)……

IPCC (2001) "Most of the observed warming over the last 50 years is likely (P>66%) to have been due to the increase in greenhouse gas concentrations."

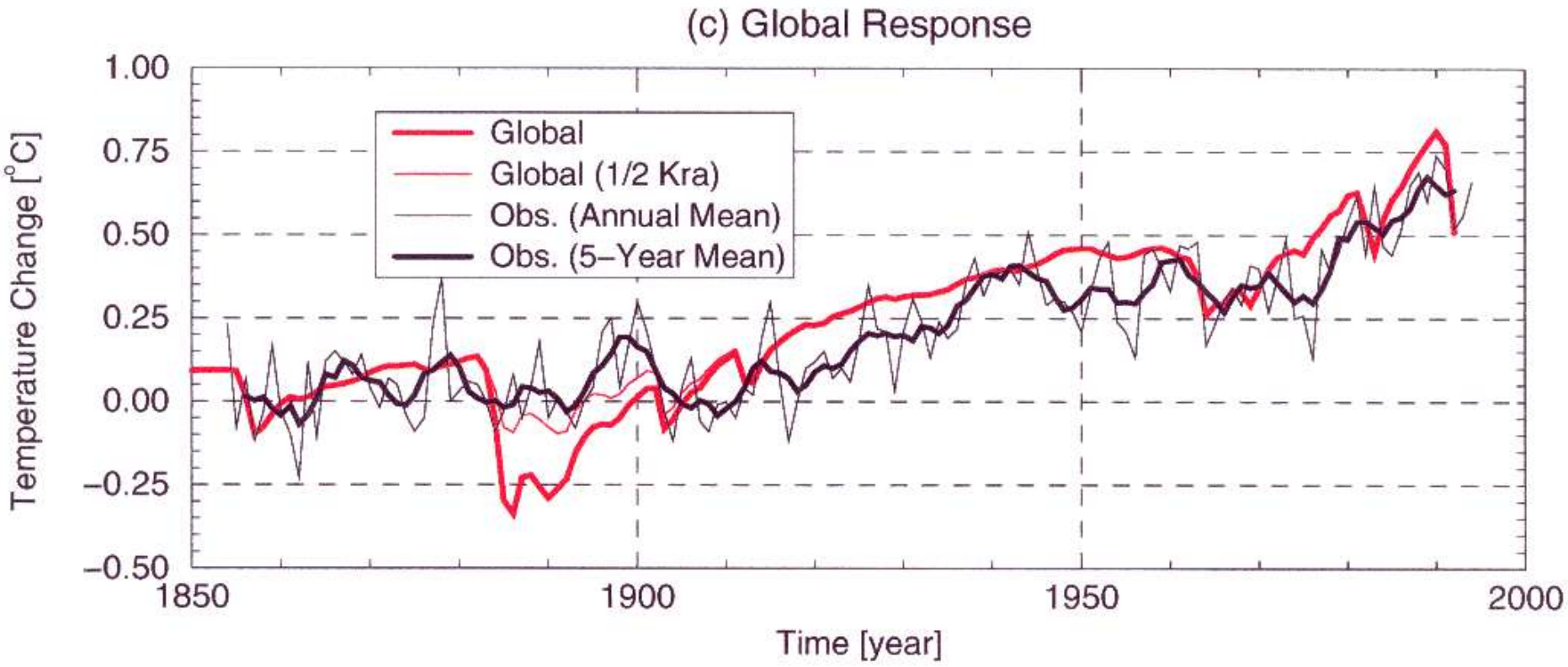
IPCC (2007) "Warming is unequivocal, and most of the mid-20th century is very likely (P>90%) due to the observed increase in anthropogenic greenhouse gas concentrations"

# Separate effect of different factors in the 2-dimensional climate model at UCL




Bertrand et al. 2001

# Combined effect of all factors in the 2-dimensional climate model at UCL

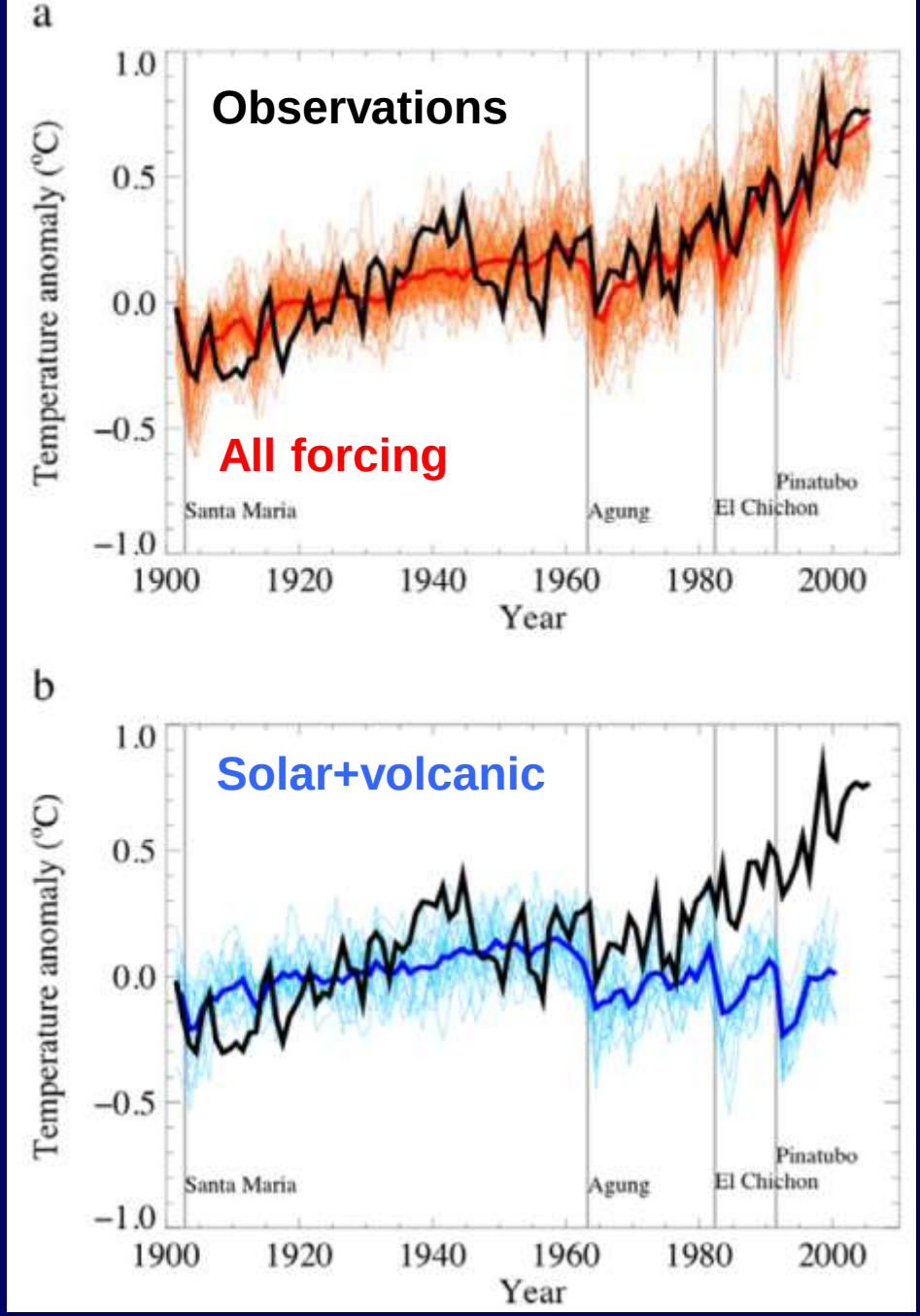



Bertrand et al. 2001

# Attribution

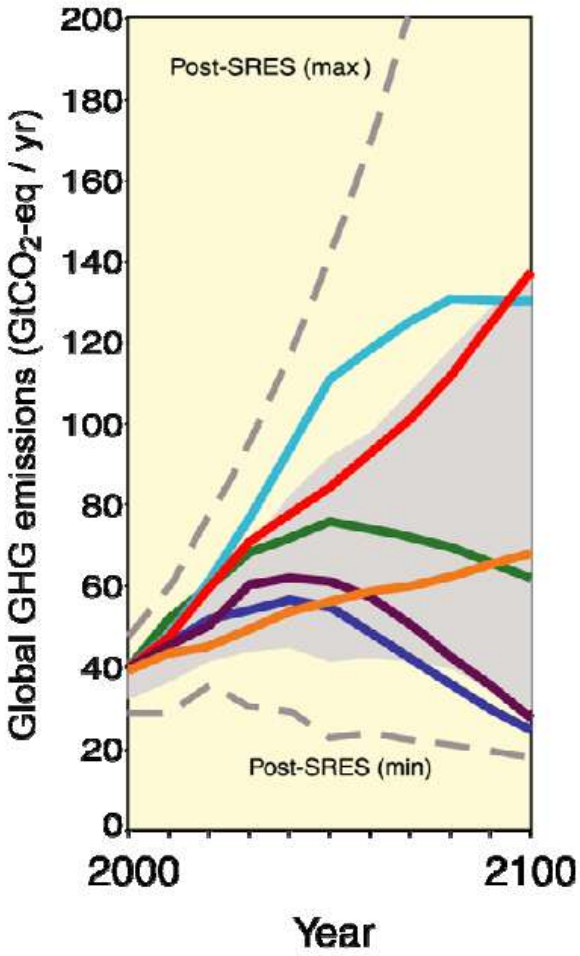
Are observed changes consistent with expected responses to natural forcings?

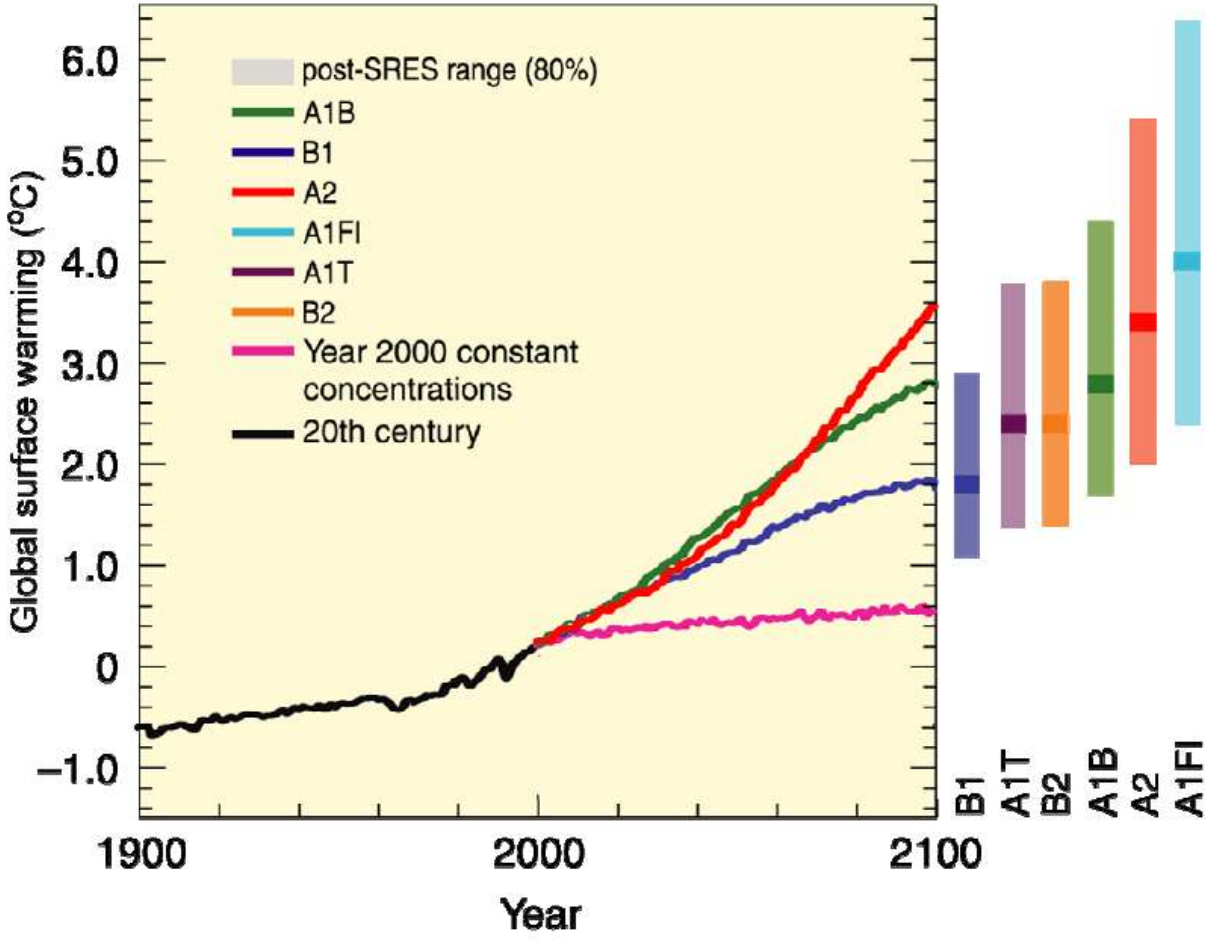
IPCC (2007):
"Warming is unequivocal, and most of the warming of the past 50 years is very likely (90%) due to increases in greenhouse gases."



Source: IPCC, AR4 (2007)

# Climate projections without mitigation




NB: écart par rapport à la moyenne 1980-1999

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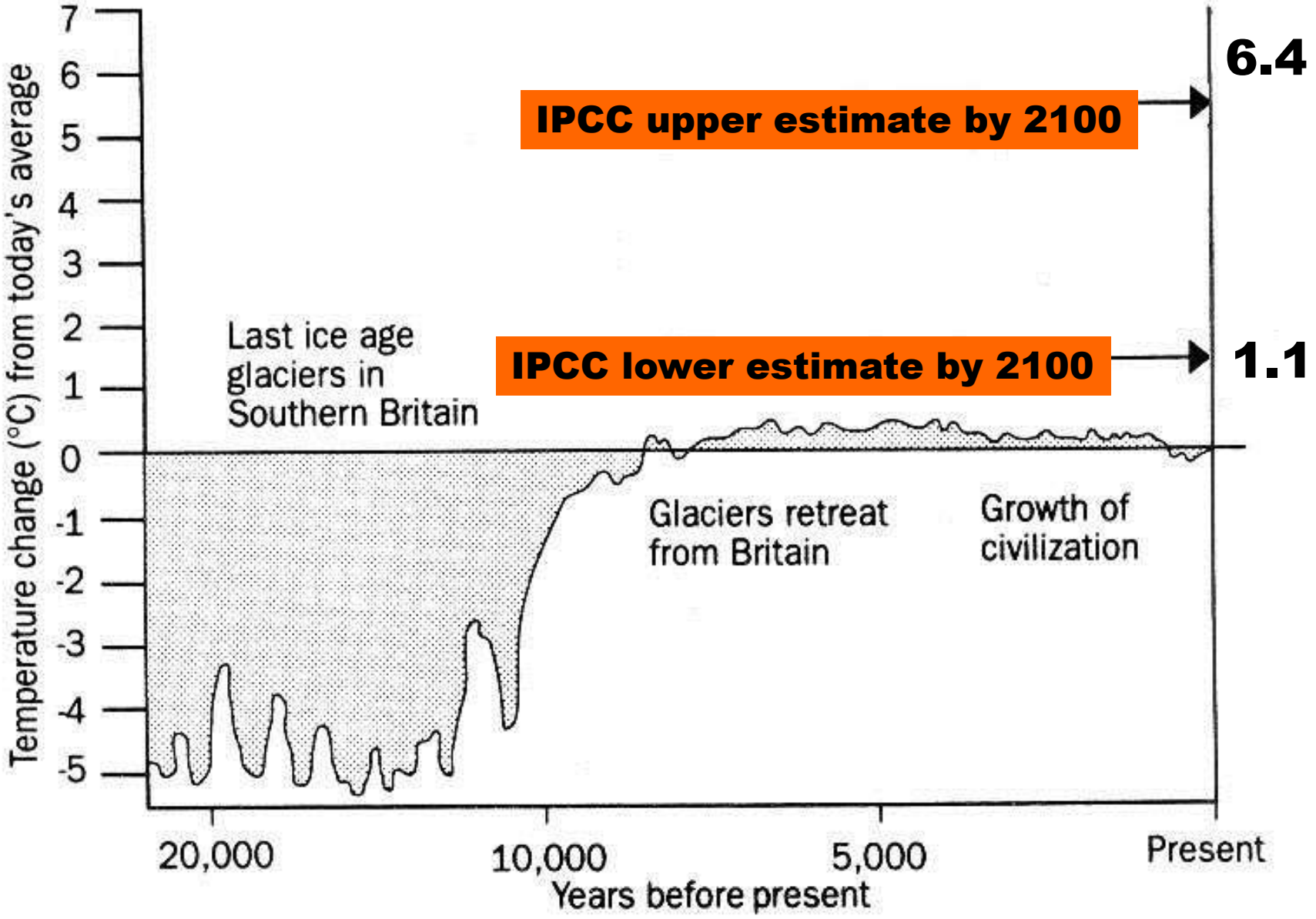
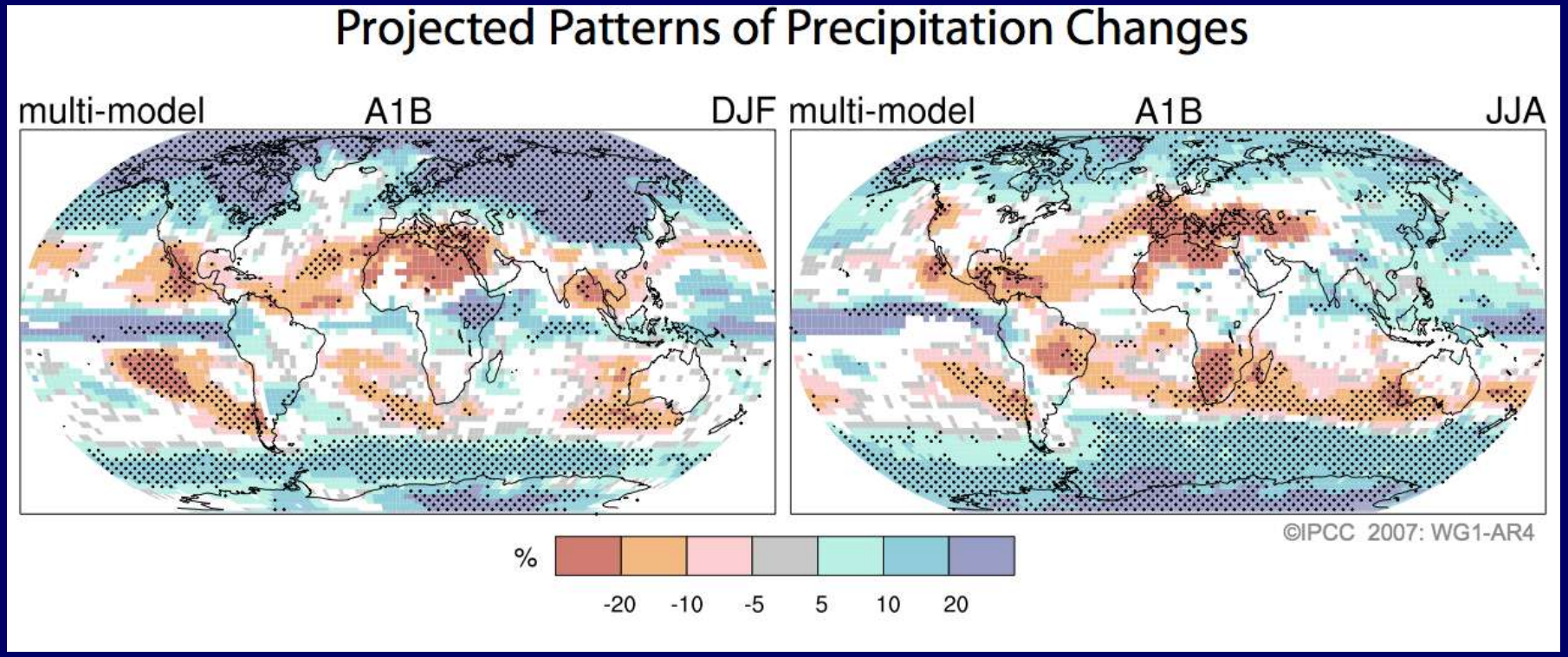

6.4
IPCC upper estimate by 2100
IPCC lower estimate by 2100
1.1
Last ice age glaciers in Southern Britain
Glaciers retreat from Britain
Growth of civilization
Temperature change (°C) from today's average
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
20,000
10,000
5,000
Present
Years before present

# Projections of Future Changes in Climate
## (A1B in 2100)




Brand new in AR4: Drying in much of the subtropics, more rain in higher latitudes, continuing the broad pattern of rainfall changes already observed.

# Assessment of projected climate change for Asia

All of Asia is very likely to warm during this century; the warming is likely to be well above the global mean in central Asia, the Tibetan Plateau and northern Asia, above the global mean in **East and South Asia**, and similar to the global mean in Southeast Asia.

It is very likely that summer heat waves/hot spells in **East Asia** will be of longer duration, more intense, and more frequent.

It is very likely that there will be fewer very cold days in **East Asia** and South Asia

IPCC AR4, WGI, Ch.11.4

# Assessment of projected climate change for Asia

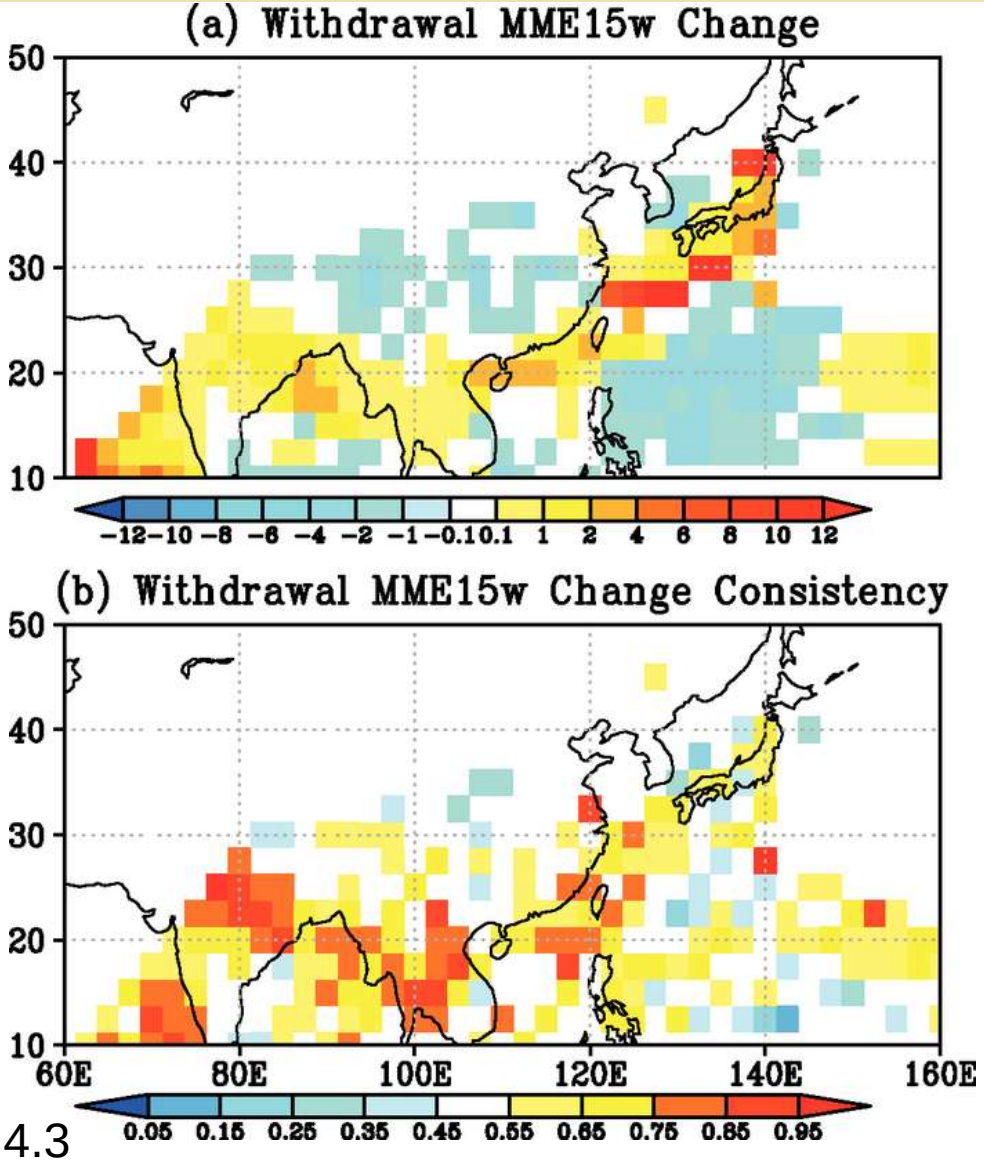
Summer precipitation is likely to increase in northern Asia, **East** and South **Asia** and most of Southeast Asia (…).

An increase in the frequency of intense precipitation events in parts of South Asia, and in **East Asia**, is very likely.

Extreme rainfall and winds associated with tropical cyclones are likely to increase in **East**, Southeast and South **Asia**. Monsoonal flows and the tropical large-scale circulation are likely to be weakened.

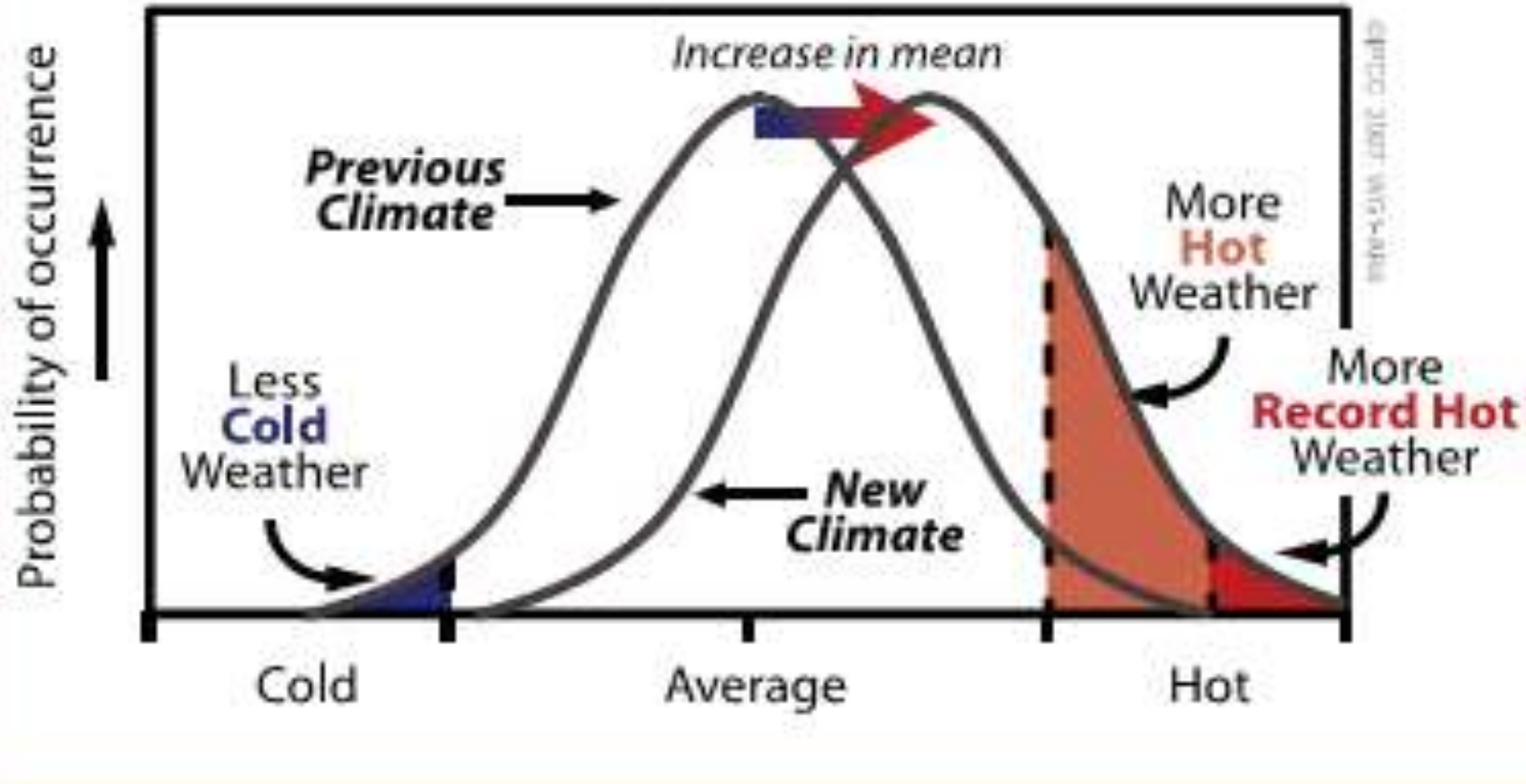
IPCC AR4, WGI, Ch.11.4

# Withdrawal times of the Asian summer rainfall season (15 MMD simulations)




IPCC AR4, WGI, Ch.11.4.3

# Changes in average produce changes in probability of extremes




**Box TS.5, Figure 1.** *Schematic showing the effect on extreme temperatures when the mean temperature increases, for a normal temperature distribution.*

# More heavy precipitation and more droughts….

# Climate change and extremes (IPCC AR4 WG1)

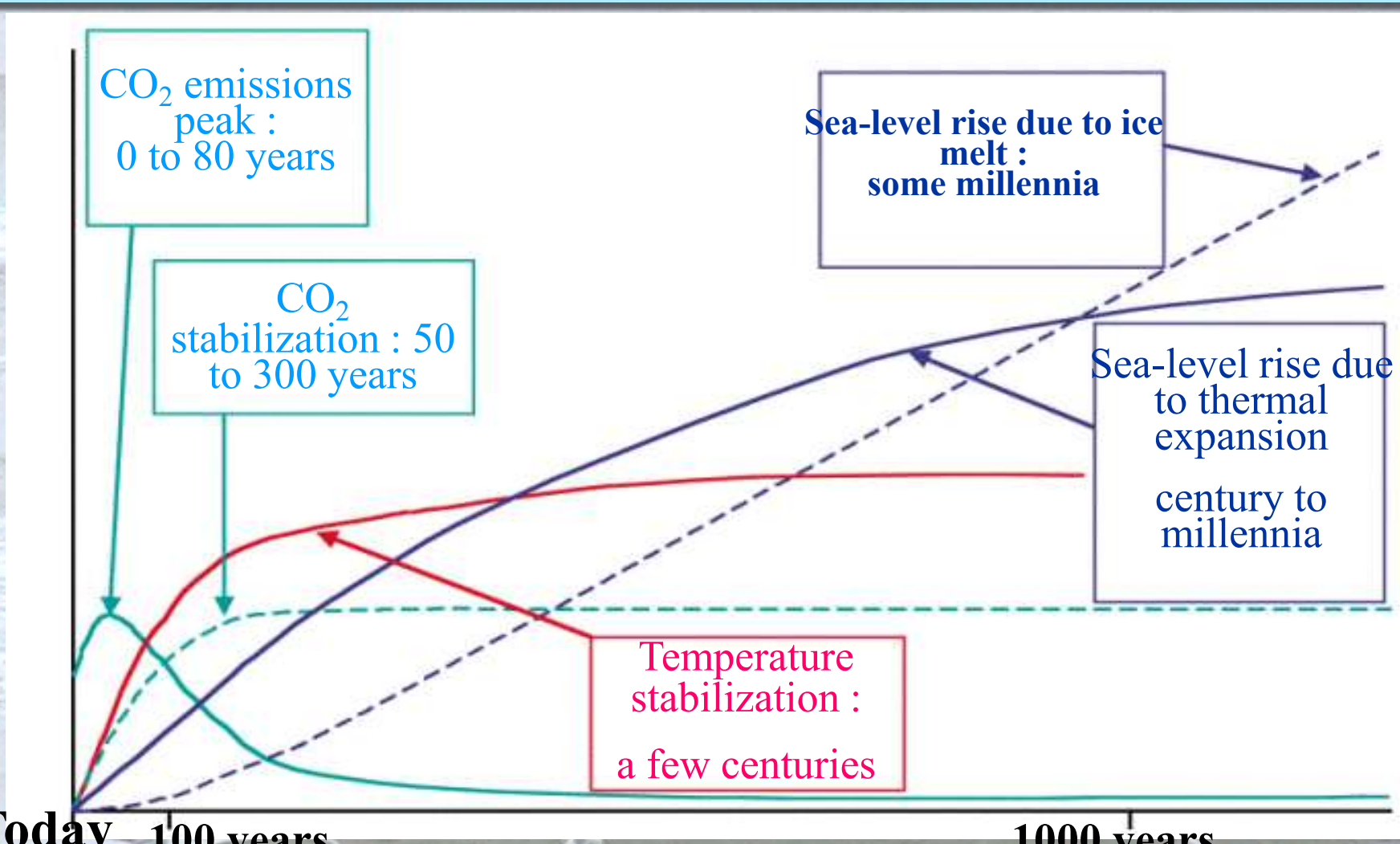
| | Post 1960 | | 21th century |
|---|---|---|---|
| **Phenomenon[a] and direction of trend** | **Likelihood that trend occurred in late 20th century (typically post 1960)** | **Likelihood of a human contribution to observed trend [b]** | **Likelihood of future trends based on projections for 21st century 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] |

**Virtually certain > 99%, very likely > 90%, likely > 66%, more likely than not > 50%**

# Ice sheet melting

- Melting of the Greenland ice sheet
  - Total melting would cause 7 m SLR contribution
- Melting of the West Antarctic Ice Sheet
  - Total melting would cause 5 m SLR contribution
- Warming of 1 – 4$^{o}$C over present-day temperatures would lead to partial melting over centuries to millennia

# Significant inertia exists in the climate system






Source: IPCC (2001

# IPCC Working Group II: Impacts, Vulnerability, and adaptation

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# Following addressed by WG II:

- Impacts observed so far

- Future scenarios
- Impacts on sectors:
  - Water
  - Ecosystems
  - Agriculture, forestry, fisheries
  - Coasts
  - Settlements and industry
  - Health

WMO

UNEP

# Following addressed (cont.):

- Impacts on regions:
  - Africa, Asia, Australia and New Zealand, Latin America, North America, Polar regions, Small islands, and
  - Europe (including the Alps)

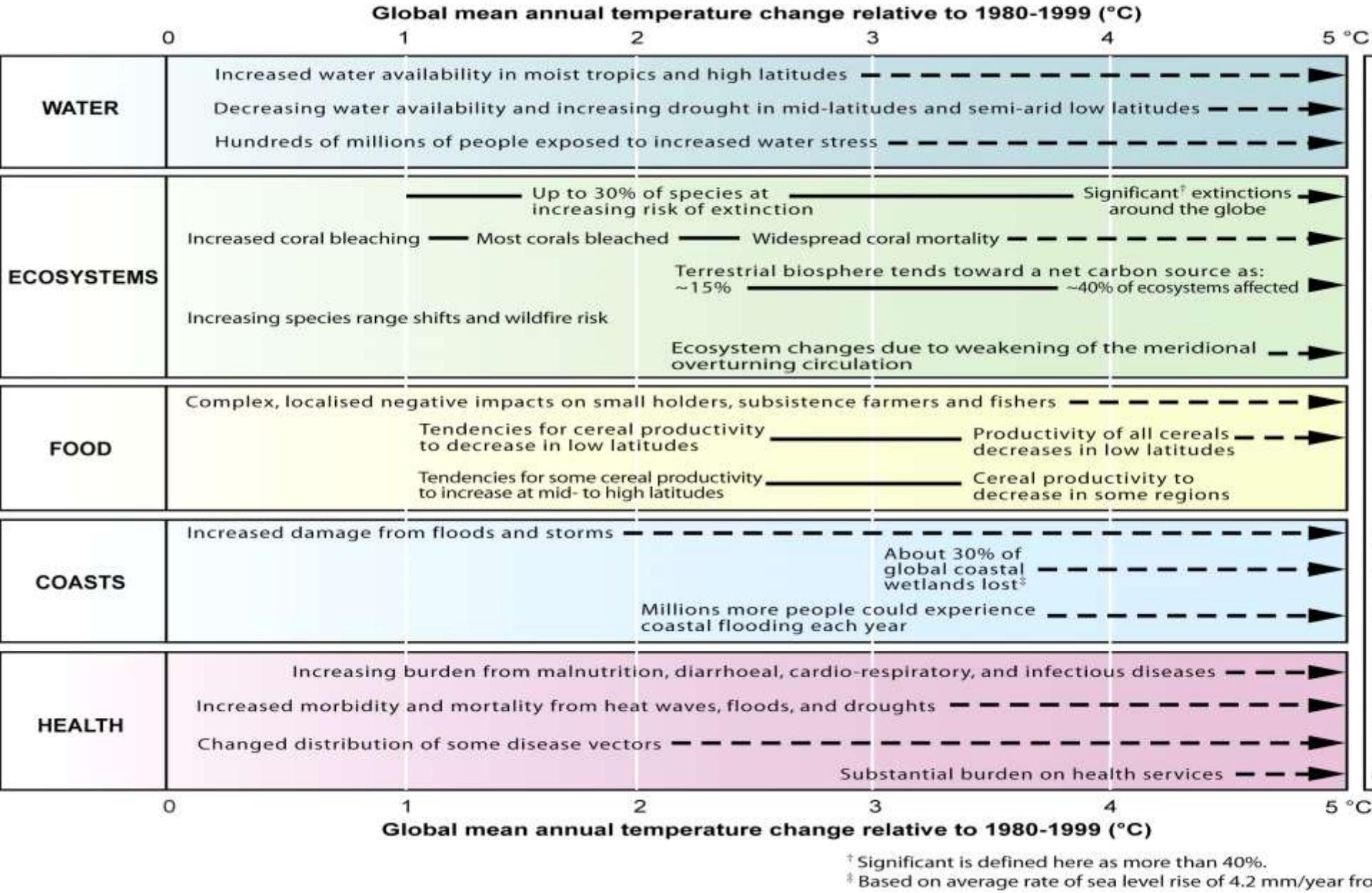
- Adaptation practices
- Adaptation vs. mitigation
- Key vulnerabilities
- Sustainability

WMO

UNEP

# Figure SPM.2. Key impacts as a function of increasing global average temperature change

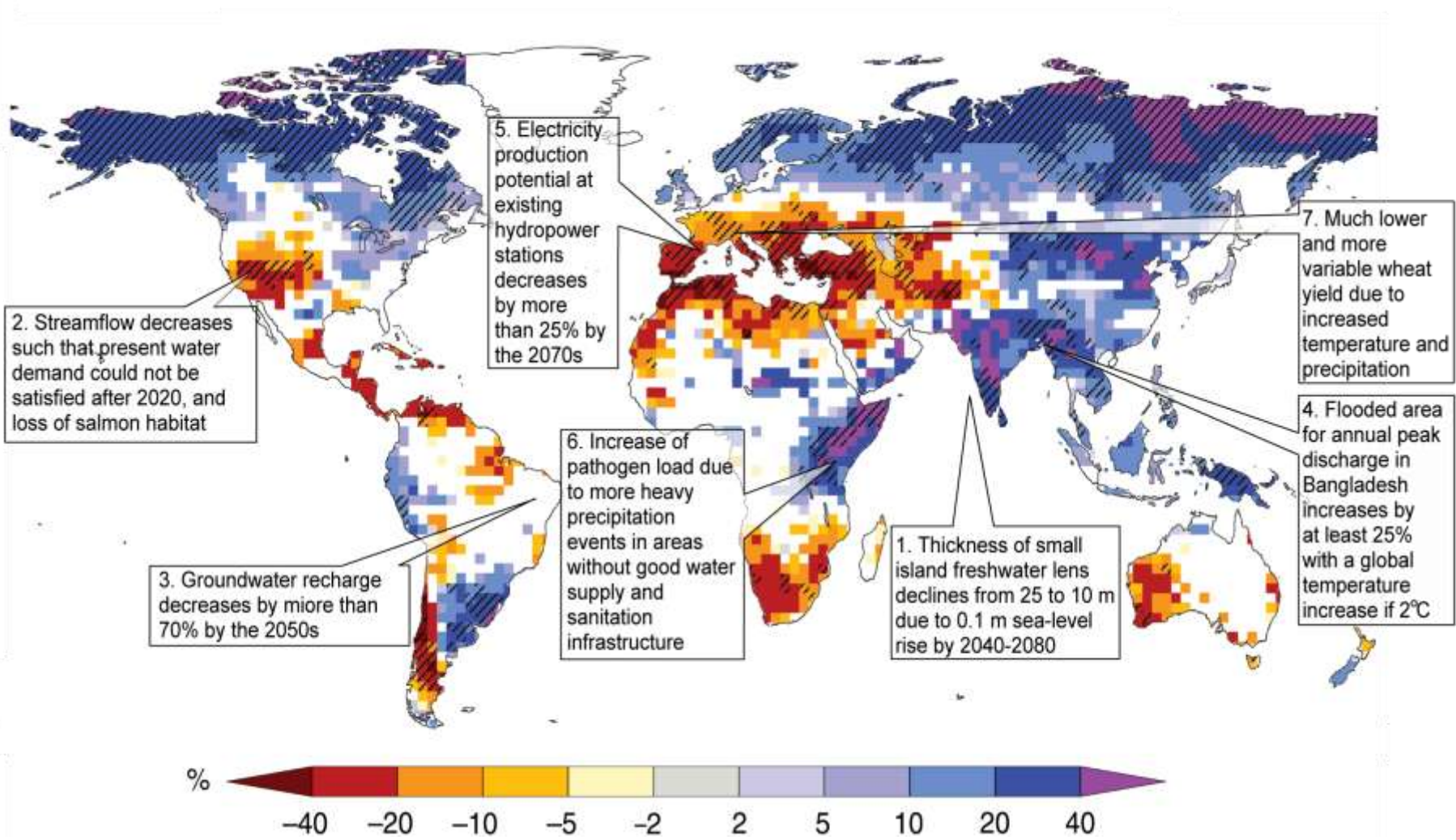
(Impacts will vary by extent of adaptation, rate of temperature change, and socio-economic pathway)




† Significant is defined here as more than 40%.

‡ Based on average rate of sea level rise of 4.2 mm/year fro

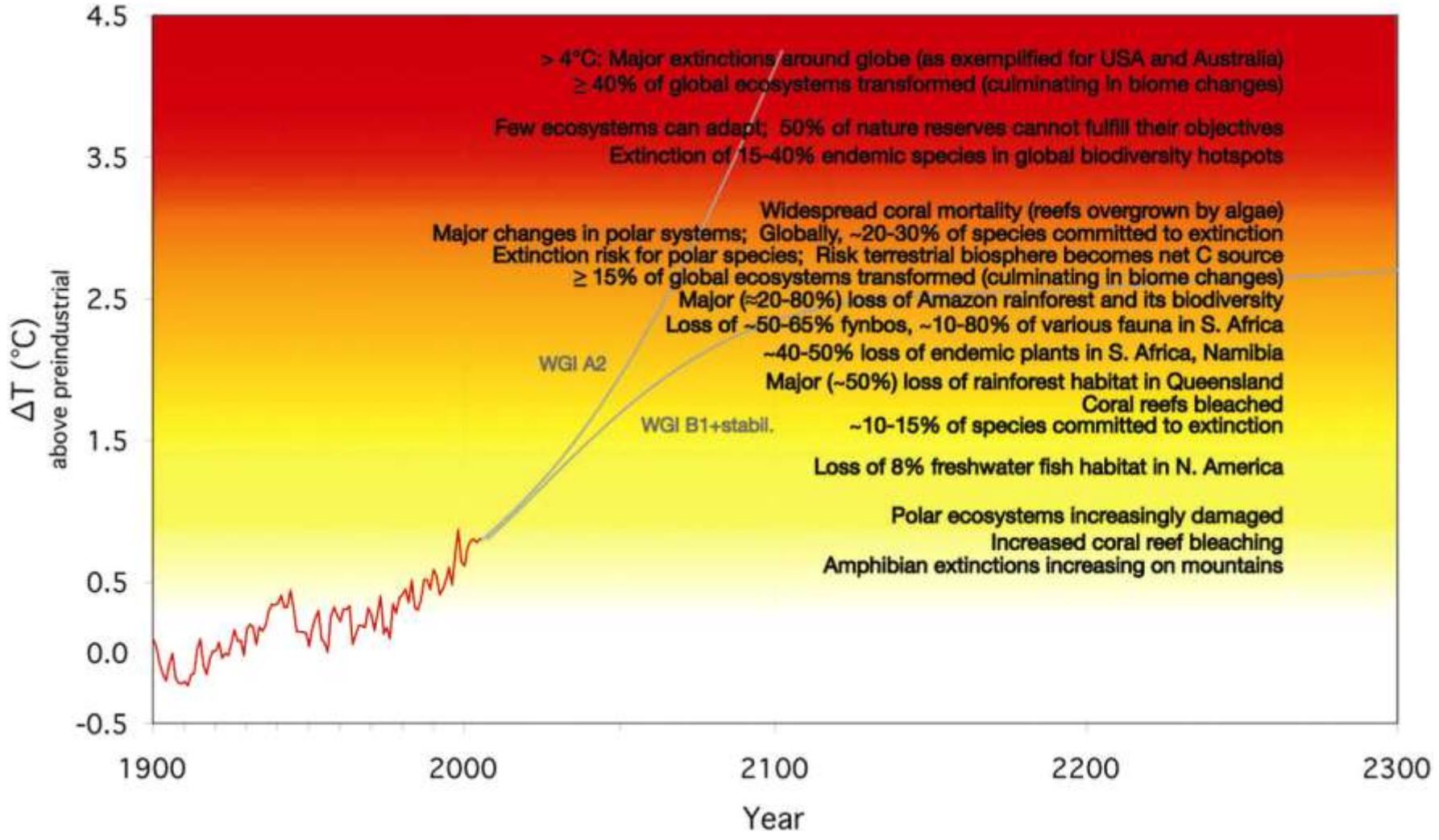
# Water at the end of the 21st century for SRES A1B




TP Figure 3.4: Ensemble mean change of annual runoff, in percent, between present (1980-1999) and 2090-2099 for the SRES A1B emissions scenario (based on Milly et al., 2005).

WMO UNEP

# Figure TS.6. Projected risks due to critical climate change impacts on ecosystems

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UNEP

# 20% - 30% of plants and animals species likely at "increased risk of extinction"

# if ΔT 1.5°C - 2.5°C (above 1990 temperature)

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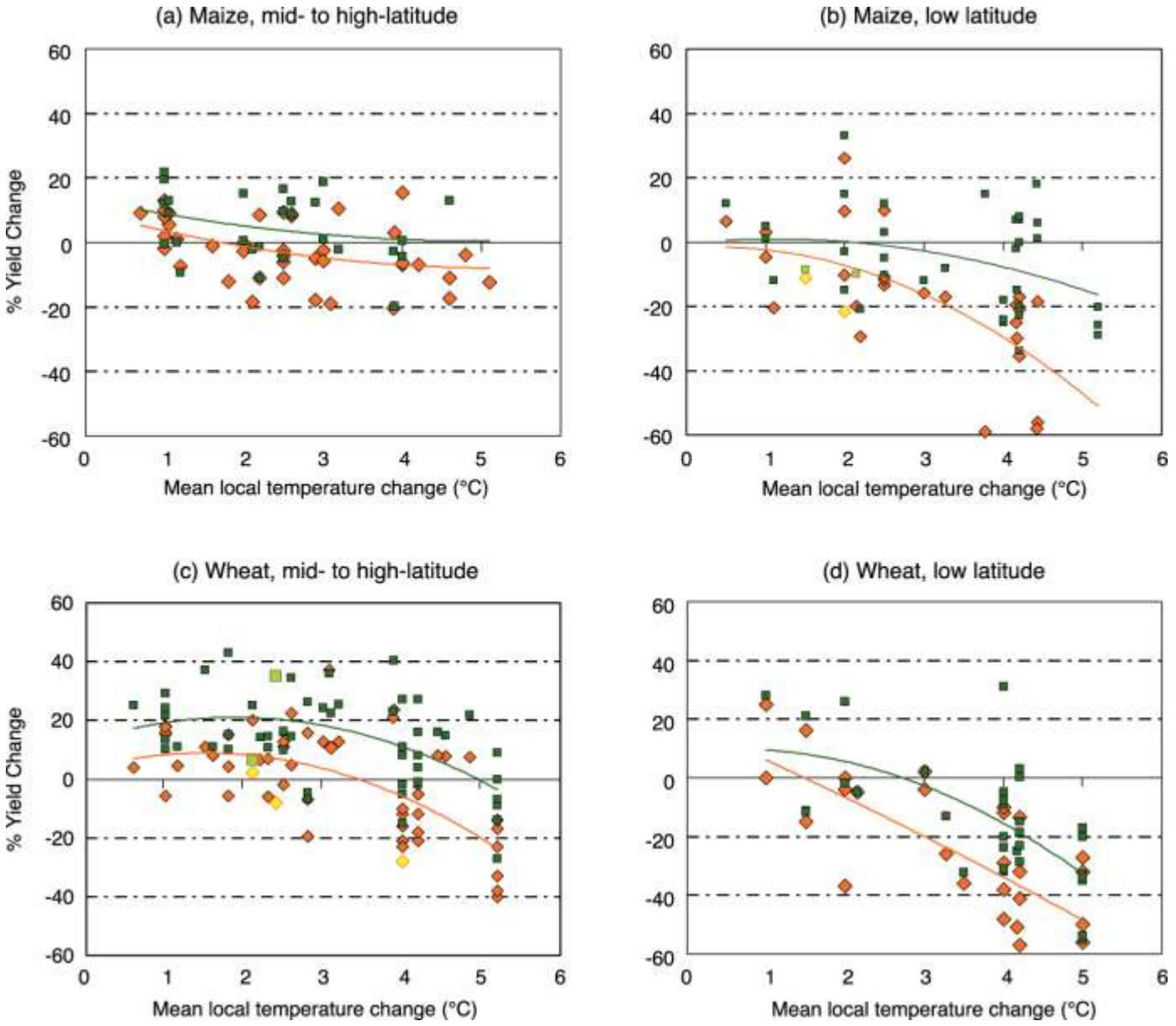
# Figure TS.7. Sensitivity of cereal yield to climate change

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UNEP

# Effects on Nile delta: 10 M people above 1m


(Time 2001)

# With 1 metre sea-level rise: 63000 ha below sea-level in Belgium (likely in 22nd century, not impossible in 21st century)

## (NB: flooded area depends on protection)


Source: N. Dendoncker (Dépt de Géographie, UCL), J.P. van Ypersele et P. Marbaix (Dépt de Physique, UCL) (www.climate.be/impact)

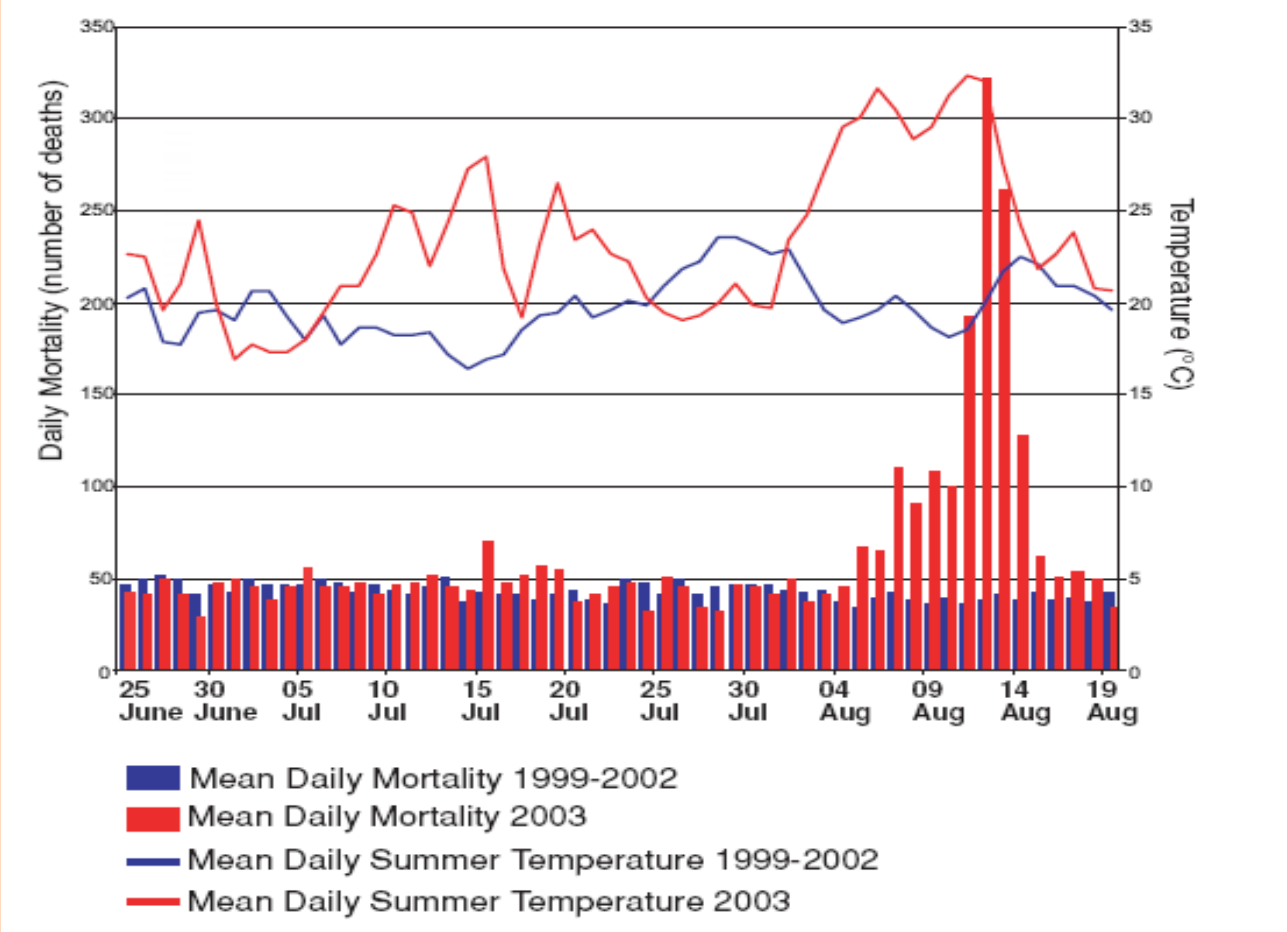
# With 8 metre sea-level rise: 3700 km$^2$ below sea-level in Belgium

## (very possible in year 3000)

## (NB: flooded area depends on protection)


Source: N. Dendoncker (Dépt de Géographie, UCL), J.P. van Ypersele et P. Marbaix (Dépt de Physique, UCL) (www.climate.be/impact)

# Daily mortality in Paris (summer 2003) (IPCC AR4 Ch 8)

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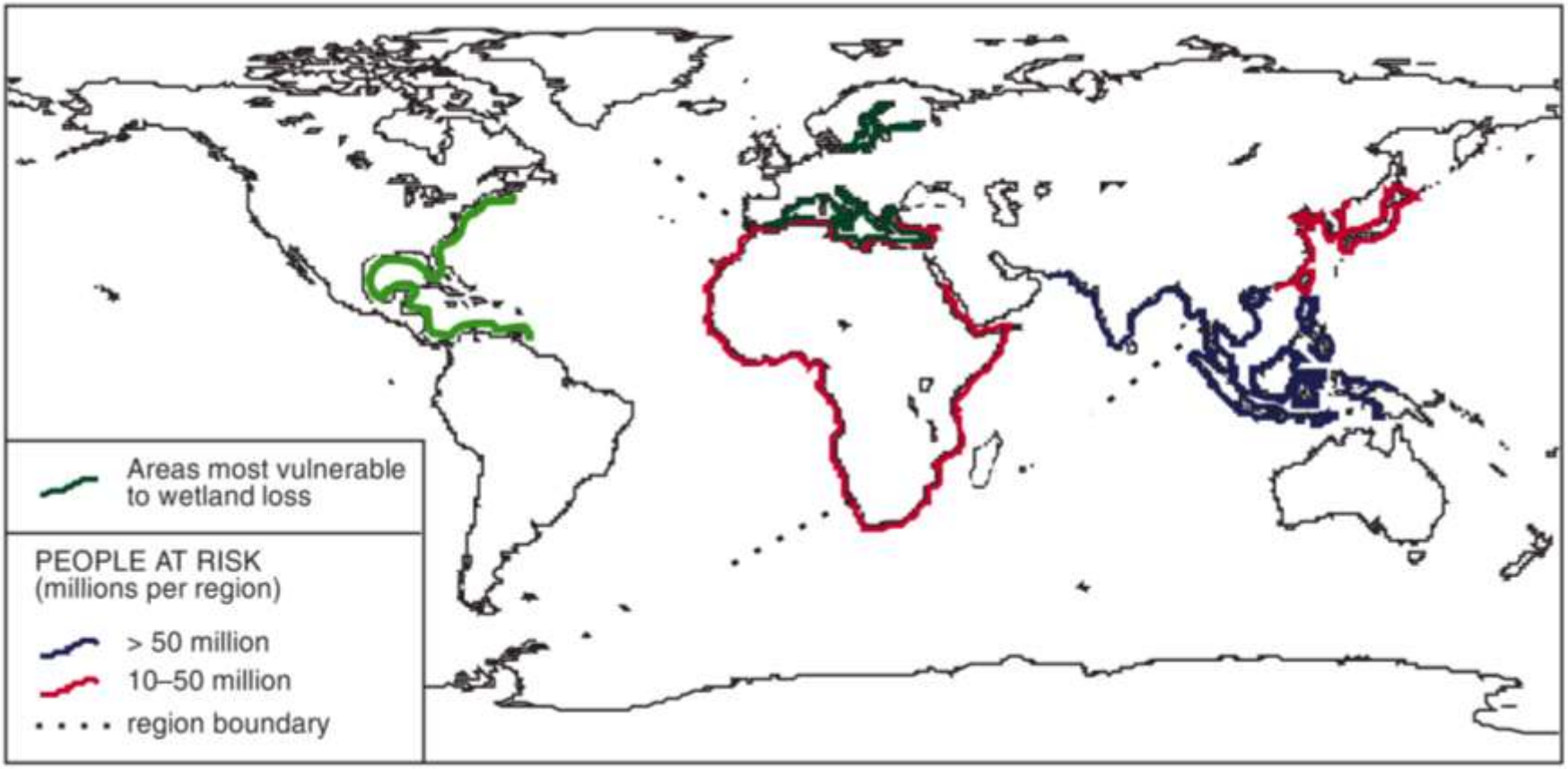
# Figure 18: Tens of millions of people are projected to be at risk of being displaced by sea level rise

**Assuming 1990s Level of Flood Protection**




*Source:* R. Nicholls, Middlesex University in the U.K. Meteorological Office. 1997. *Climate Change and Its Impacts: A Global Perspective.*

## Developing countries are the most vulnerable to climate change (from IPCC TAR)

- **Impacts are worse** - already more flood and drought prone and a large share of the economy is in climate sensitive sectors
- **Lower capacity to adapt** because of a lack of financial, institutional and technological capacity and access to knowledge
- **Climate change is likely to impact disproportionately upon the poorest countries and the poorest persons within countries**, exacerbating inequities in health status and access to adequate food, clean water and other resources.
- **Net market sector effects are expected to be negative in most developing countries**

# Regions most affected

- The Arctic
- Sub-Saharan Africa
- Small islands
- Large megadeltas

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# In all regions, there are some areas and communities which are particularly vulnerable

- The poor
- Young children
- The elderly

# Excerpts from IPCC AR4 WG2 (Chapter Asia)

**New evidences show that climate change has affected many sectors in Asia (medium confidence).**

- The crop yield in many countries of Asia has declined, partly due to rising temperatures and extreme weather events. The retreat of glaciers and permafrost in Asia in recent years is unprecedented as a consequence of warming. The frequency of occurrence of climate-induced diseases and heat stress in Central, East, South and South-East Asia has increased with rising temperatures and rainfall variability. Observed changes in terrestrial and marine ecosystems have become more pronounced

WMO UNEP

# Excerpts from IPCC AR4 WG2 (Chapter Asia)

**Future climate change is likely to affect agriculture, risk of hunger and water resource scarcity with enhanced climate variability and more rapid melting of glaciers (medium confidence).**

- **About 2.5 to 10% decrease in crop yield is projected for parts of Asia in 2020s and 5 to 30% decrease in 2050s compared with 1990 levels without CO2 effects (medium confidence).**
- **Freshwater availability in Central, South, East and South-East Asia, particularly in large river basins such as Changjiang, is likely to decrease due to climate change, along with population growth and rising standard of living that could adversely affect more than a billion people in Asia by the 2050s (high confidence)**

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# Excerpts from IPCC AR4 WG2 (Chapter Asia)

**Marine and coastal ecosystems in Asia are likely to be affected by sea-level rise and temperature increases** (high confidence).

- **Projected sea-level rise is very likely to result in significant losses of coastal ecosystems and a million or so people along the coasts of South and South-East Asia will likely be at risk from flooding** (high confidence).
- **(…) Coastal inundation is likely to seriously affect the aquaculture industry and infrastructure (…)** (high confidence).
- **Stability of wetlands, mangroves and coral reefs around Asia is likely to be increasingly threatened** (high confidence).
- **(…) Between 24% and 30% of the coral reefs in Asia are likely to be lost during the next 10 years and 30 years, respectively** (medium confidence).

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# Excerpts from IPCC AR4 WG2 (Chapter Asia)

**Climate change is likely to affect forest expansion and migration, and exacerbate threats to biodiversity resulting from land use/cover change and population pressure in most of Asia (medium confidence).**

- Increased risk of extinction for many flora and fauna species in Asia is likely as a result of the synergistic effects of climate change and habitat fragmentation
- In North Asia, forest growth and northward shift in the extent of boreal forest is likely
- The frequency and extent of forest fires in North Asia is likely to increase in the future (…)

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# Excerpts from IPCC AR4 WG2 (Chapter Asia)

**Future climate change is likely to continue to adversely affect human health in Asia (high confidence).**

- **Increases in endemic morbidity and mortality due to diarrhoeal disease primarily associated with climate change are expected in South and South-East Asia (high confidence).**
- **Increases in coastal water temperature would exacerbate the abundance and/or toxicity of cholera in south Asia (high confidence).**
- **Natural habitats of vector-borne and water-borne diseases in north Asia are likely to expand in the future (medium confidence).**

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# Excerpts from IPCC AR4 WG2 (Chapter Asia)

**Multiple stresses in Asia will be compounded further due to climate change (high confidence).**

- **It is likely that climate change will impinge on sustainable development of most developing countries of Asia as it compounds the pressures on natural resources and the environment associated with rapid urbanisation, industrialisation and economic development.**
- **Mainstreaming sustainable development policies and the inclusion of climate-proofing concepts in national development initiatives are likely to reduce pressure on natural resources and improve management of environmental risks**

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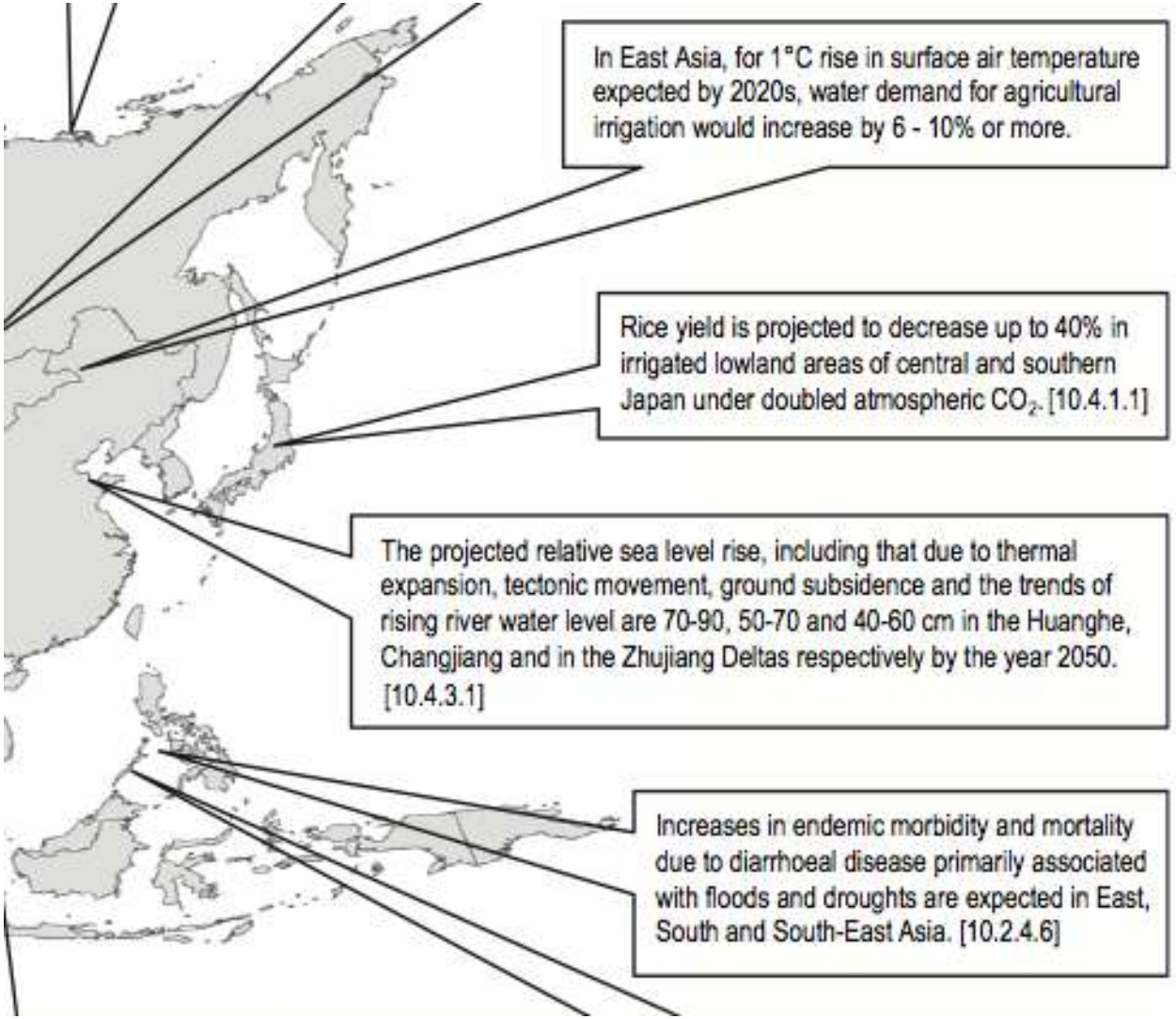
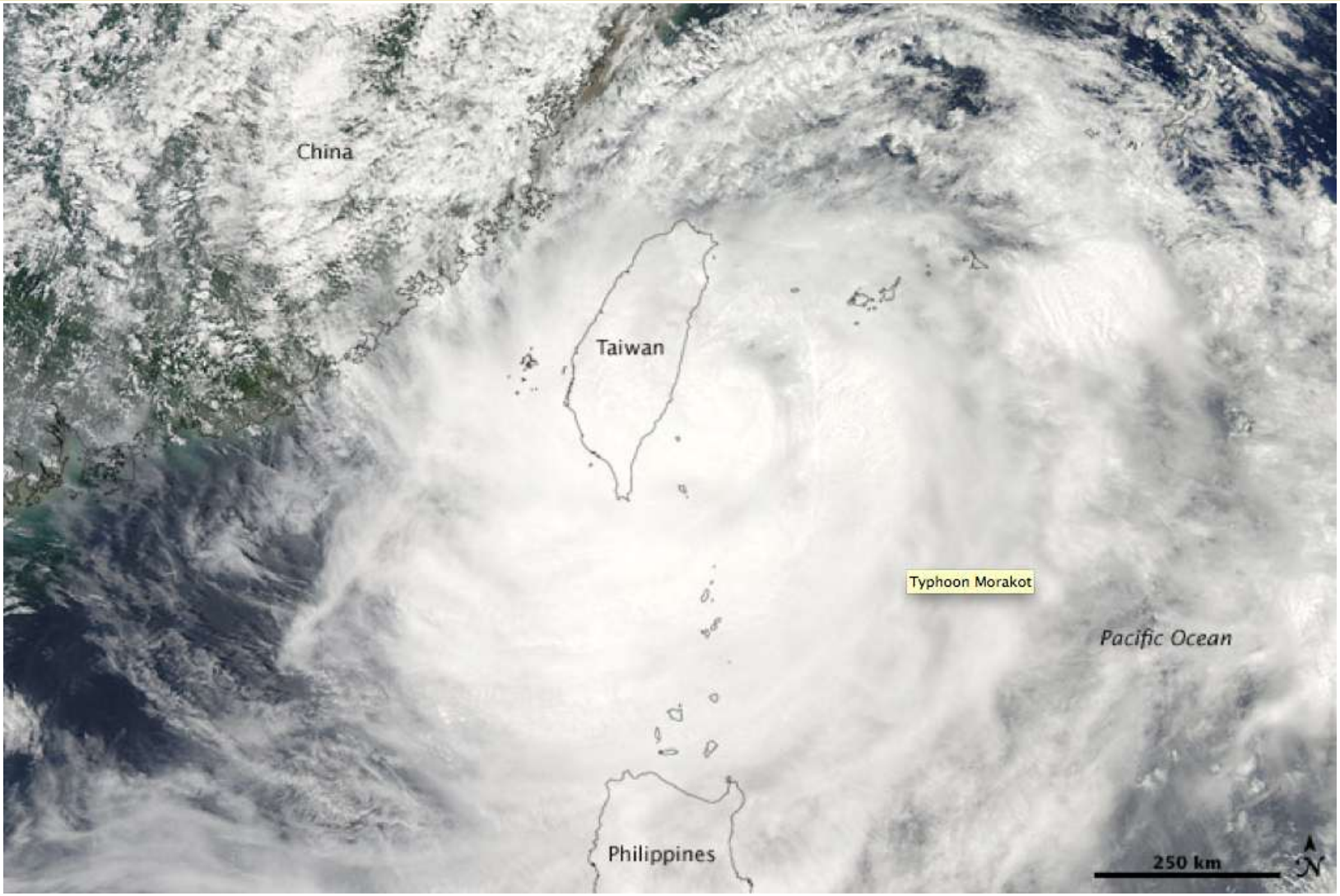
# Hotspots of key future climate impacts and vulnerabilities in East Asia



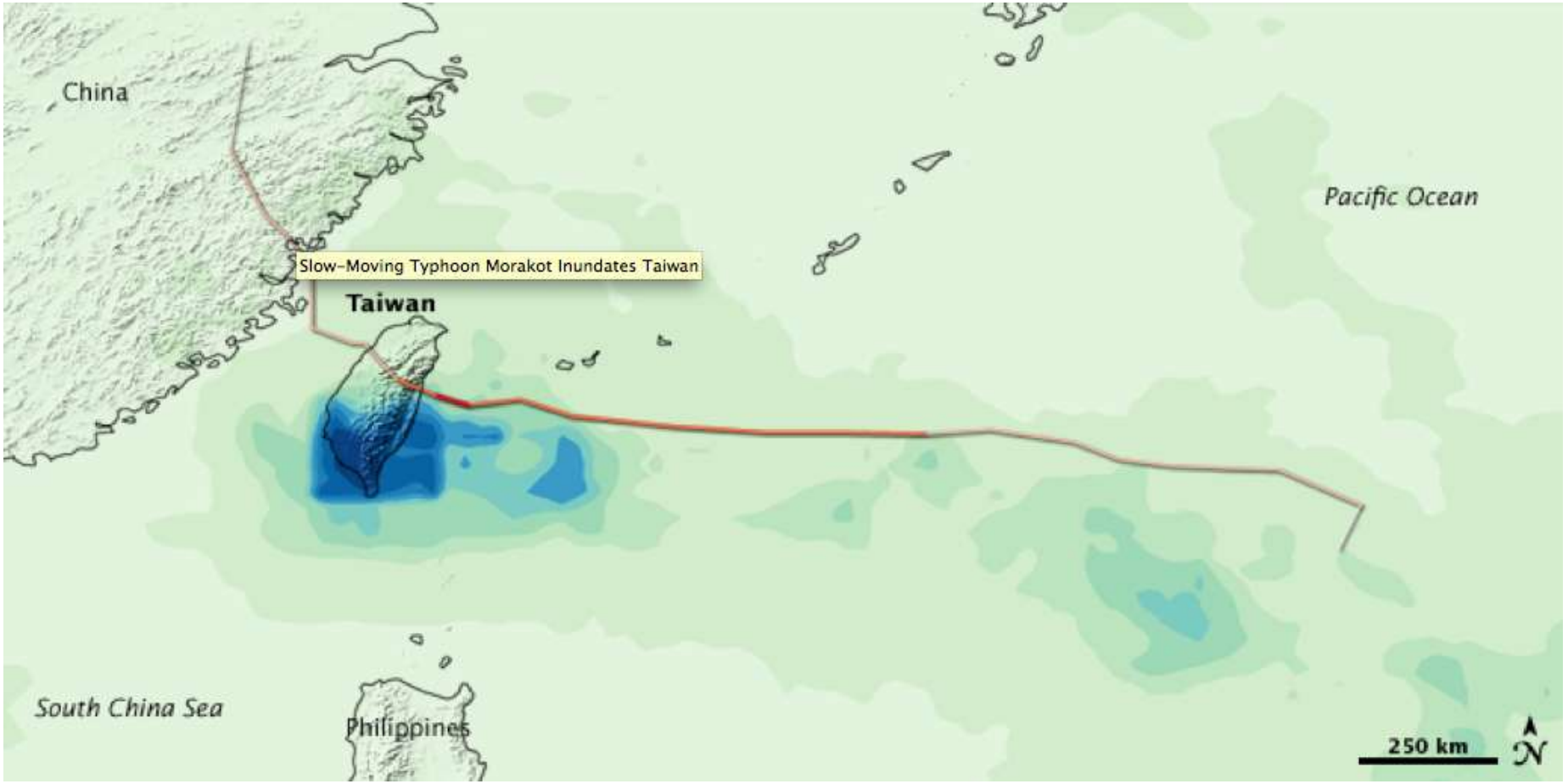

IPCC AR4, WGII, Ch.10.4, Fig. 10.4

# Typhoon Morakot (August 2009)




Nasa Earth Observatory

# Slow-Moving Typhoon Morakot Inundates Taiwan

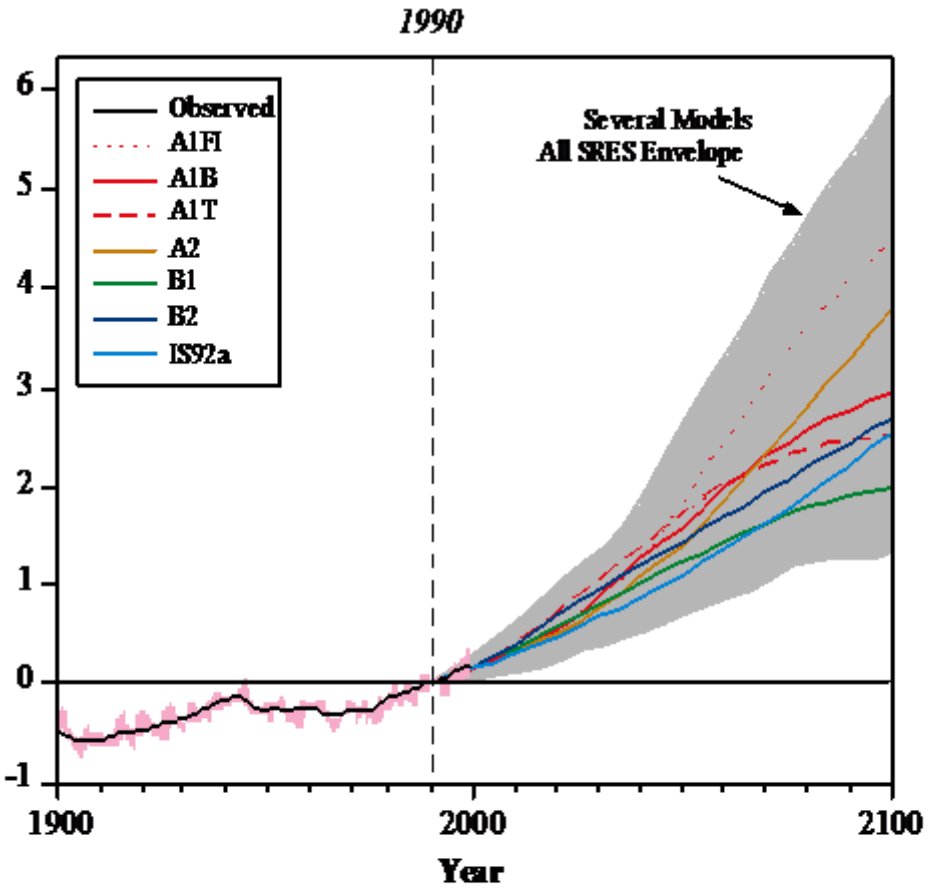


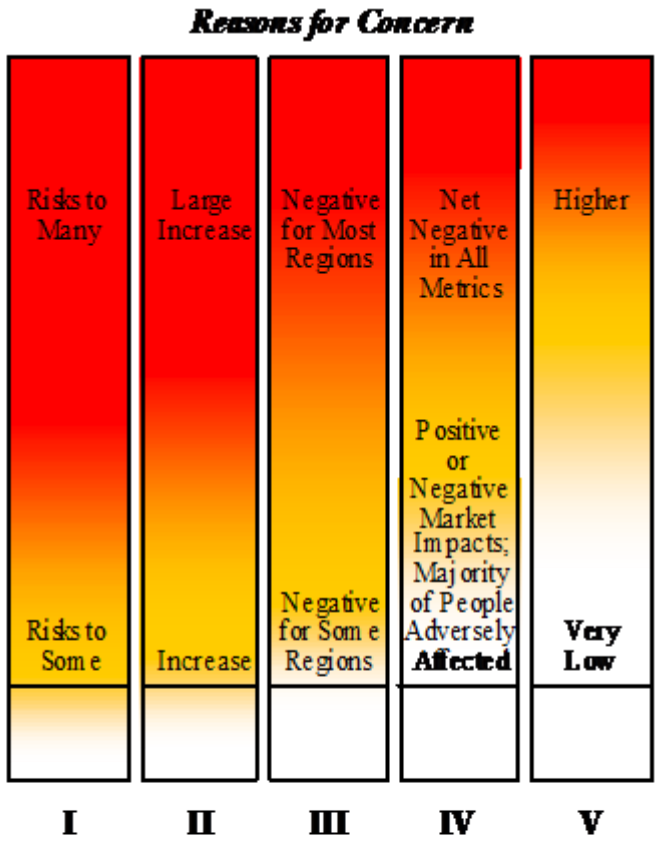

Nasa Earth Observatory

# Typhoon Morakot: Taiwan mounts rescue operation to save 700 villagers

The Telegraph (BST 12 Aug 2009)

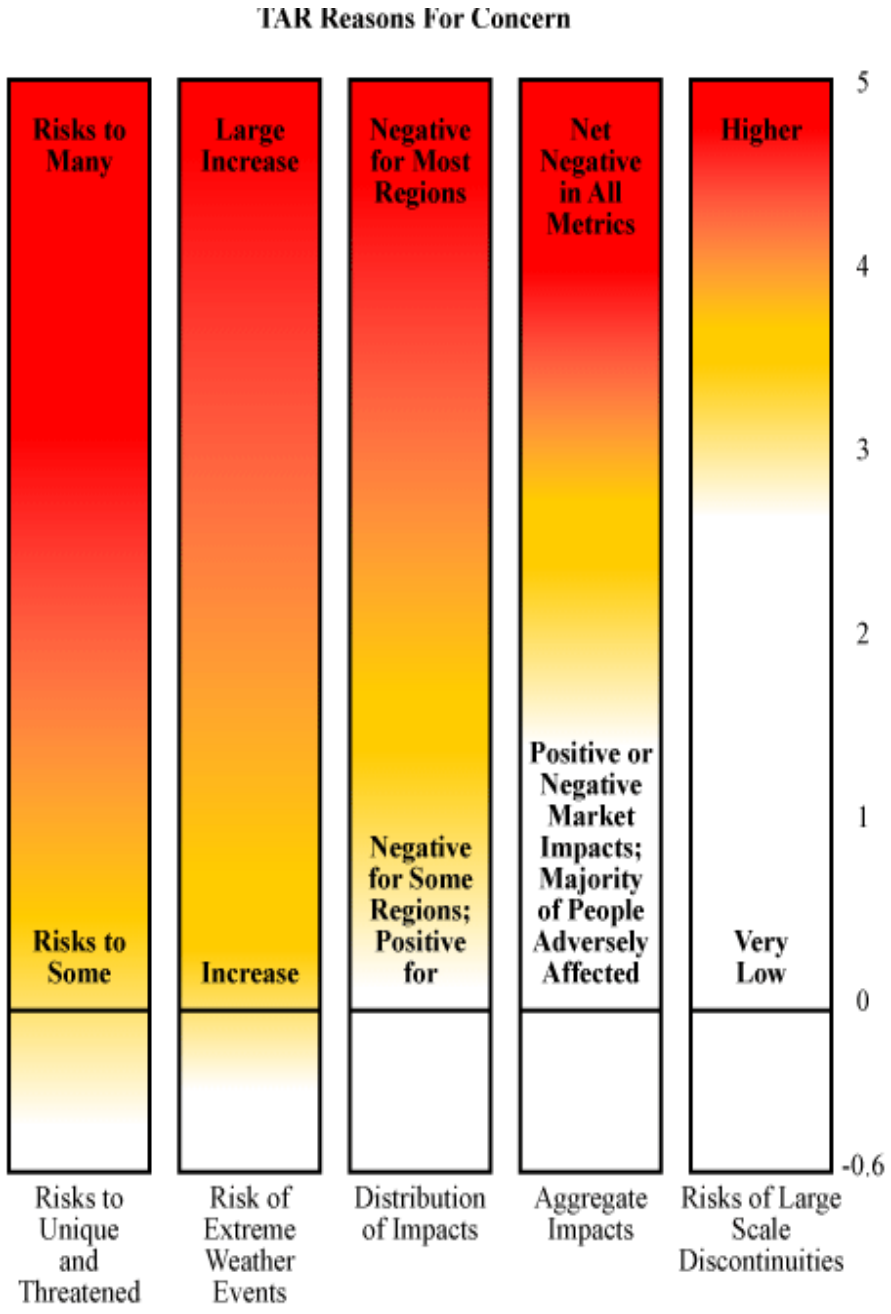
# Reasons for Concern

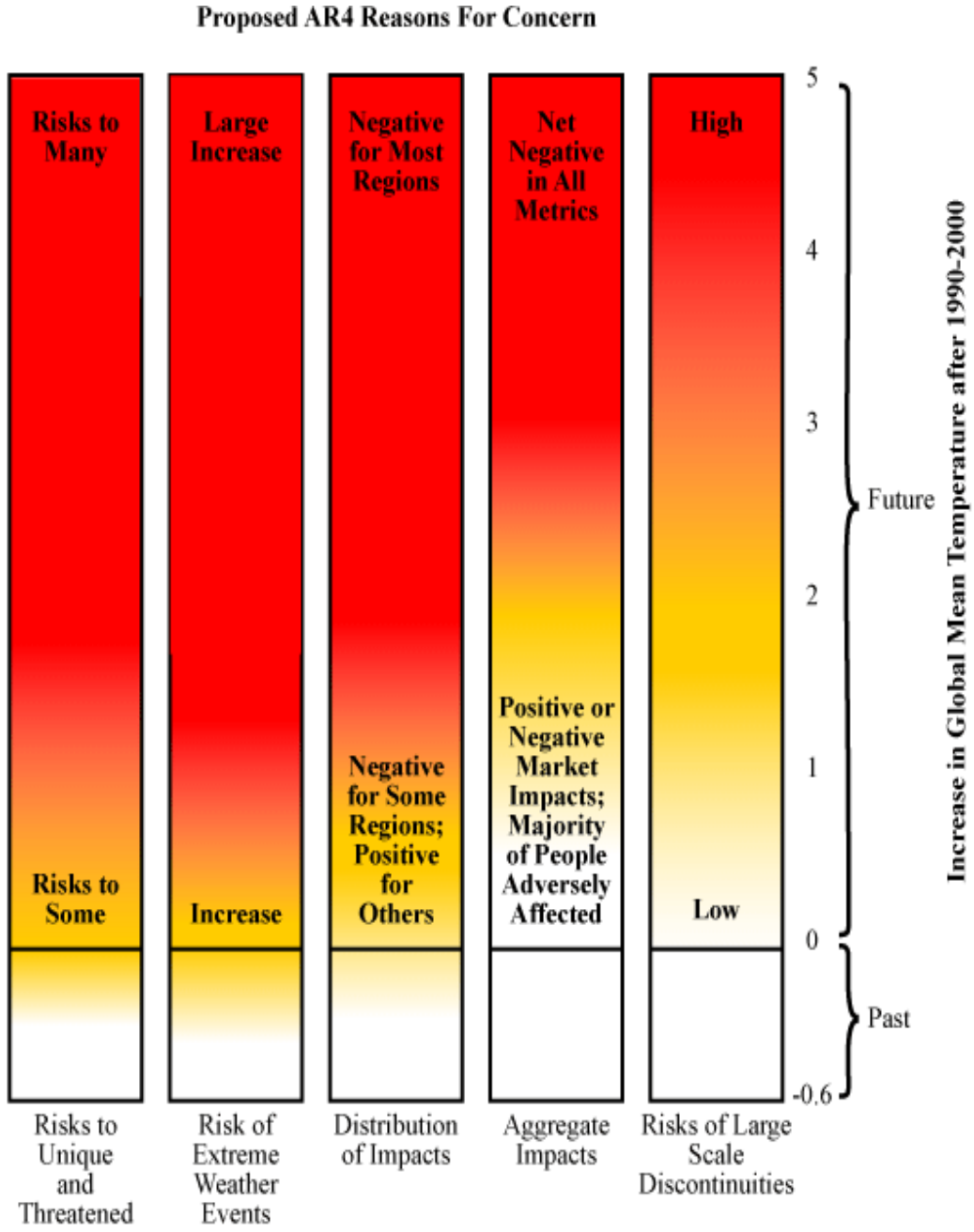



I Risks to unique and threatened systems
II Risks from extreme climate events
III Distribution of Impacts
IV Aggregate Impacts
V Risks from large-scale discontinuities

**Source: IPCC TAR WG2 (2001)**


TAR Reasons For Concern
Risks to Many
Risks to Some
Large Increase
Increase
Negative for Most Regions
Negative for Some Regions; Positive for
Net Negative in All Metrics
Positive or Negative Market Impacts; Majority of People Adversely Affected
Higher
Very Low
5
4
3
2
1
0
-0.6
Risks to Unique and Threatened
Risk of Extreme Weather Events
Distribution of Impacts
Aggregate Impacts
Risks of Large Scale Discontinuities


Proposed AR4 Reasons For Concern
Risks to Many
Risks to Some
Large Increase
Increase
Negative for Most Regions
Negative for Some Regions; Positive for Others
Net Negative in All Metrics
Positive or Negative Market Impacts; Majority of People Adversely Affected
High
Low
5
4
3
2
1
0
-0.6
Future
Past
Increase in Global Mean Temperature after 1990-2000
Risks to Unique and Threatened
Risk of Extreme Weather Events
Distribution of Impacts
Aggregate Impacts
Risks of Large Scale Discontinuities

# Adaptation will be necessary to address unavoidable impacts

# Adaptation/Mitigation

(not verbatim)

- Some adaptation is occurring now, faces limitations and barriers
- Other stresses can exacerbate vulnerability
- Vulnerability depends also on development paths
- Sustainable development can reduce vulnerability
- Mitigation can reduce, delay or avoid impacts

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# What does IPCC tell us on mitigation?

- WG3: Mitigation

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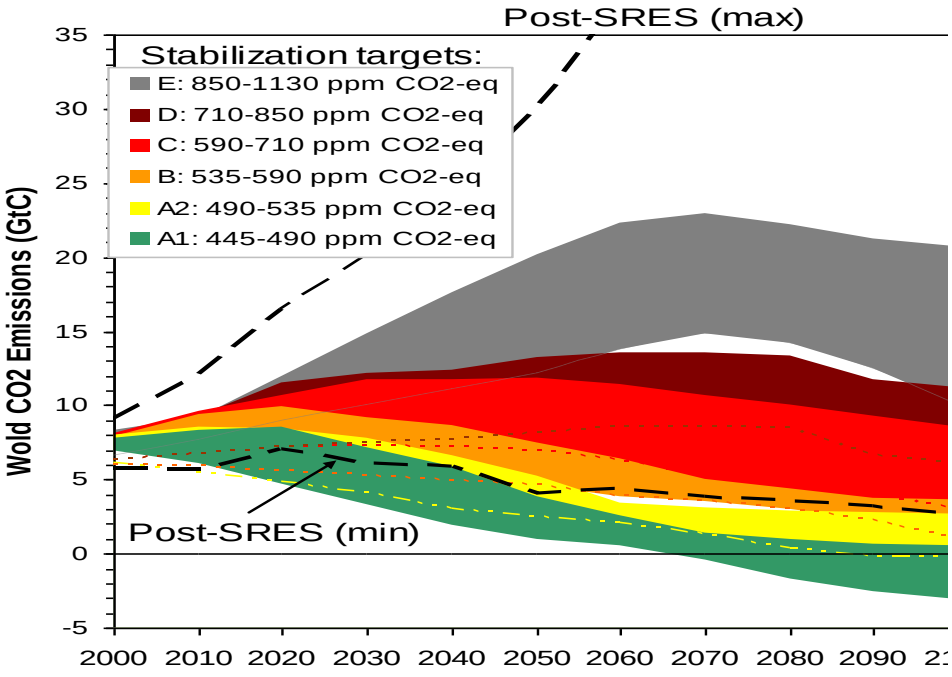
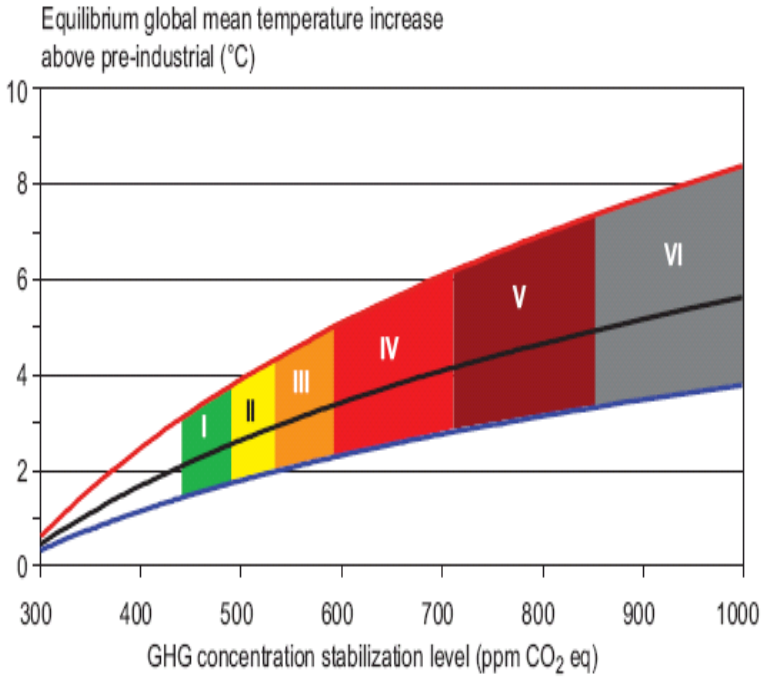
# The lower the stabilisation level the earlier global emissions have to go down




Multigas and CO2 only studies combined



# Long term mitigation (after 2030)

- The lower the stabilization level, the more quickly emissions would need to peak and to decline thereafter
- Mitigation efforts over the next two to three decades will have a large impact on opportunities to achieve lower stabilization levels

| Stab level (ppm CO2-eq) | Global Mean temp. increase at equilibrium (°C) | Year CO2 needs to peak | Reduction in 2050 compared to 2000 |
|---|---|---|---|
| 445 – 490 | 2.0 – 2.4 | 2000 - 2015 | -85 to -50 |
| 490 – 535 | 2.4 – 2.8 | 2000 - 2020 | -60 to -30 |
| 535 – 590 | 2.8 – 3.2 | 2010 - 2030 | -30 to +5 |
| 590 – 710 | 3.2 – 4.0 | 2020 - 2060 | +10 to +60 |
| 710 – 855 | 4.0 – 4.9 | 2050 - 2080 | +25 to +85 |
| 855 – 1130 | 4.9 – 6.1 | 2060 - 2090 | +90 to +140 |

# Contribution of Working Group III to the Fourth Assessment Report of the IPCC,

- **Chapter 13, page 776:**

**Box 13.7 The range of the difference between emissions in 1990 and emission allowances in 2020/2050 for various GHG concentration levels for Annex I and non-Annex I countries as a group[a]**

| Scenario category | Region | 2020 | 2050 |
|---|---|---|---|
| *A-450 ppm $CO_2$-eq[b]* | Annex I | –25% to –40% | –80% to –95% |
| | Non-Annex I | Substantial deviation from baseline in Latin America, Middle East, East Asia and Centrally-Planned Asia | Substantial deviation from baseline in all regions |
| *B-550 ppm $CO_2$-eq* | Annex I | -10% to -30% | -40% to -90% |
| | Non-Annex I | Deviation from baseline in Latin America and Middle East, East Asia | Deviation from baseline in most regions, especially in Latin America and Middle East |
| *C-650 ppm $CO_2$-eq* | Annex I | 0% to -25% | -30% to -80% |
| | Non-Annex I | Baseline | Deviation from baseline in Latin America and Middle East, East Asia |

Notes:

[a] The aggregate range is based on multiple approaches to apportion emissions between regions (contraction and convergence, multistage, Triptych and intensity targets, among others). Each approach makes different assumptions about the pathway, specific national efforts and other variables. Additional extreme cases – in which Annex I undertakes all reductions, or non-Annex I undertakes all reductions – are not included. The ranges presented here do not imply political feasibility, nor do the results reflect cost variances.

[b] Only the studies aiming at stabilization at 450 ppm $CO_2$-eq assume a (temporary) overshoot of about 50 ppm (See Den Elzen and Meinshausen, 2006).

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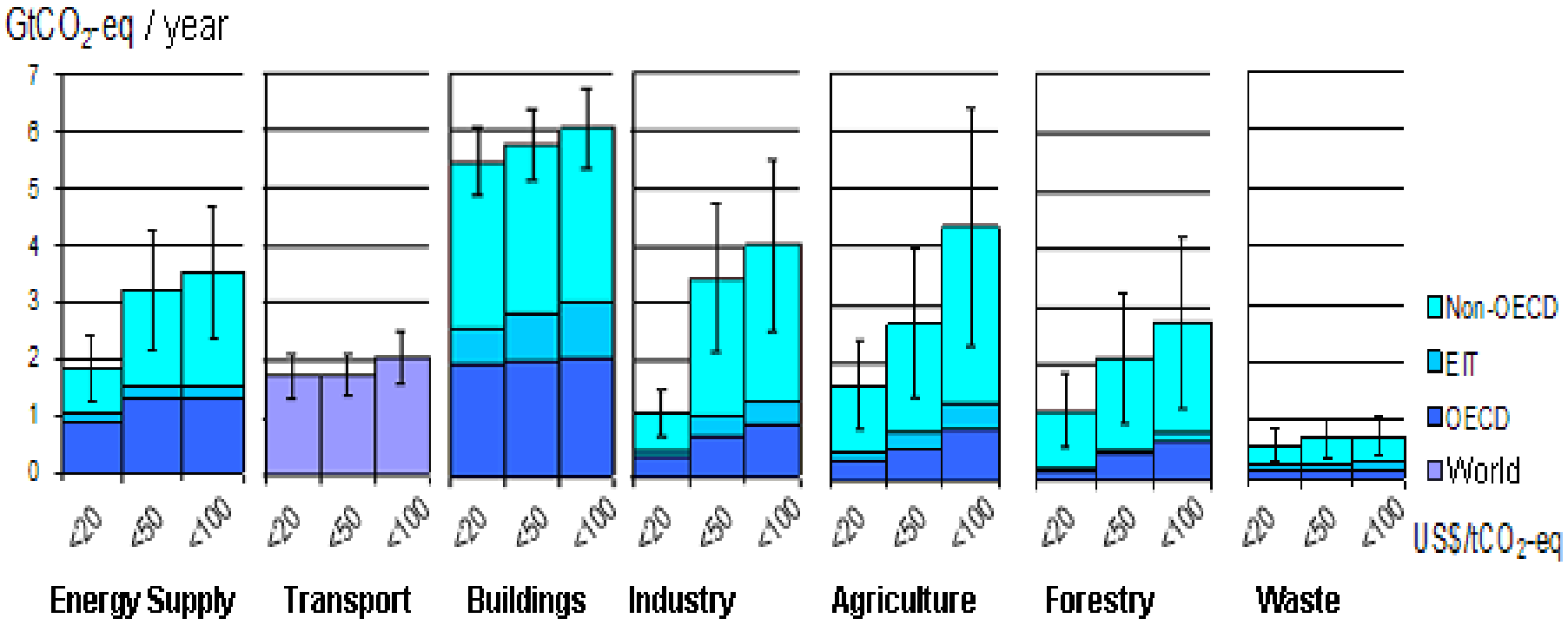
# All sectors and regions have the potential to contribute by 2030



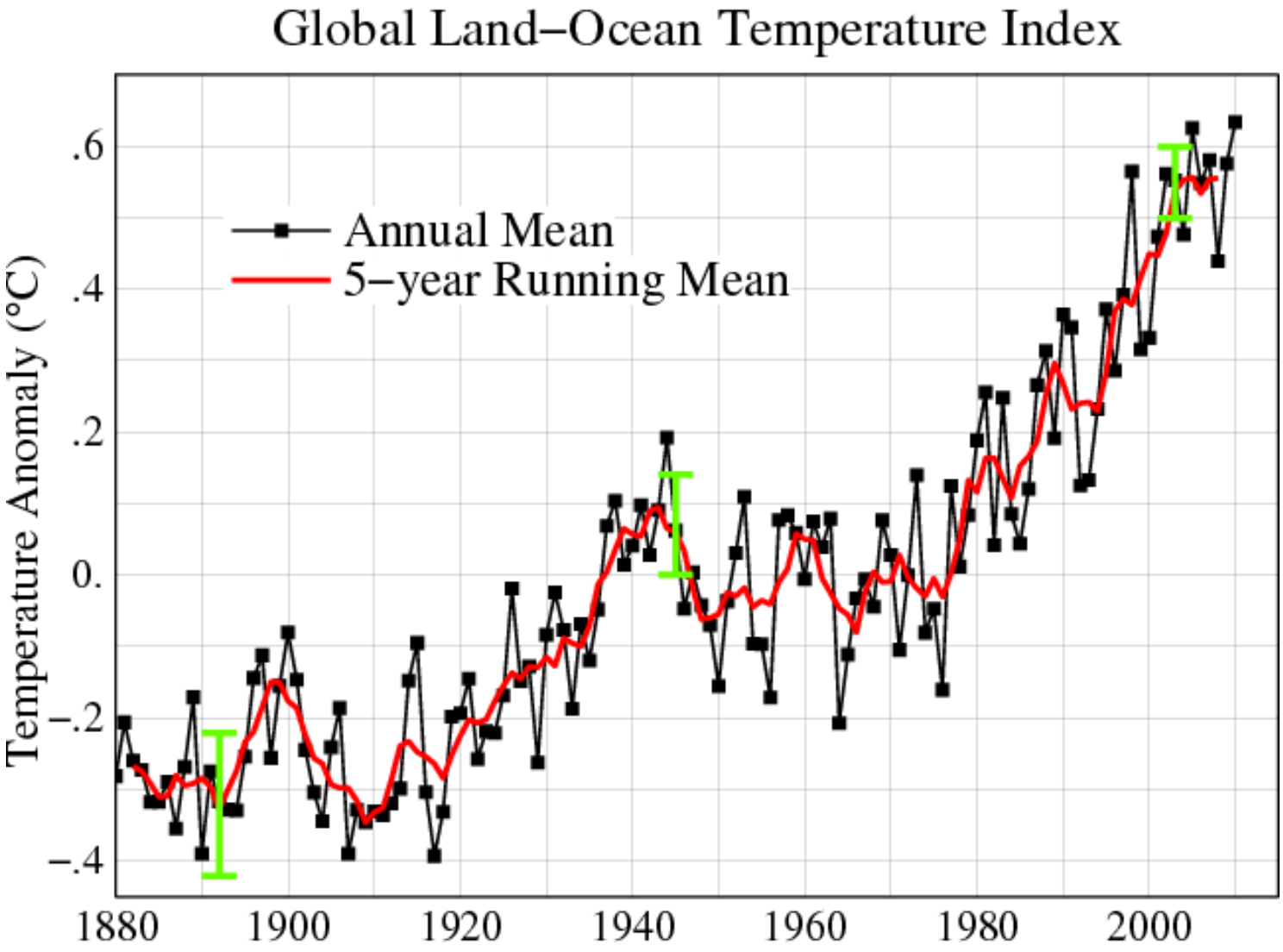

Note: estimates do not include non-technical options, such as lifestyle changes.

## **John Holdren, Past-President of the American Association for the Advancement of Science, now President Obama's science adviser**

- ***'We basically have three choices – mitigation, adaptation, and suffering.***
- ***We're going to do some of each. The question is what the mix is going to be.***
- ***The more mitigation we do, the less adaptation will be required, and the less suffering there will be.'***

Jean-Pascal van Ypersele
(vanypersele@astr.ucl.ac.be)

# *Warming has not « stopped »: Global (land & ocean) mean surface temperature change from NASA GISS until 2010*




Source: NASA GISS

# Useful links:

- www.ipcc.ch : IPCC
- www.unfccc.int : Climate Convention
- www.climate.be/JCM: interactive climate model
- www.climate.be/vanyp : my slides and other documents

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