Climate Change: What do we know, according to IPCC (WG1)?

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NB: Unless labeled otherwise, the source of the diagrams and tables shown is the IPCC AR4

Introduction

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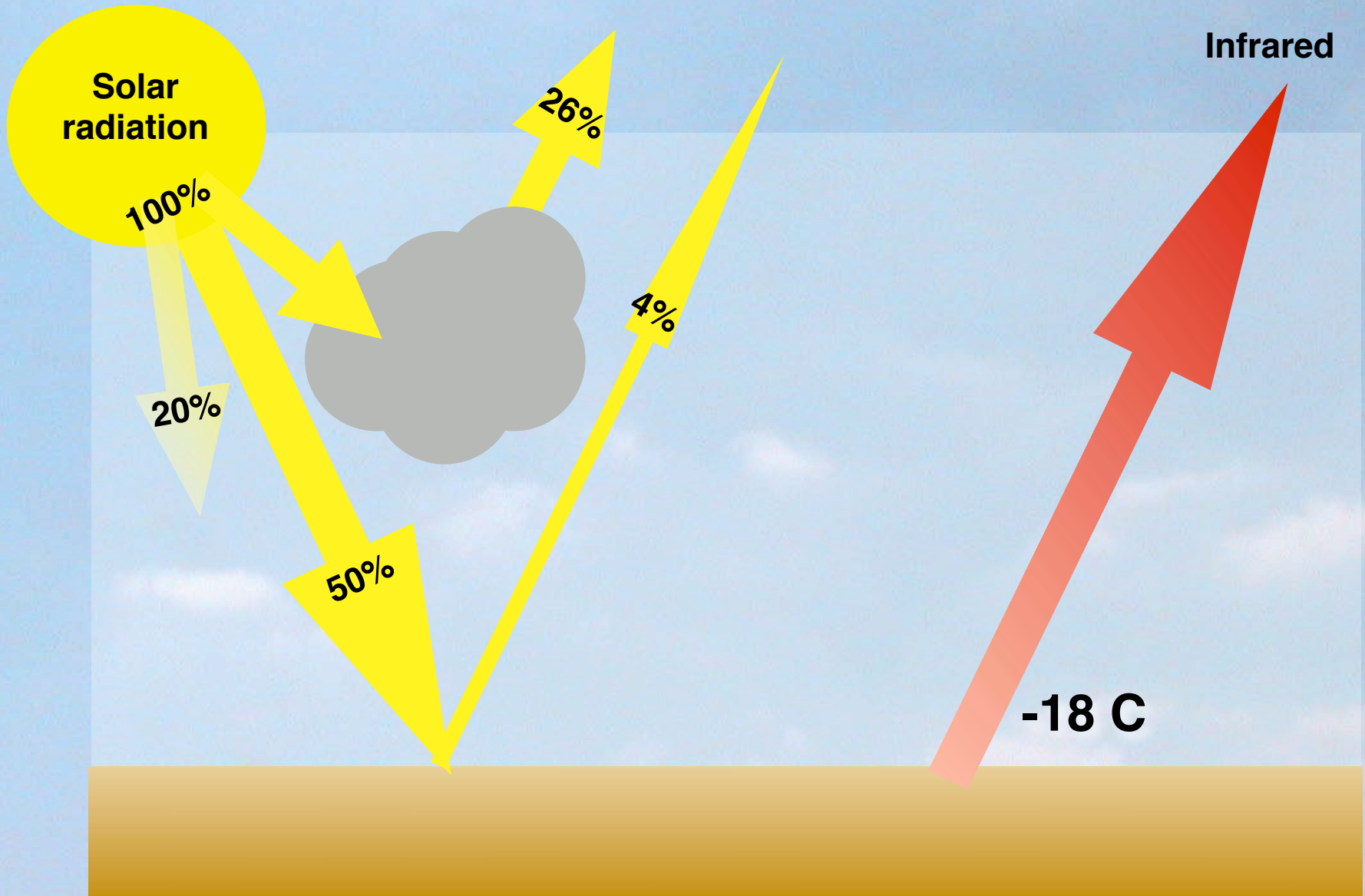
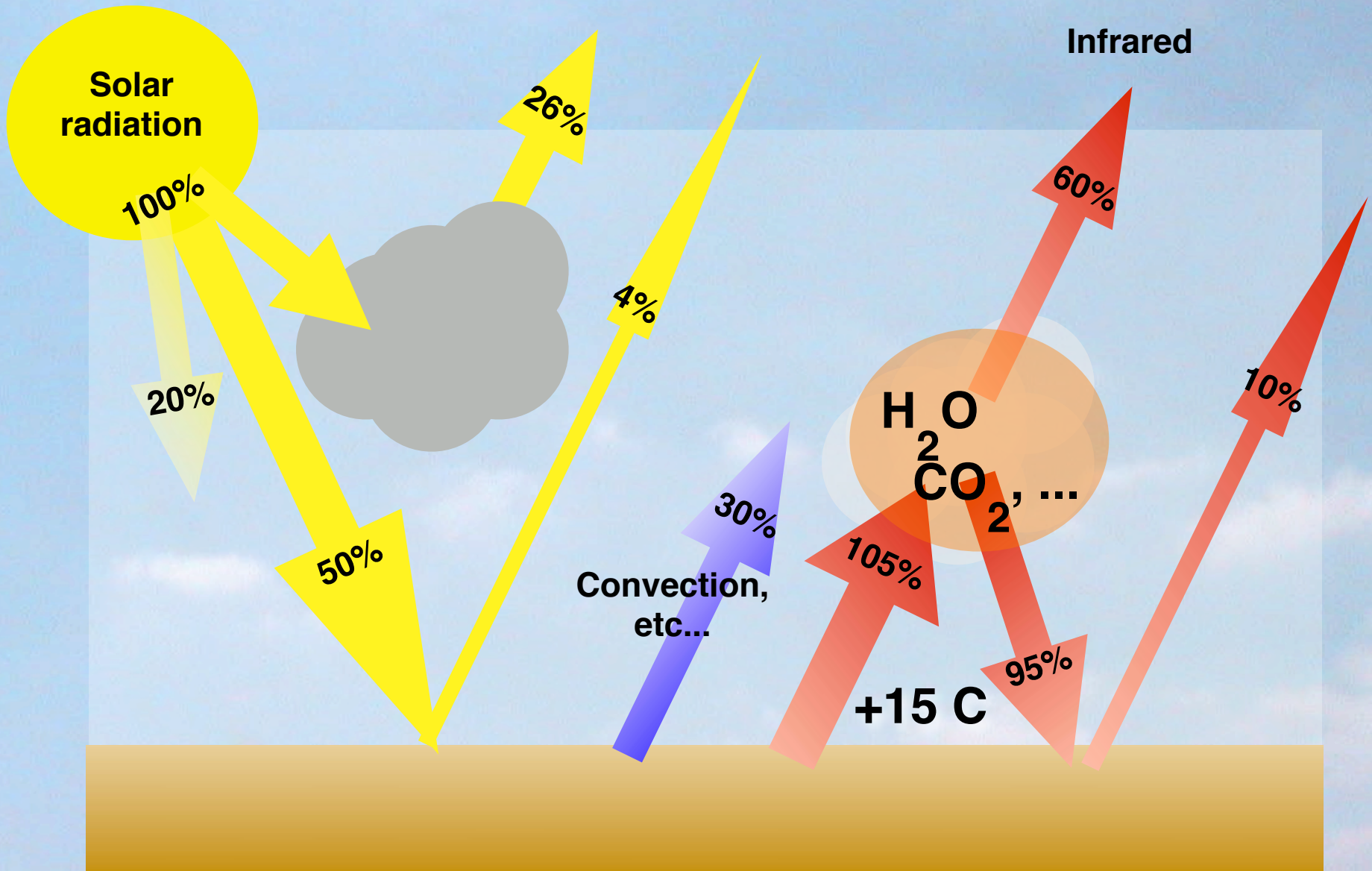
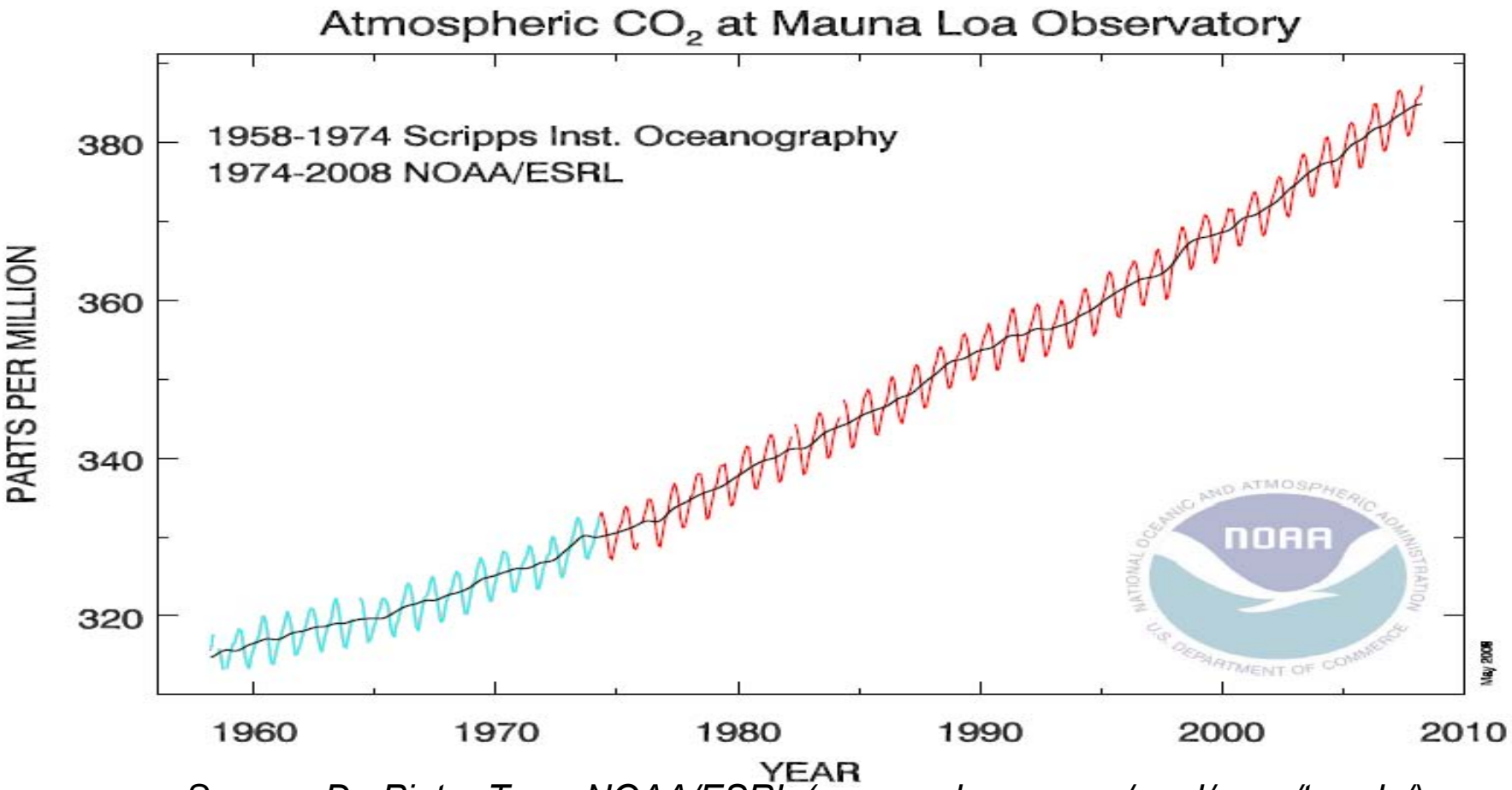
Energy cycle without greenhouse effect



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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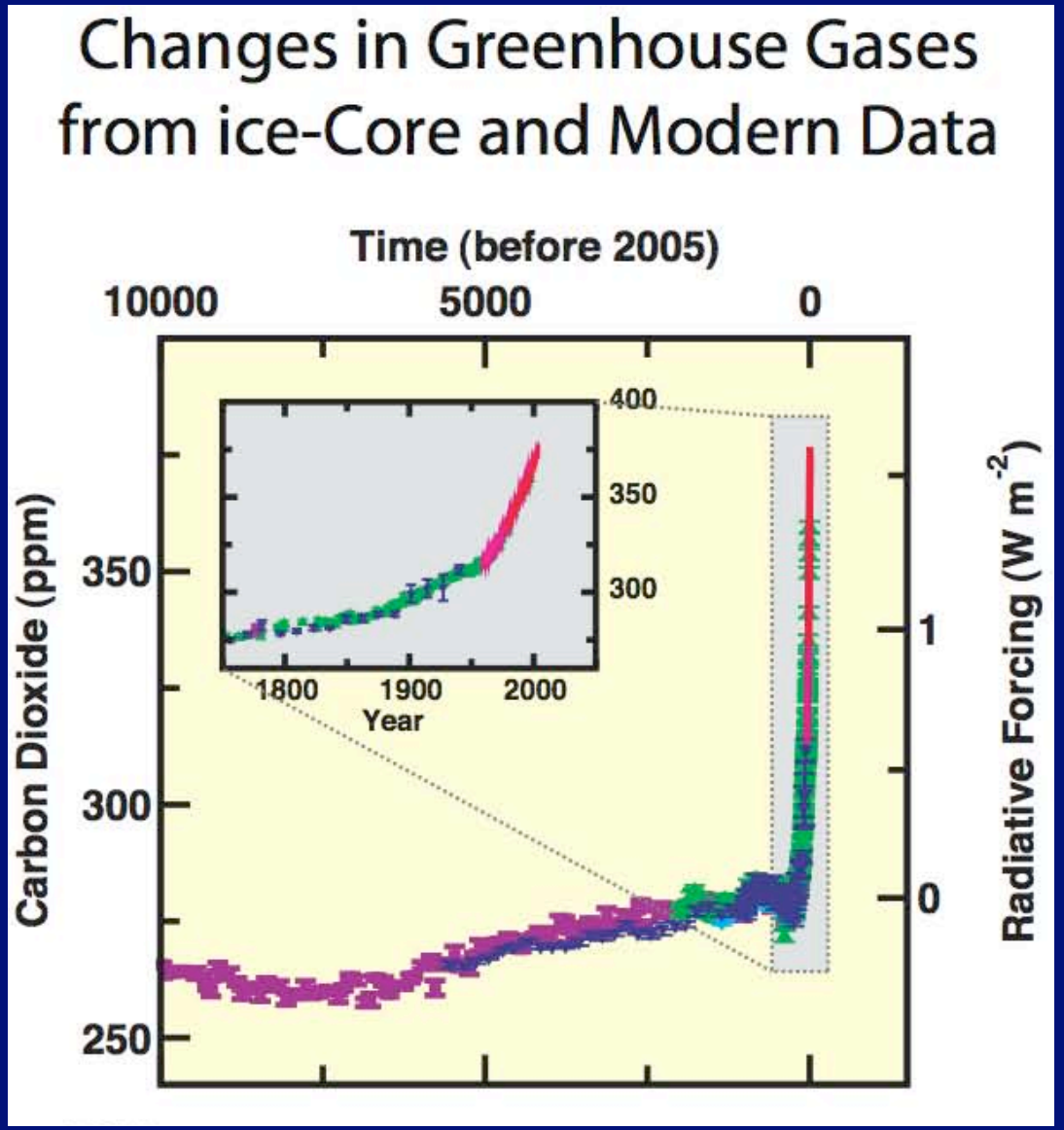
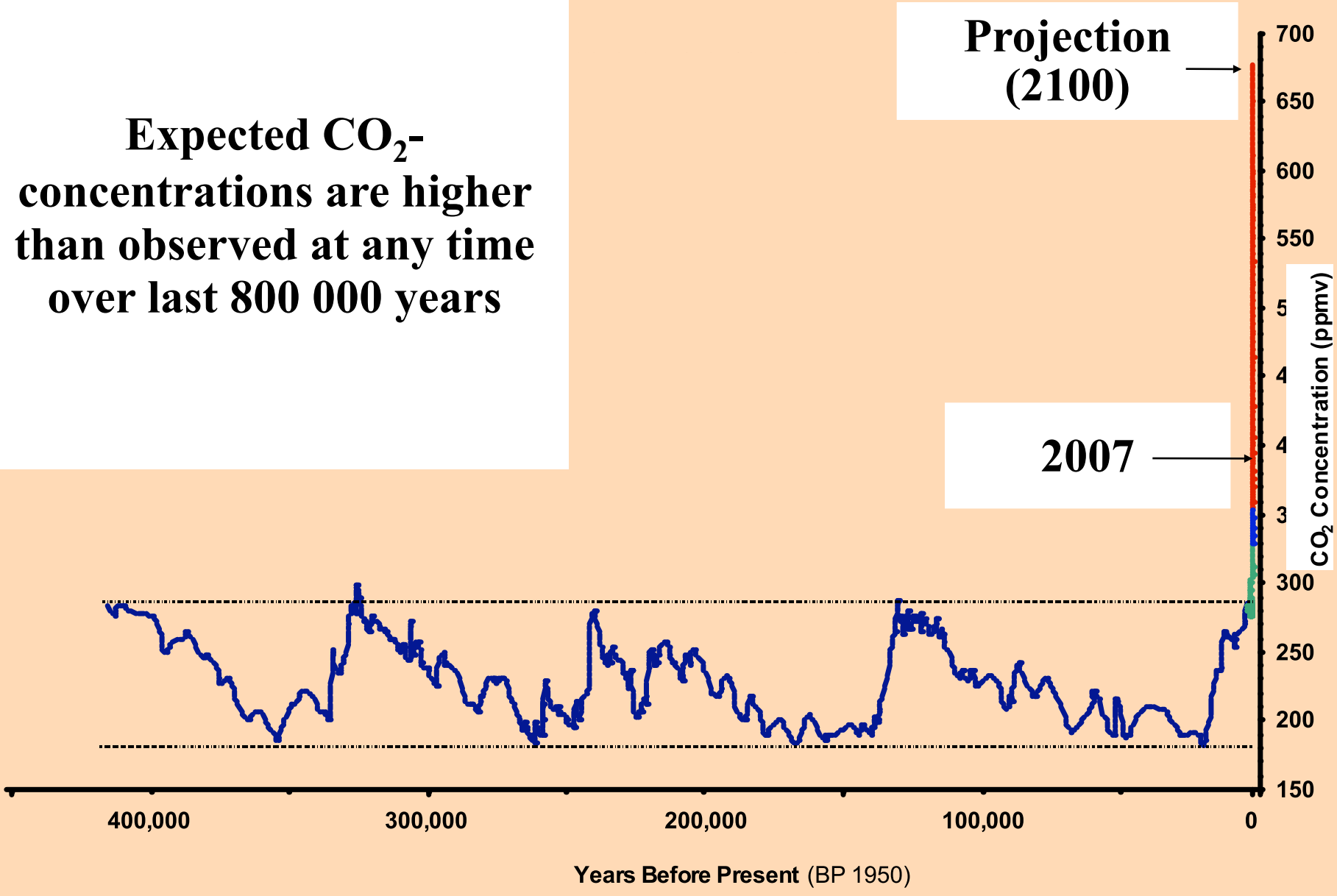
Human and Natural Drivers of Climate Change: Unprecedented

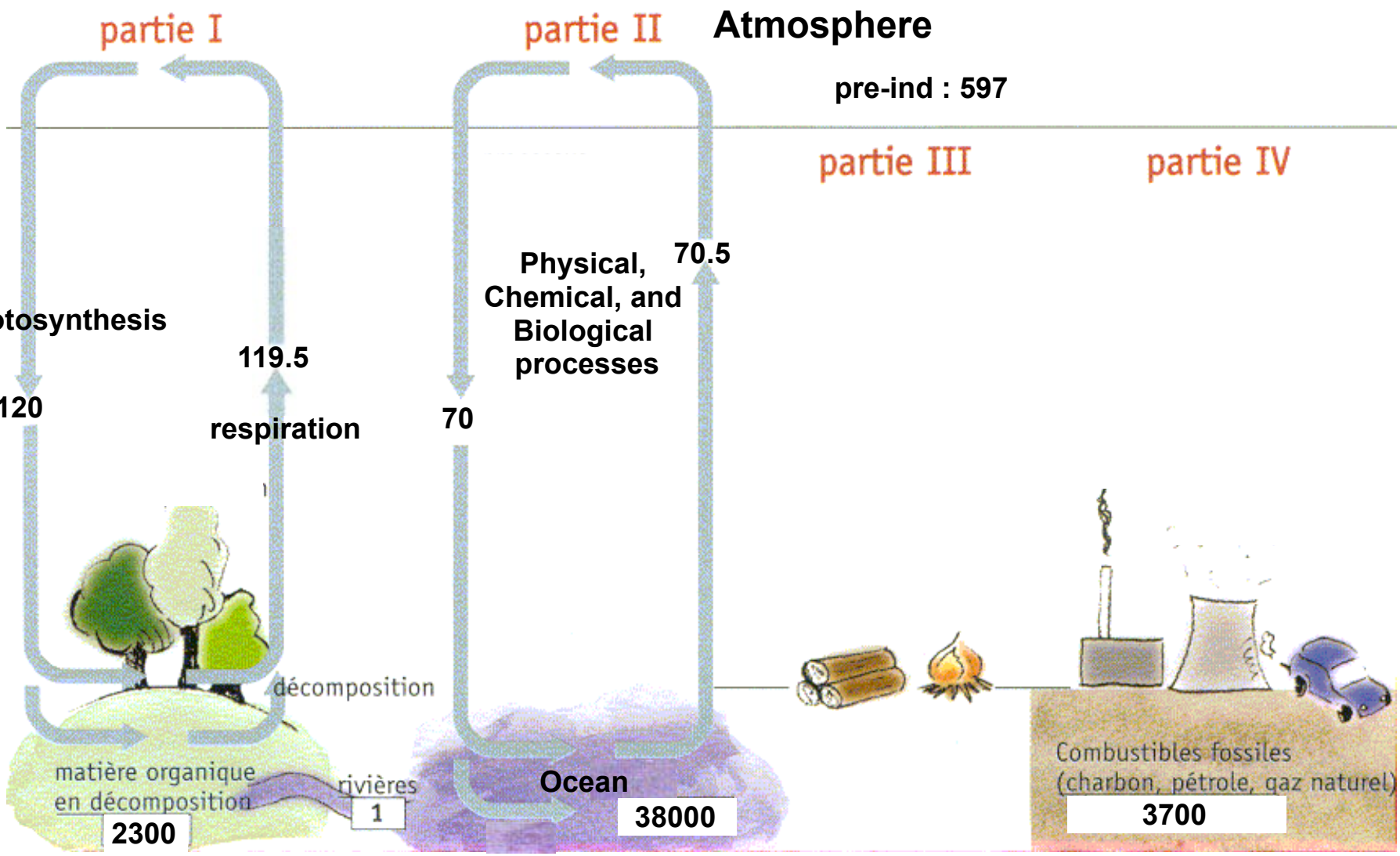
- Dramatic rise in the industrial era
- Largest growth rate of CO2 seen over the last ten years (1995-2005) than in any decade at least since direct measurements began (1960).



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



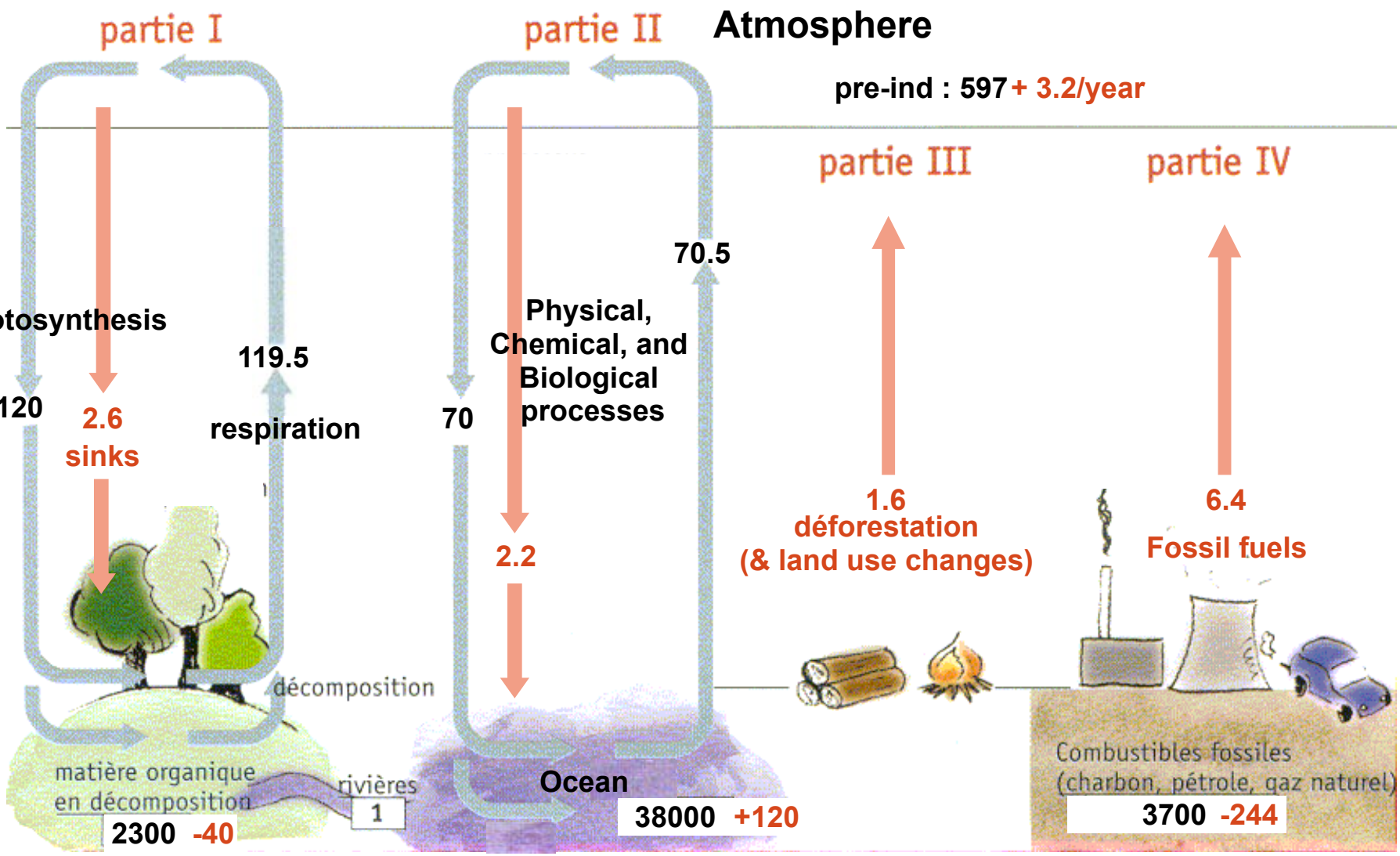
Carbon cycle



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

Source: vanyp@climate.be

Carbon cycle



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

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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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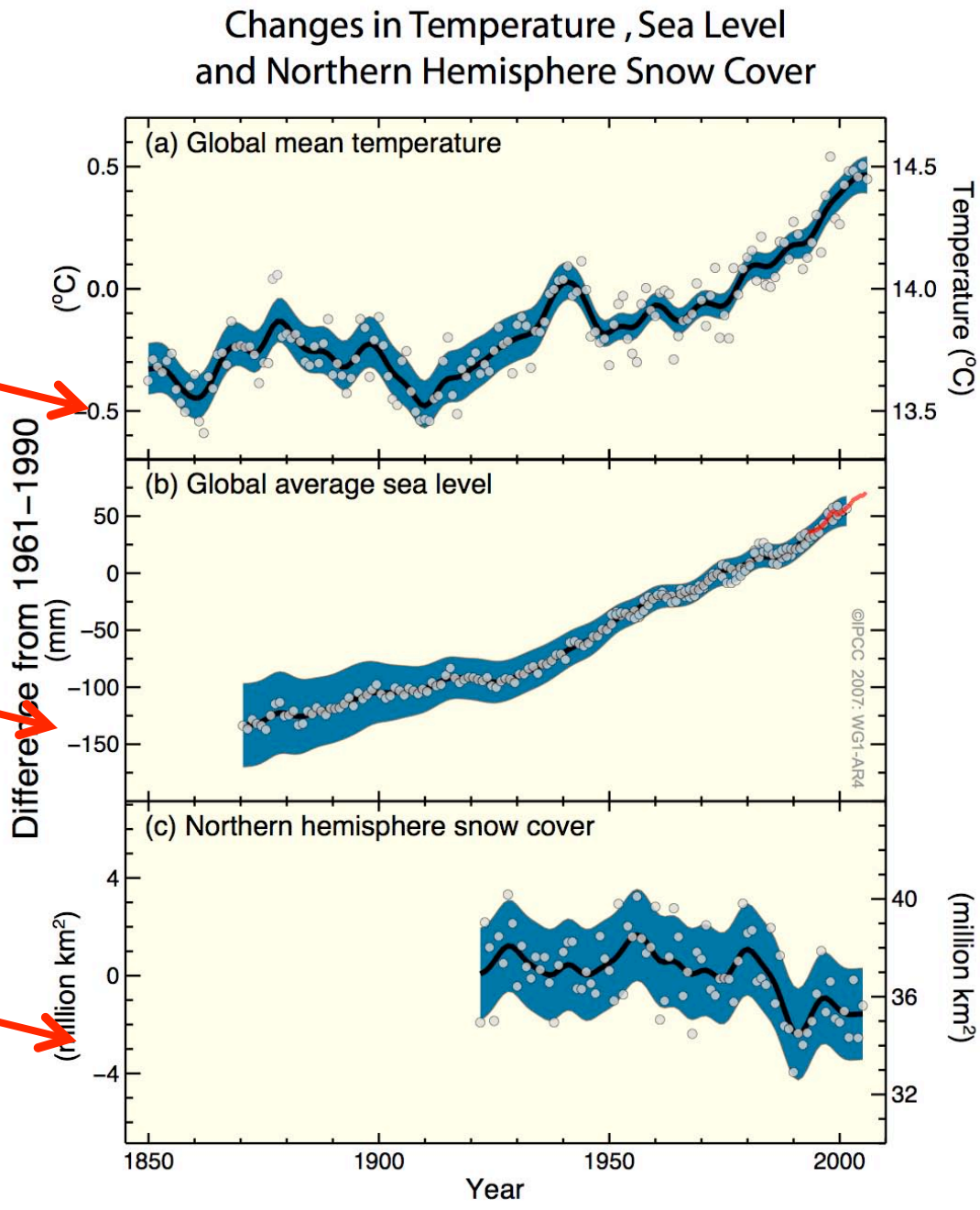
Warming is Unequivocal

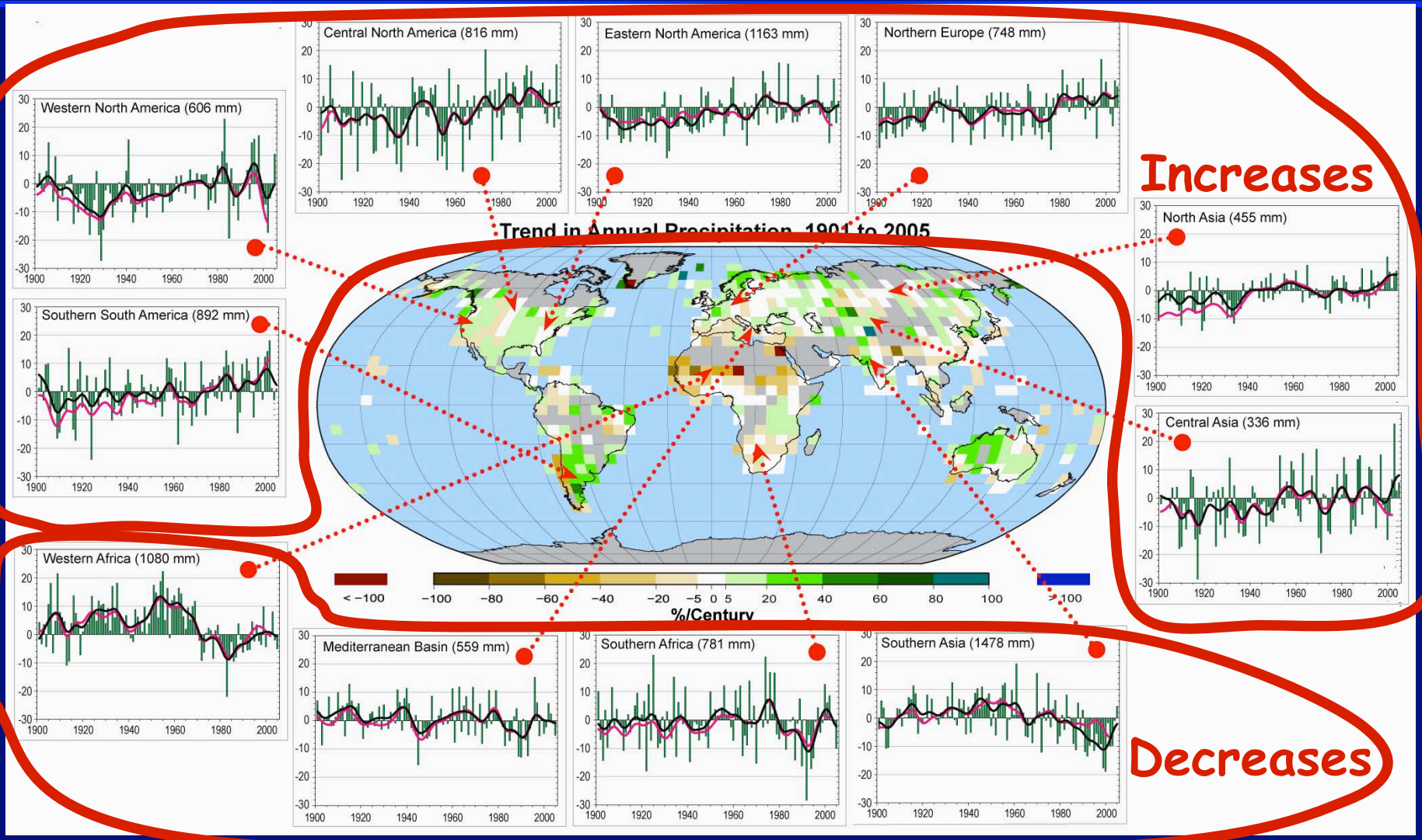
Rising atmospheric temperature

Rising sea level

Reductions in NH snow cover

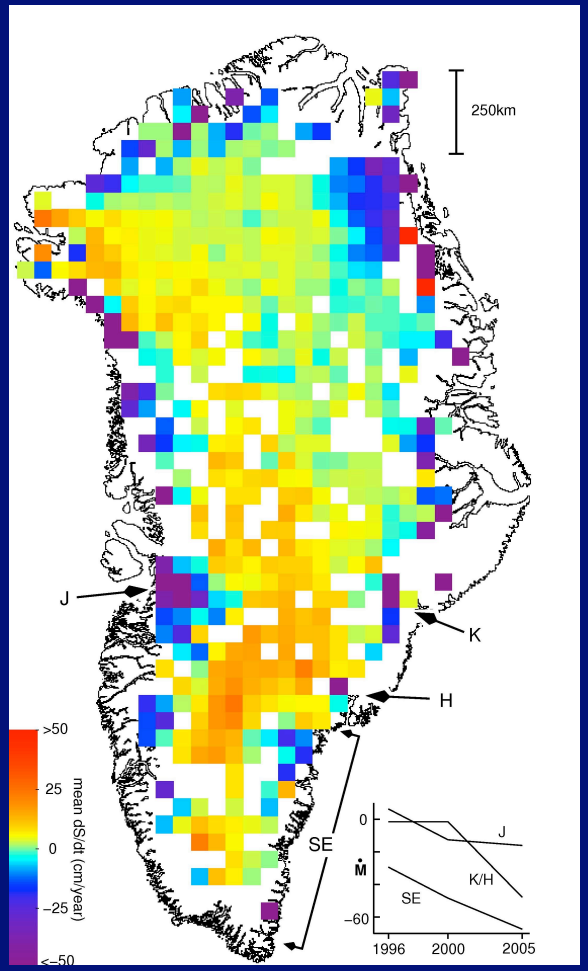


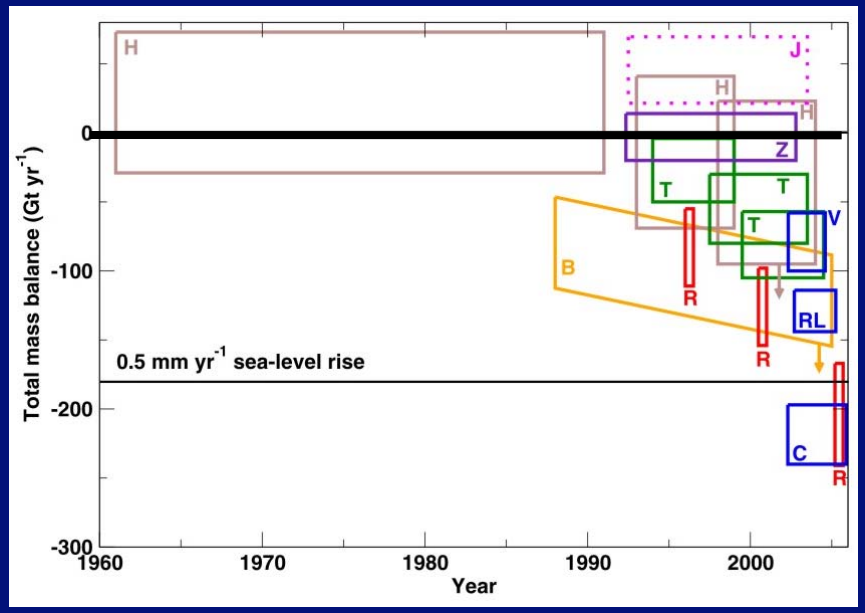
Land precipitation is changing significantly over broad areas



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

Greenland and Antarctic ice sheets are shrinking





Greenland mass loss is increasing

Loss: glacier discharge, melting

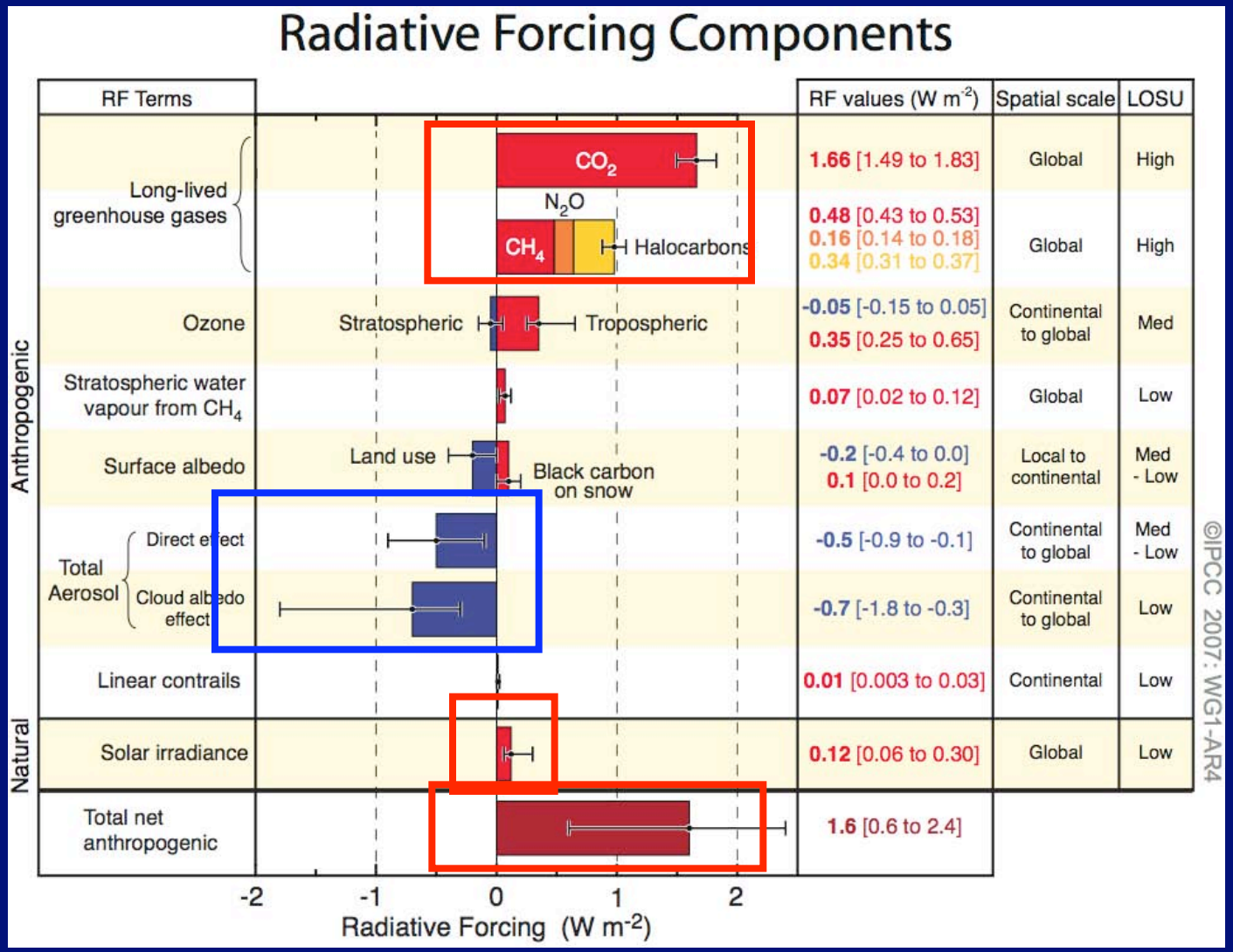
Greenland gains mass in the interior, but loses more at the margins

Human and Natural Drivers of Climate Change

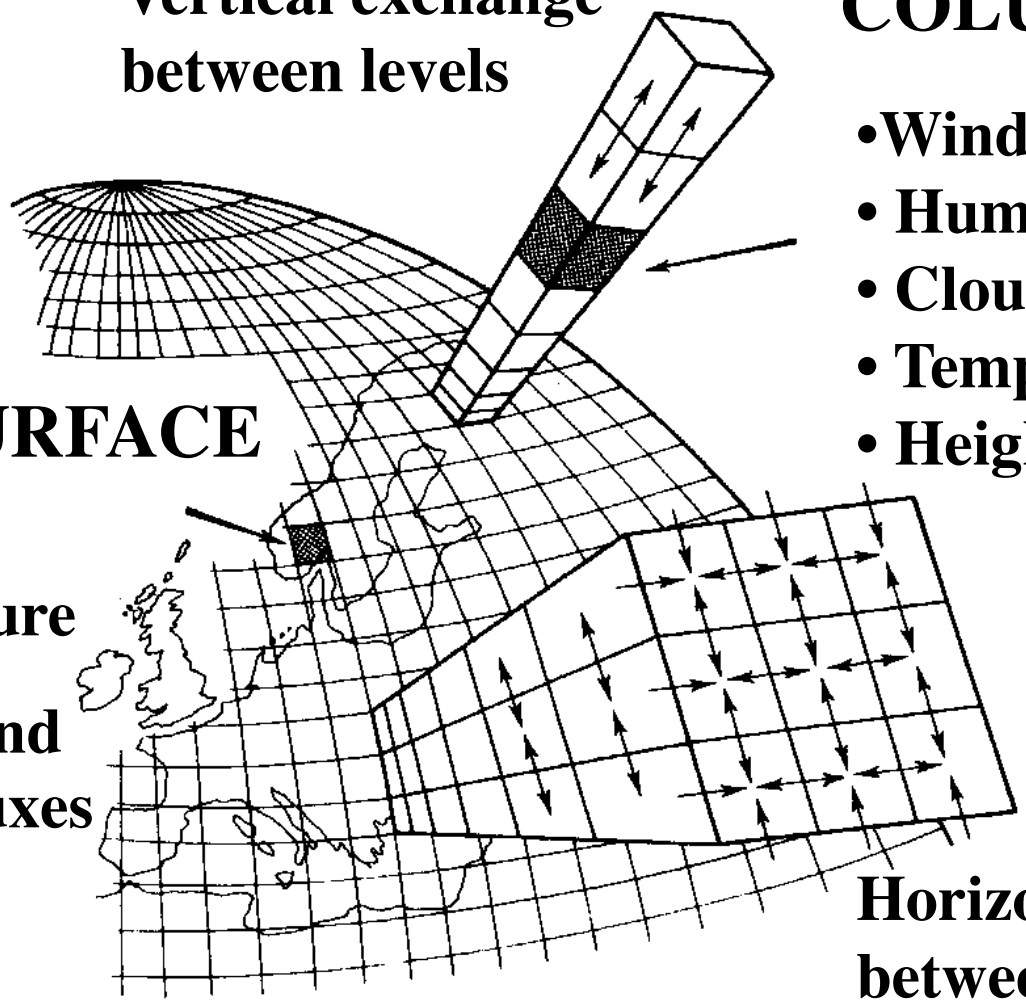
Major improvements in understanding forcing compared to IPCC (2001).

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.



A climate model:



Vertical exchange between levels

IN THE ATMOSPHERIC COLUMN

- Wind vectors
- Humidity
- Clouds
- Temperature
- Height

AT THE SURFACE

- Ground temperature
- Water and energy fluxes

Horizontal exchange between columns

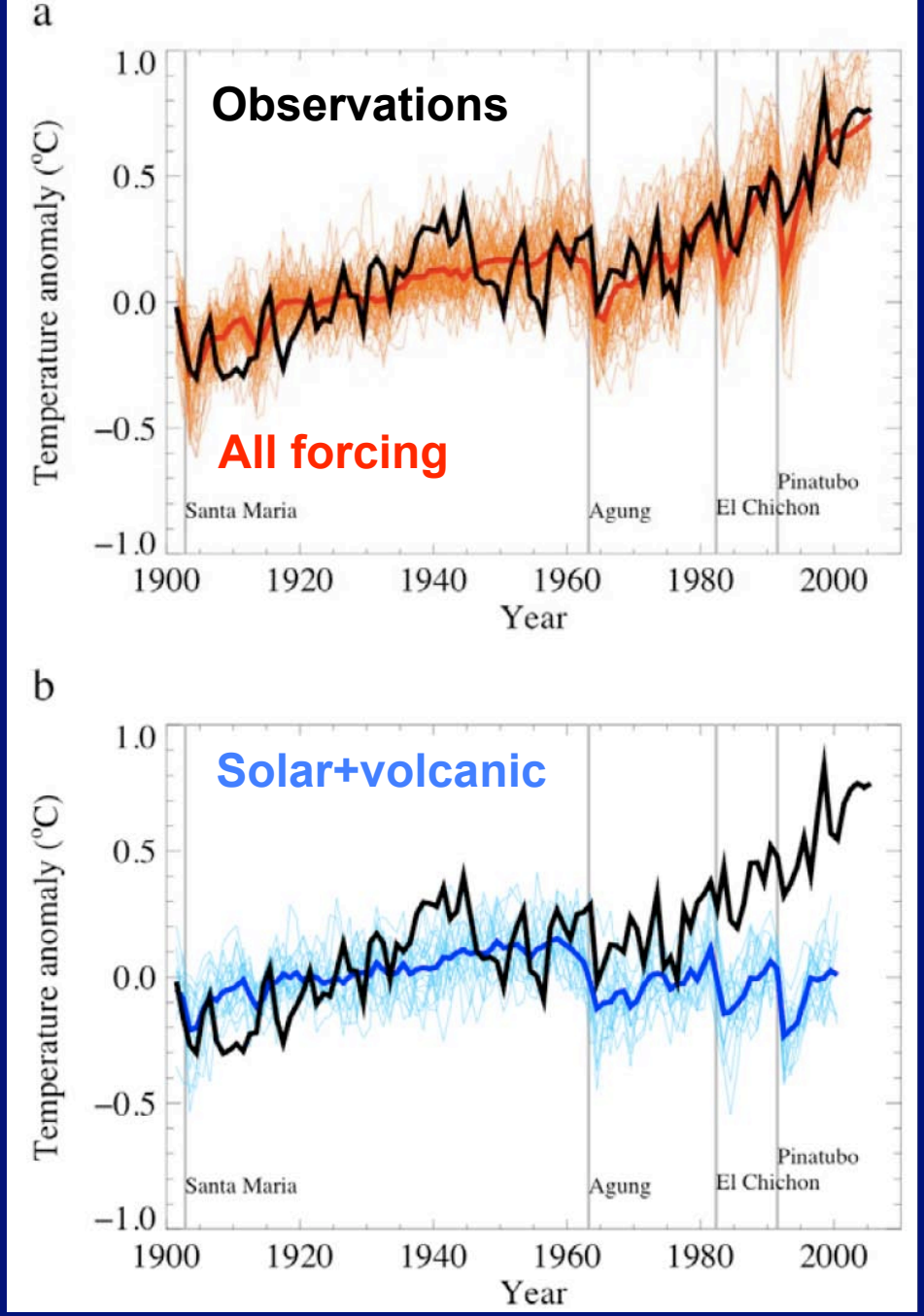
Time step ~ 30 minutes

Grid spacing ~ 3°x 3°

Source: McGuffie & Henderson-Sellers (1997)

Attribution

- are observed changes
  - **consistent with expected responses to forcings?**
  - **inconsistent with alternative explanations?**



Understanding and Attributing Climate Change

- Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely (>90%) due to the observed increase in anthropogenic greenhouse gas concentrations.
- This is an advance since the TAR's conclusion that "most of the observed warming over the last 50 years is likely (>66%) to have been due to the increase in greenhouse gas concentrations".

The IPCC WG1 Sequence……

IPCC (1990) Broad overview of climate change science, discussion of uncertainties and evidence for warming.

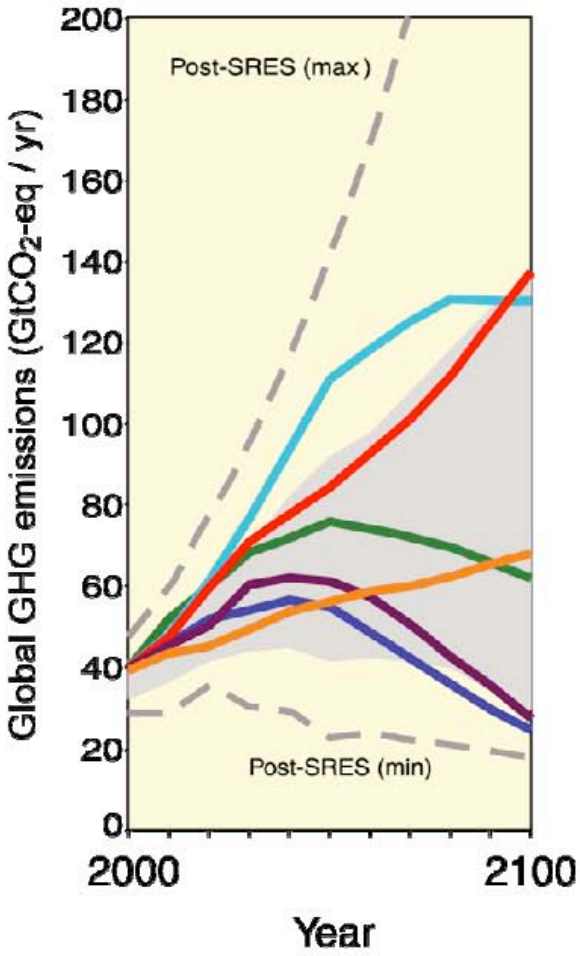
IPCC (1995) "The balance of evidence suggests a discernible human influence on global climate."

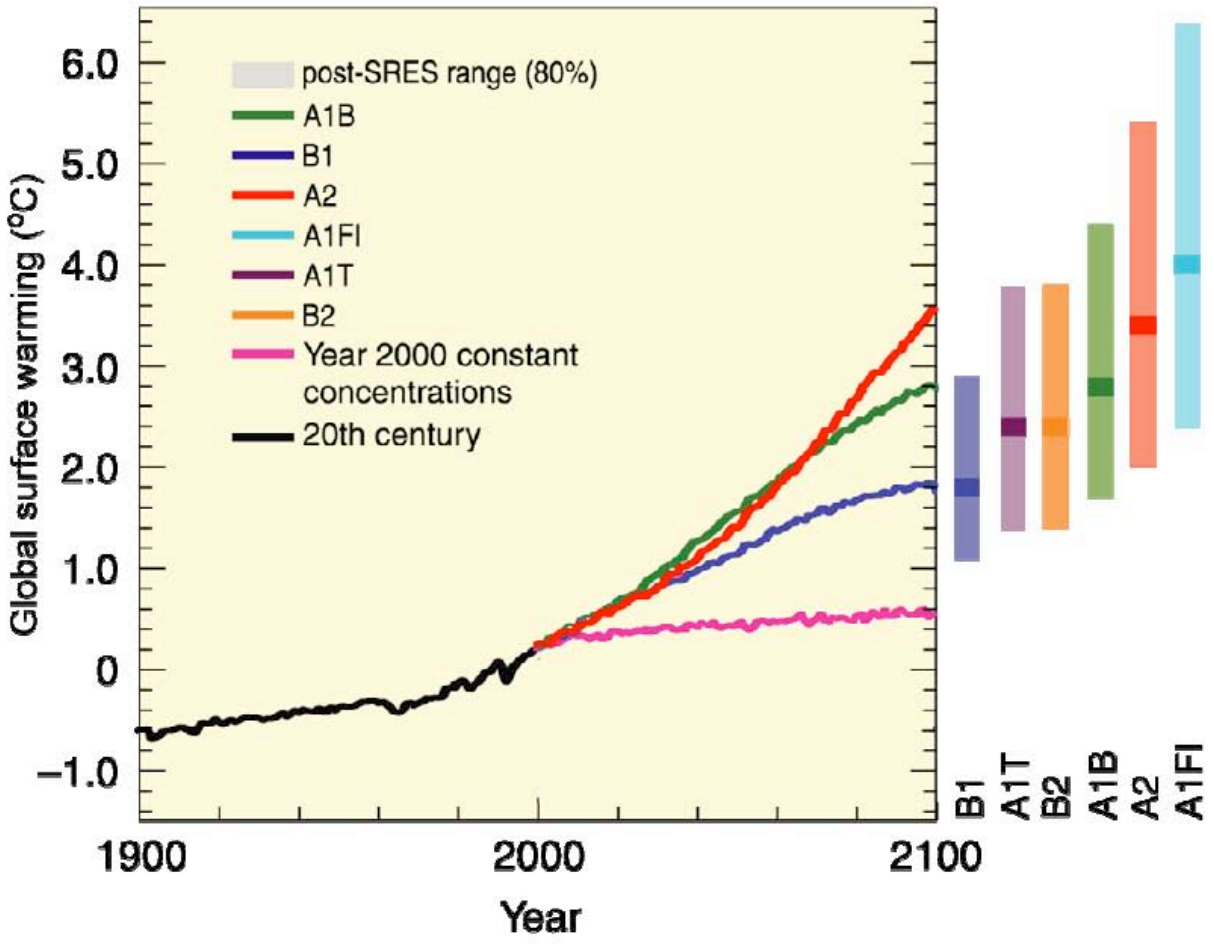
IPCC (2001) "Most of the warming of the past 50 years is likely (>66%) to be attributable to human activities."

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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Projected globally averaged surface warming and sea level rise at the end of the 21st century (IPCC WG1 AR4)

	Temperature Change (°C at 2090-2099 relative to 1980-1999) [a]		Sea Level Rise (m at 2090-2099 relative to 1980-1999)
Case	Best estimate	*Likely* range	Model-based range excluding future rapid dynamical changes in ice flow
Constant Year 2000 concentrations [c]	0.6	0.3 – 0.9	NA
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

NB: add 0.5°C to get pre-industrial reference

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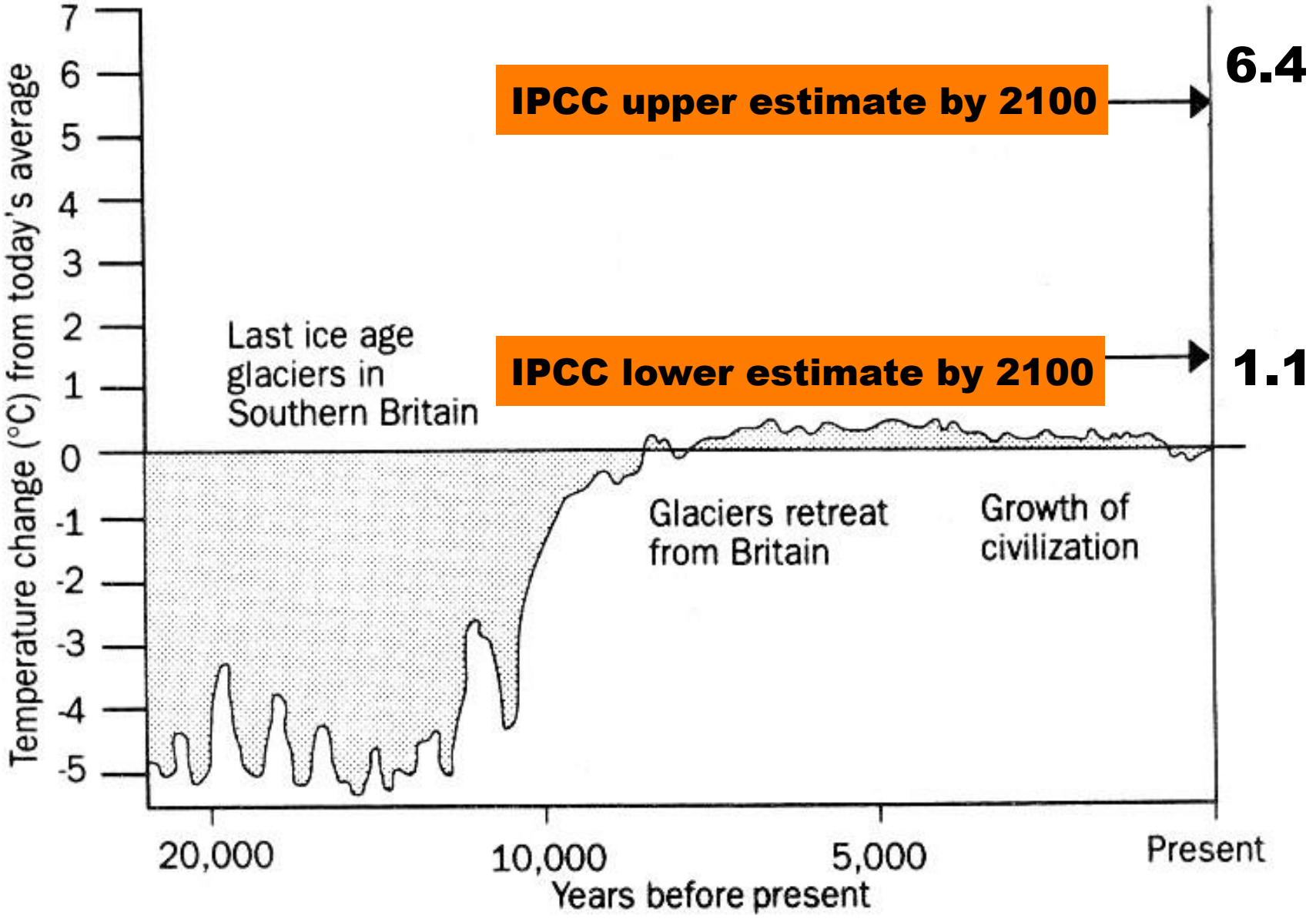
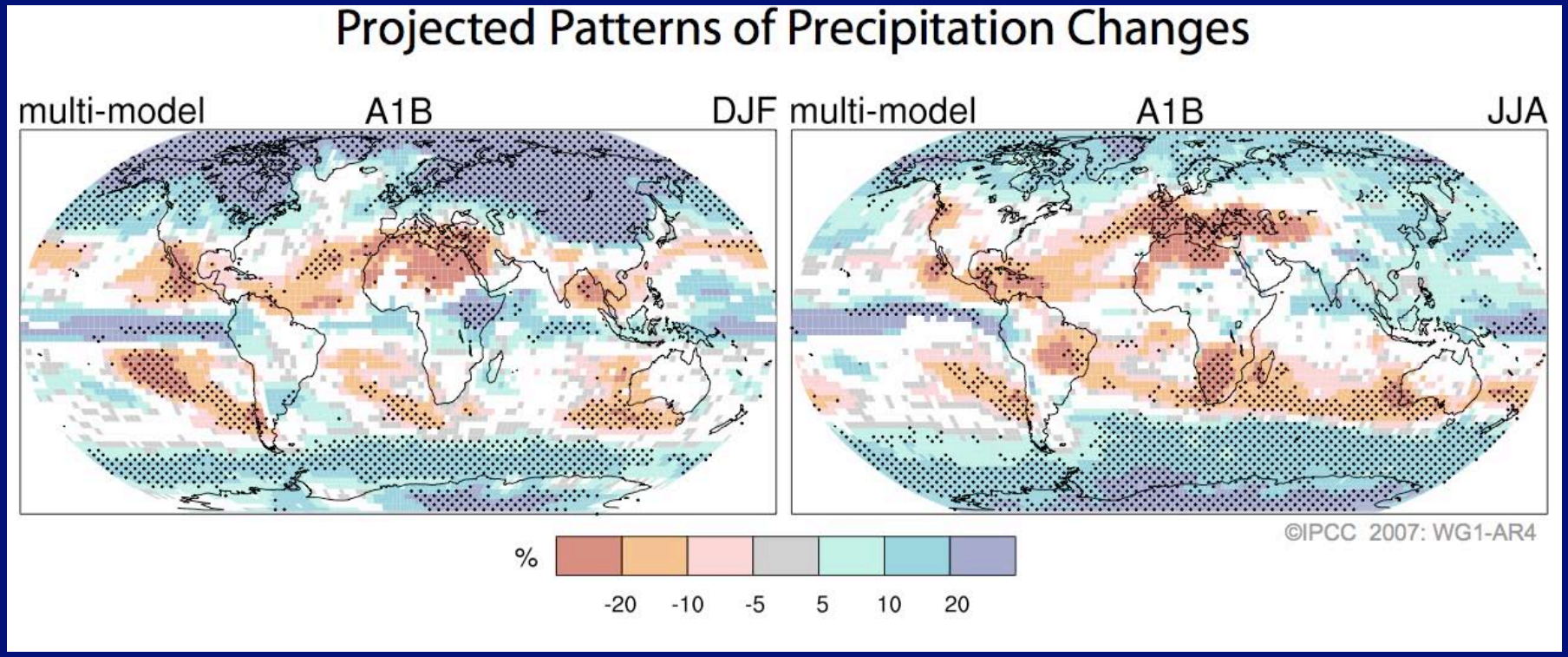


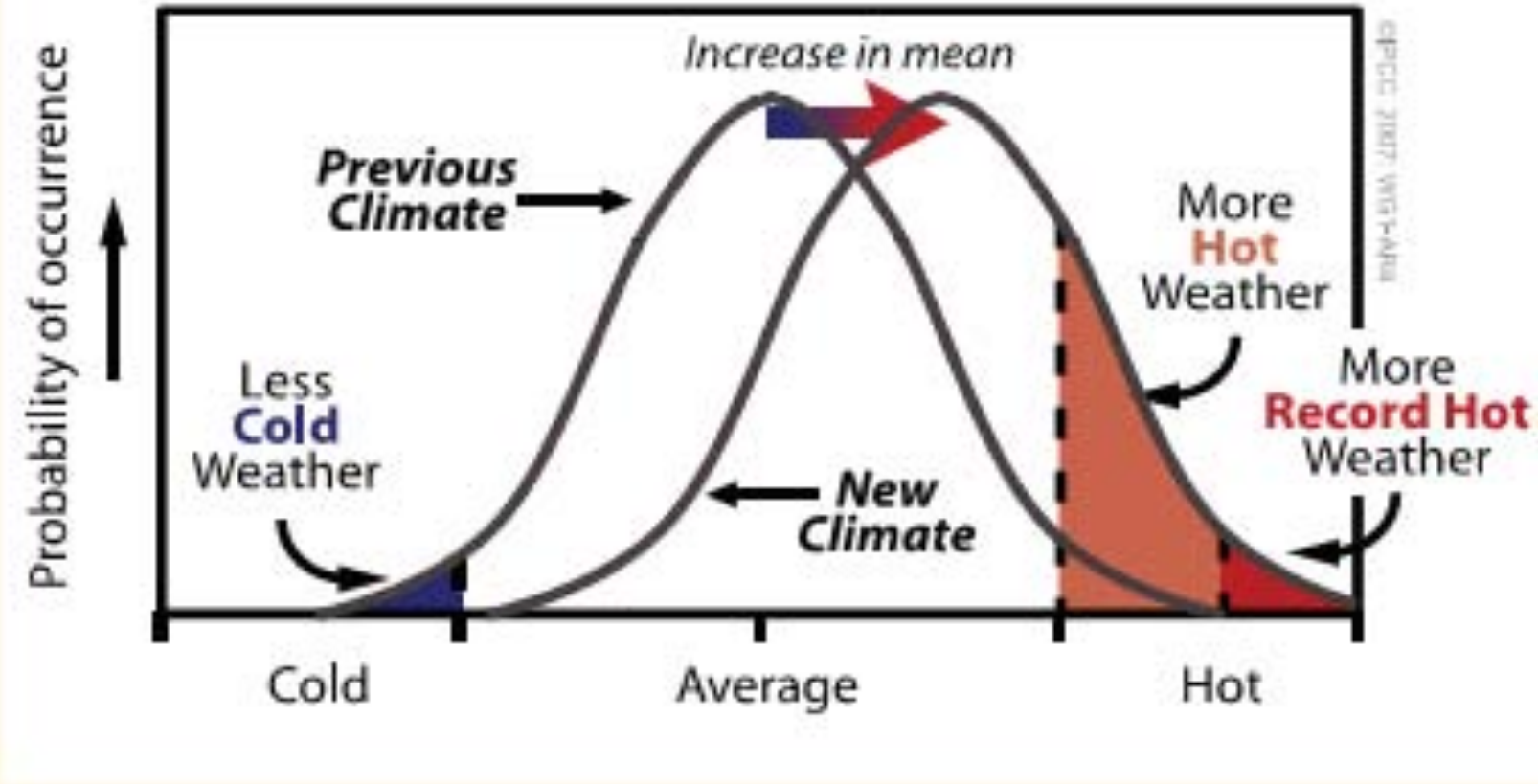
Source: *not* AR4

Projections of Future Changes in Climate



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

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.*

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%

What if the Gulf Stream is affected?

- Based on current model simulations, it is *very likely* that the meridional overturning circulation (MOC) of the Atlantic Ocean will slow down during the 21st century.
  - **longer term changes not assessed with confidence**
- Temperatures in the Atlantic region are projected to increase despite such changes due to the much larger warming associated with projected increases of greenhouse gases.

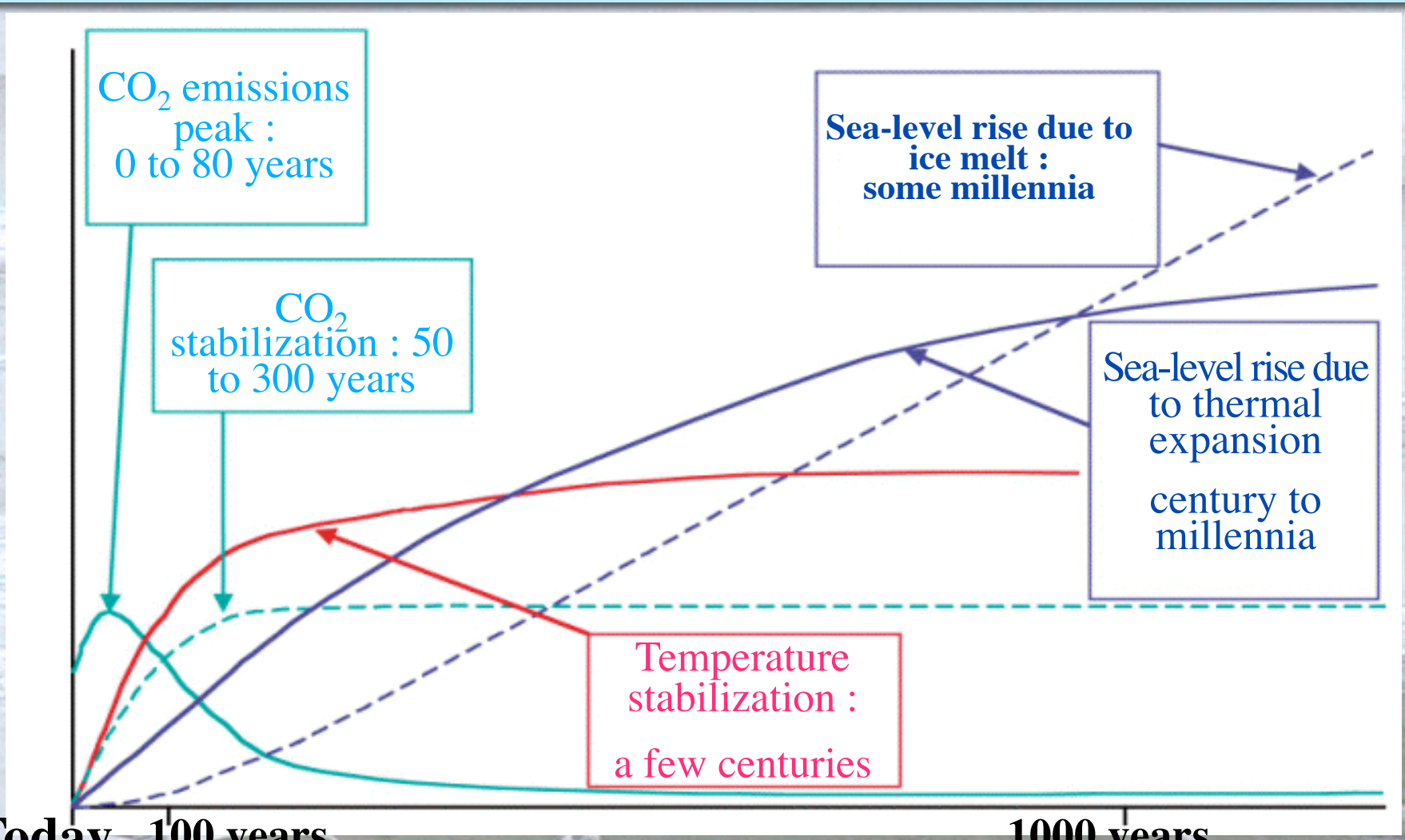
Ice sheet melting

- 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

Projections of Future Changes in Climate

- **Anthropogenic warming and sea level rise would continue for centuries due to the timescales associated with climate processes and feedbacks, even if greenhouse gas concentrations were to be stabilized.**
- **Temperatures in excess of 1.9 to 4.6°C warmer than pre-industrial sustained for millennia…eventual melt of the Greenland ice sheet. Would raise sea level by 7 m. Comparable to 125,000 years ago.**

Significant inertia exists in the climate system



Source: IPCC (2001)

John Holdren, President of the American Association for the Advancement of Science

- **'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.'**

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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