# How is climate projected to evolve in response to human activities?

Pr Jean-Pascal van Ypersele

UCL-ASTR
(Université catholique de Louvain, Institut d'astronomie et de géophysique G. Lemaître)

vanyp@climate.be & www.climate.be

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# Plan:

- **What is the IPCC?**
- **Key points IPCC report**
- **Is climate changing?**
- **Why is climate changing?**
- **Hydrological processes: precipitation**
- **Climate scenarios: how do climate models work, how are scenarios generated?**
- **Projections for future climate: on a global scale, in Belgium**
- **What are some of the impacts?**
- **Is Kyoto enough?**

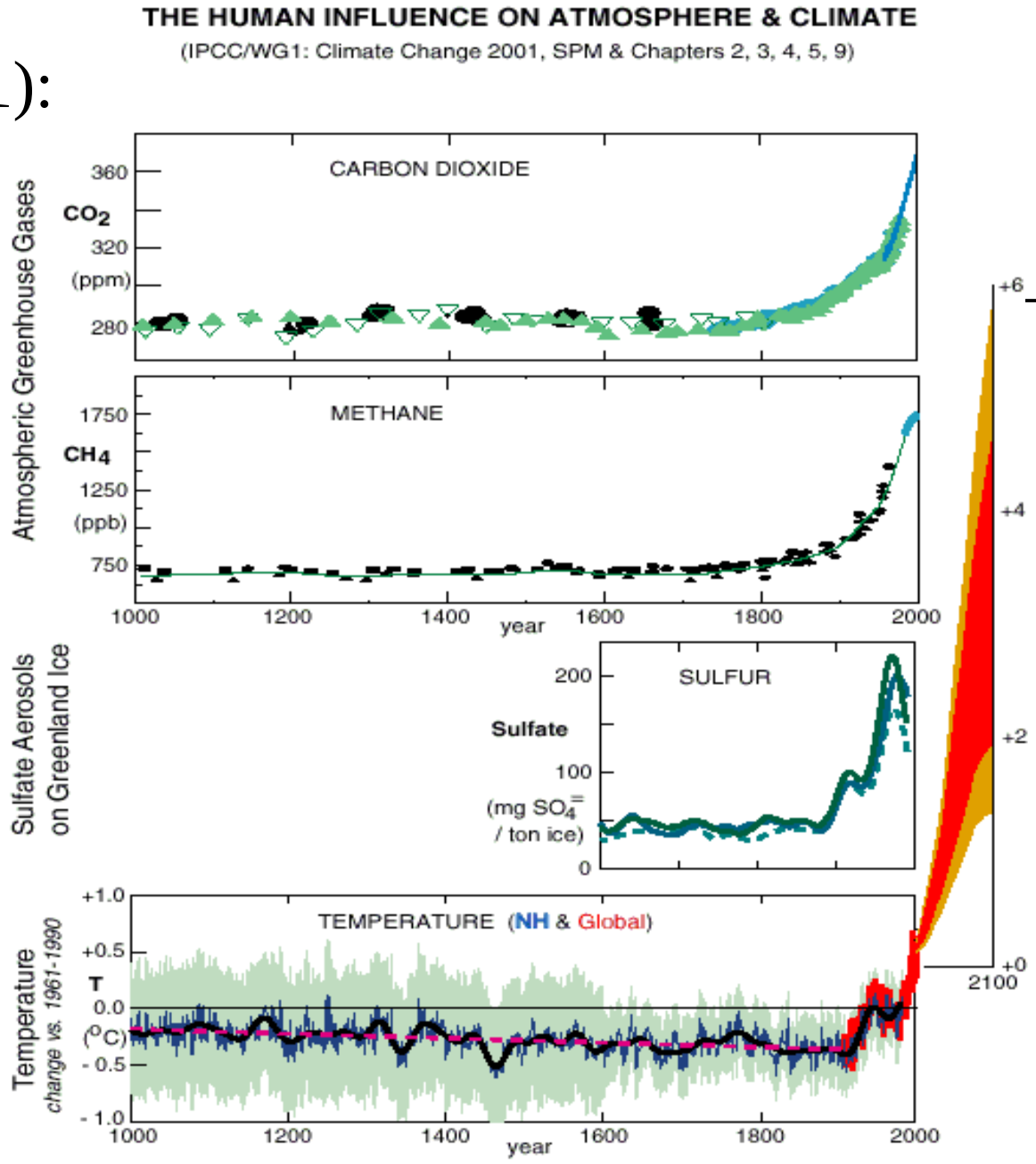
# Definitions

- **Climate system: made of the atmosphere, oceans, cryosphere (ice + snow), continental surface, biosphere…**
- **Climate =*average* state of that system, in particular of the *weather* over 30 years, + *variability* around this mean**

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

IPCC

TAR (2001):




**AR4:**

**+6.4°C**

+5.8°C

+1.4°C**+1.1°C**

# What is the IPCC?

- **IPCC : Intergovernmental Panel on Climate Change (GIEC in French)**
- **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**
- **Web : http://www.ipcc.ch**

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

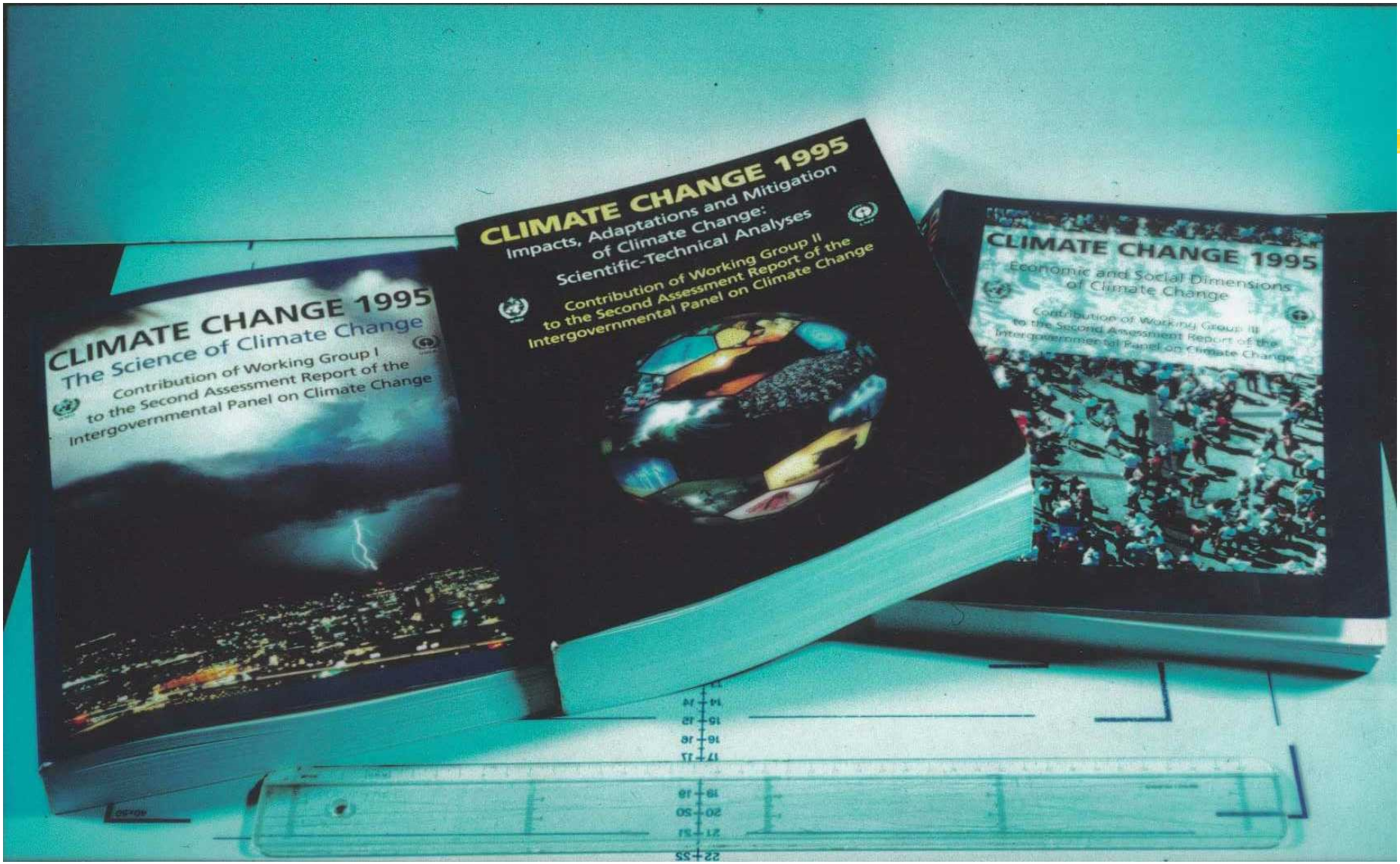
# IPCC Structure

- **3 Working Groups, 1 Task Force**
- WG1: Physical basis for climate change
- WG2: Impacts, adaptation & vulnerability
  - Plenary: Brussels 2-6 April 2007
- WG3: Mitigation (emission reductions)
- TF: Emission inventories

# 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 – *Draft 2* – Combined expert/government review – *Draft 3* – Government review of Summary for Policy Makers (SPM) – Approval Plenary (interaction authors – governments) – *SPM and full report***

Jean-Pascal van Ypersele
(jeanpvanypersele@uclouvain.be)




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

# 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**

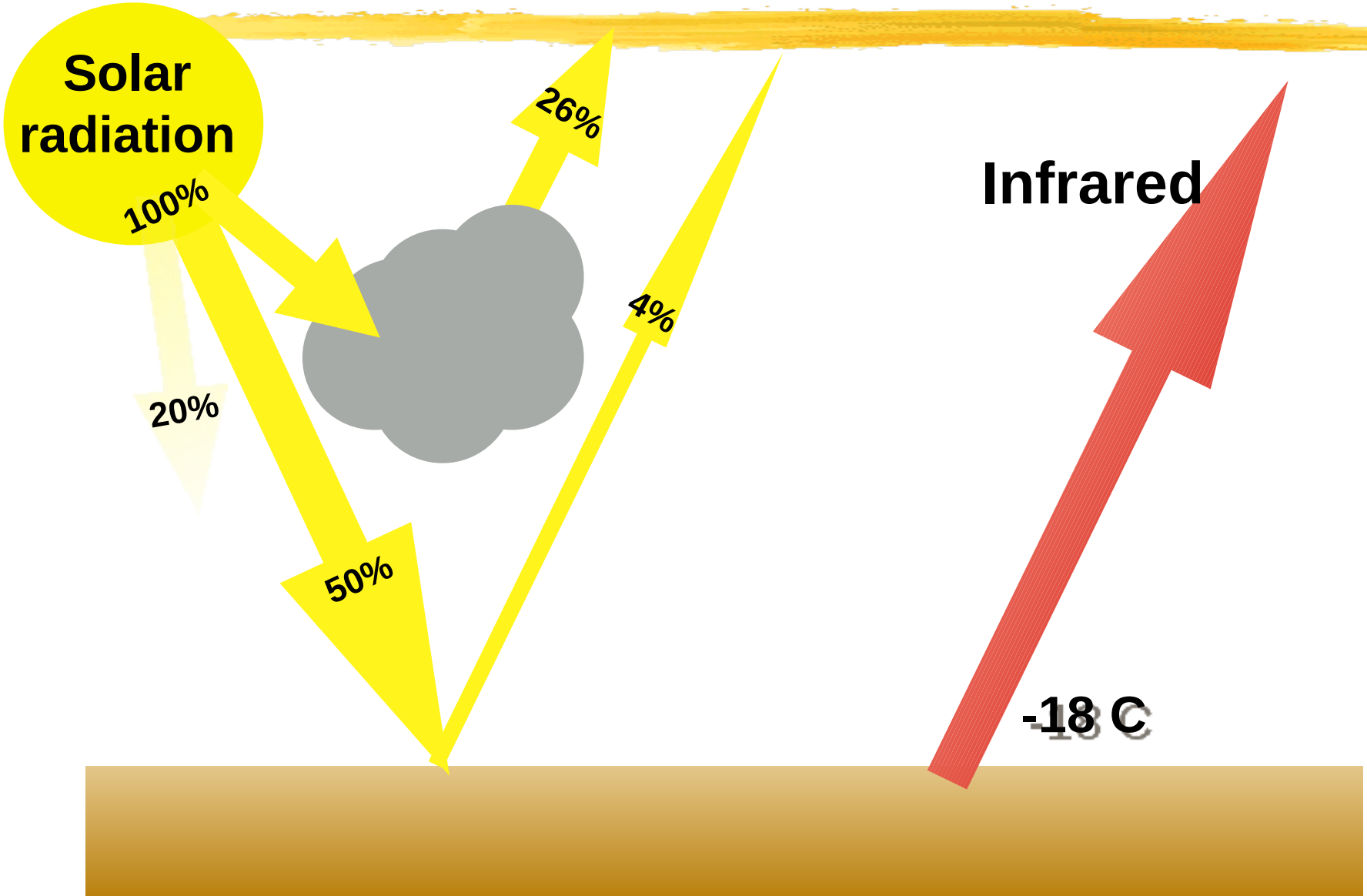
Jean-Pascal van Ypersele
(vanypersele@astr.ucl.ac.be)

# How does the climate system work ?

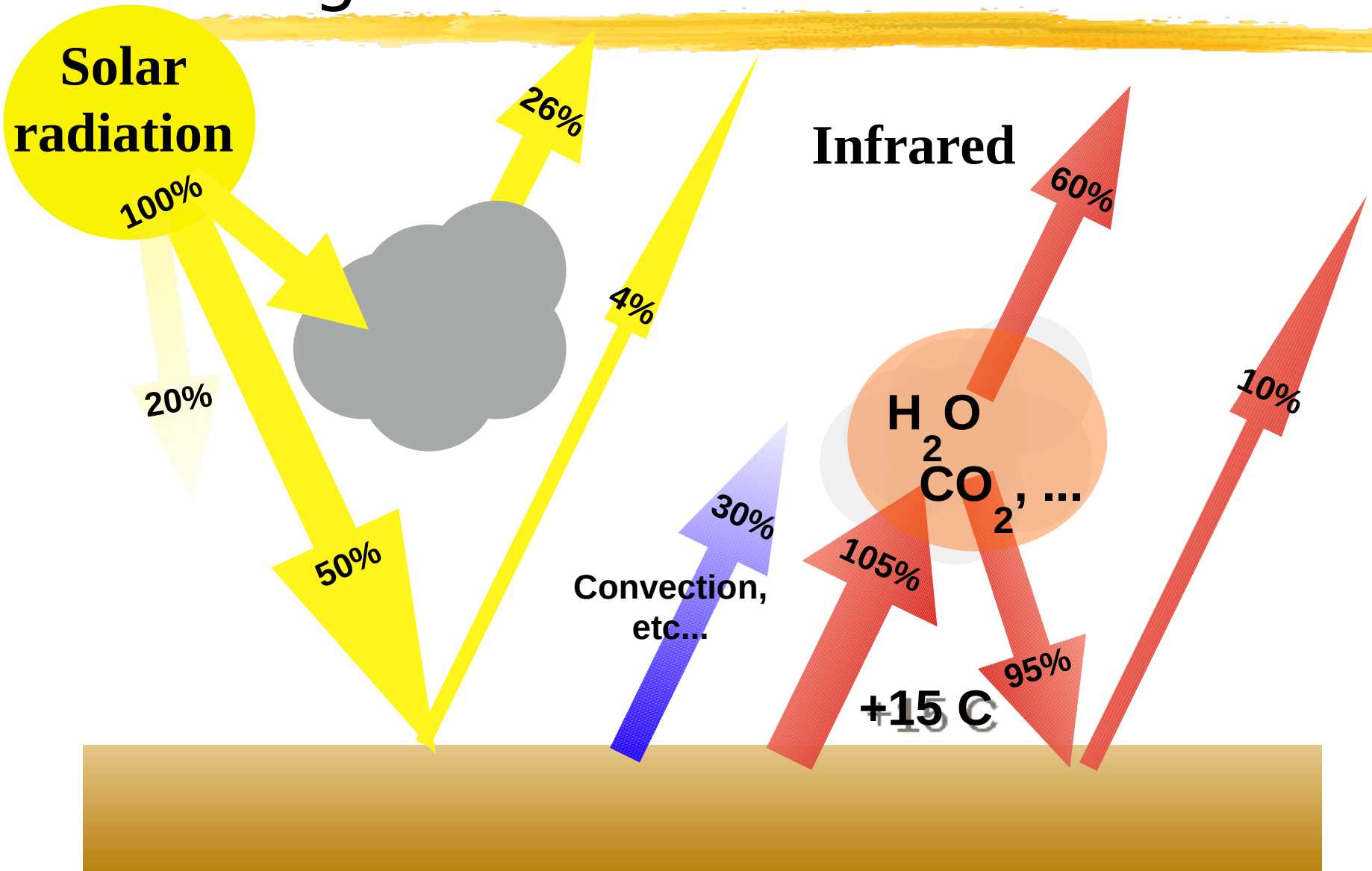
- **Huge thermal engine powered by the Sun (1400 W/m² at top of the atmosphere)**
- **Complex fluid dynamics on a «  sphere  » in rotation**
- **Ocean = 70% of surface: large inertia**
- **Very thin atmosphère ($N_2$, $O_2$, $H_2O$, $CO_2$,…)**
- **Greenhouse effect**
- **Bio-geo-chemical cycles, now perturbed by human activities**

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

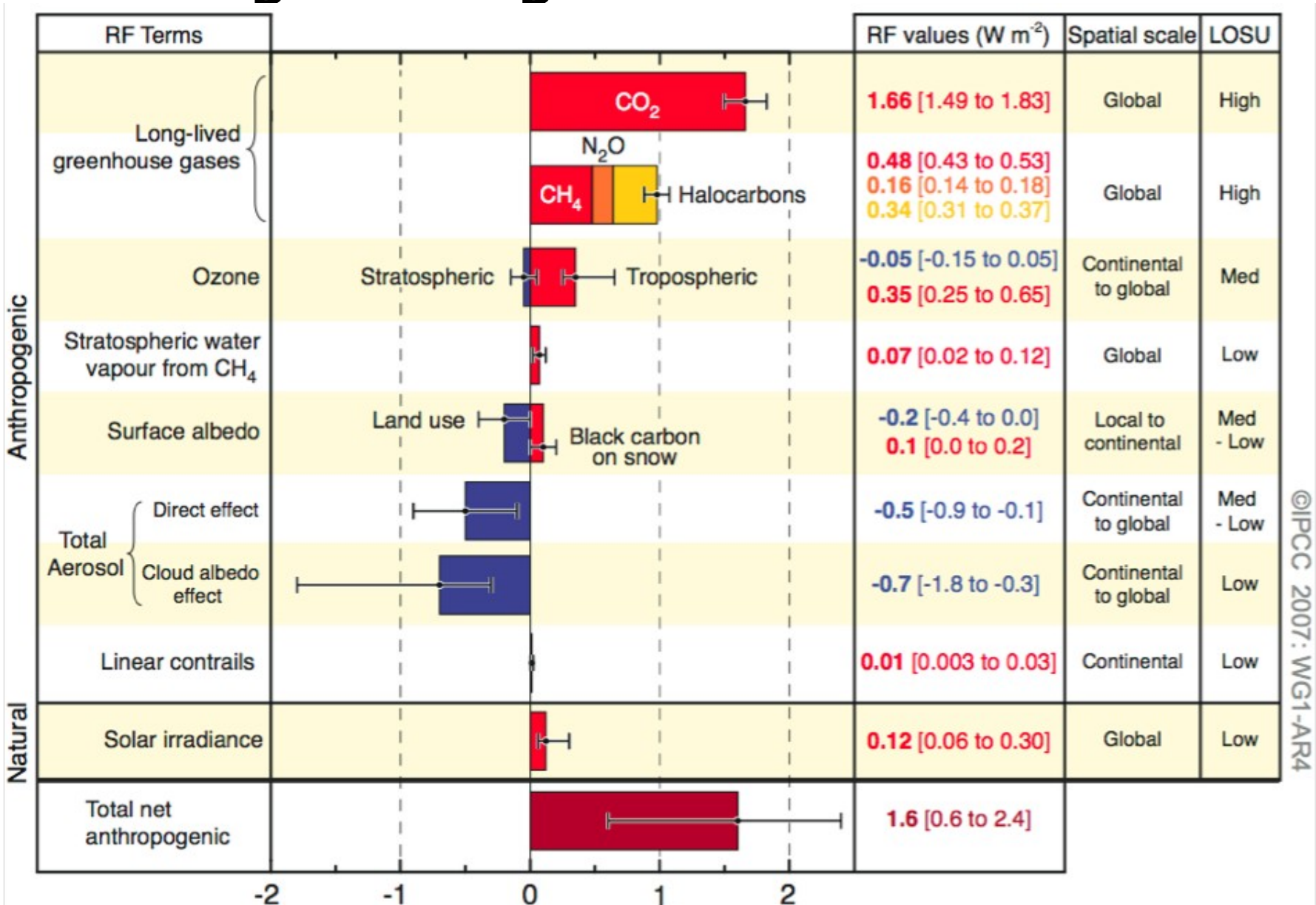
# Energy cycle in the atmosphere 1: without greenhouse effect



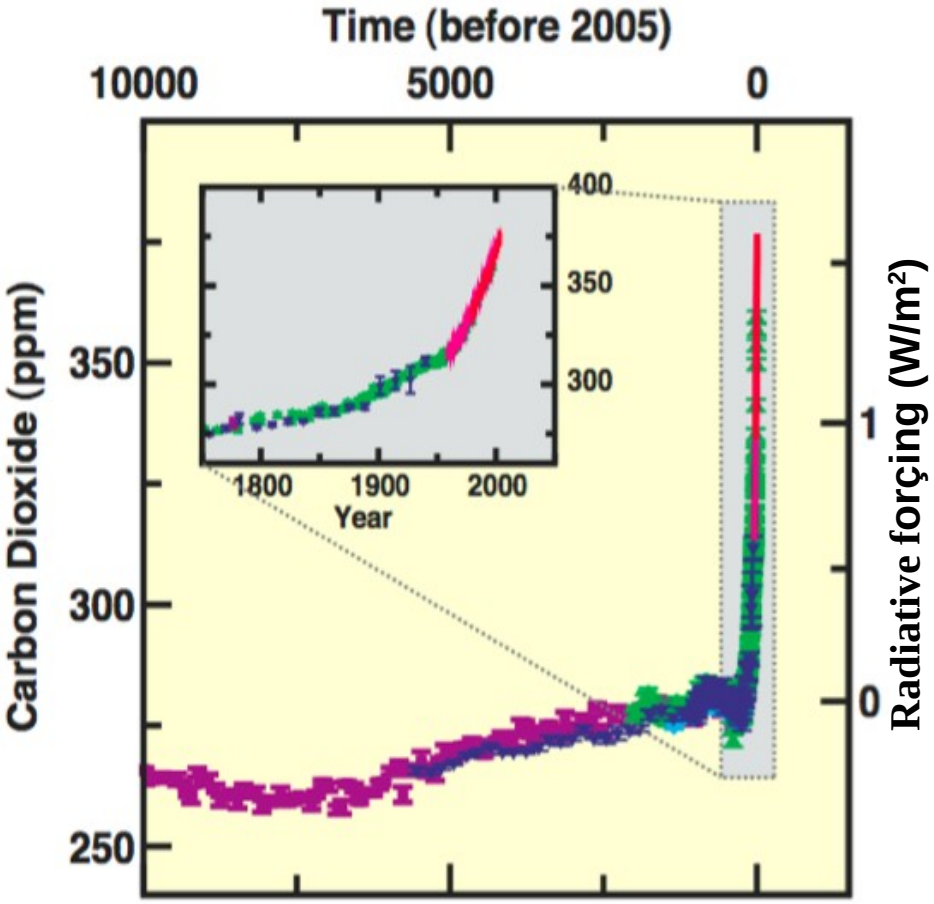
# Energy cycle in the atmosphere 2: with greenhouse effect



# Components of radiative forcing (changes 1750-2005)



# *The main human greenhouse gas: $CO_2$*




- **$CO_2$ concentration is measured in ppm (parts per million)**
- **It was 280 ppm before the industry revolution, it is now more than 380 ppm**
- **Over the last 650 000 years, it stayed between 180 and 300 ppm**

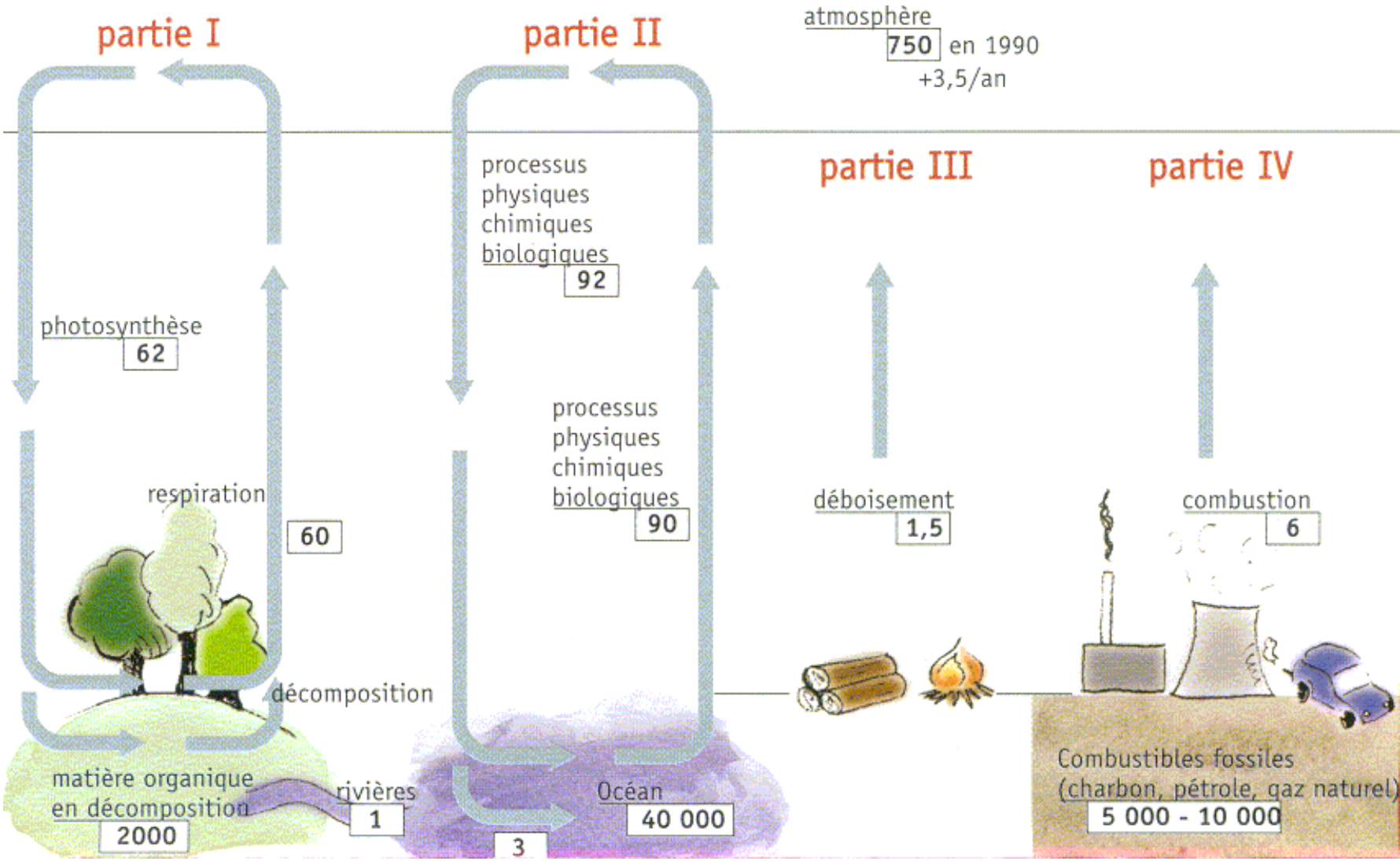
Source: IPCC WG1 AR4

# World human $CO_2$ emissions

- **Fossil fuel: ~ 23.5 $GtCO_2$ per year in the 1990's, plus ~ 6 from deforestation and other land use changes**
- **During 2000-2005: ~ 26.4 $GtCO_2$ from fossil fuel**
- **Total: more than 30 billions tonnes of $CO_2$/year emitted**
- **How much stays in the atmosphere ?**

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

# Carbon cycle:




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

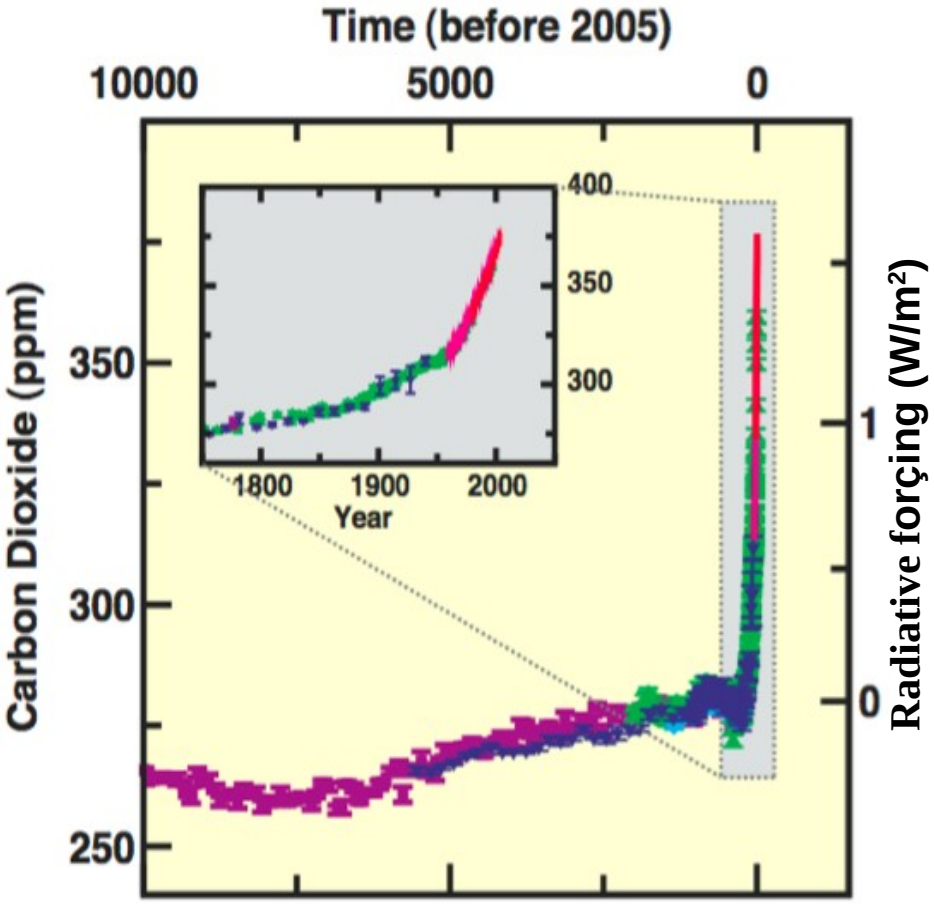
Unités: GtC (milliards de tonnes de carbone) ou GtC/an

# The $CO_2$ bath tub

- Every year, we emit 30 $GtCO_2$ to the atmosphere (input)
- Natural systems (ocean & vegetation) absorb 15 $GtCO_2$/year (output)
- The level in the bath tub increases as long as the input ≥ output
- Conclusion: just to stabilize the problem, reductions of over 50% are needed globally

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

# *The main human greenhouse gas: $CO_2$*

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Source: IPCC WG1 AR4

# Direct Observations of Recent Climate Change

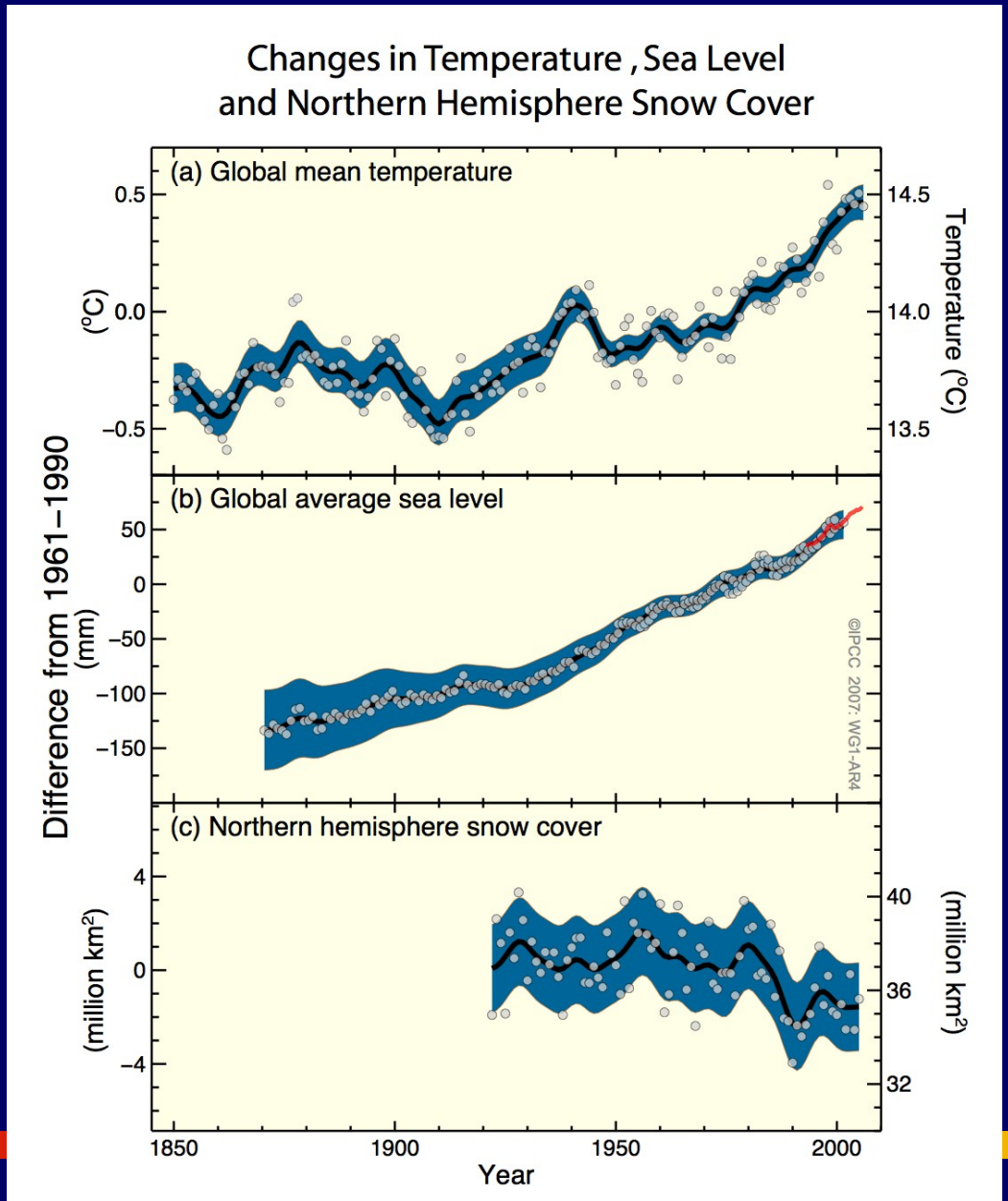
**Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level.**

# Direct Observations of Recent Climate Change

Gobal mean temperature

Global average sea level

Northern hemisphere Snow cover



# Direct Observations of Recent Climate Change

Global average air temperature

- Updated 100-year linear trend of 0.74 [0.56 to 0.92] $^{o}$C for 1906-2005
- Larger than corresponding trend of 0.6 [0.4 to 0.8] $^{o}$C for 1901-2000 given in TAR

- Average ocean temperature increased to depths of at least 3000 m – ocean has absorbed 80% of heat added

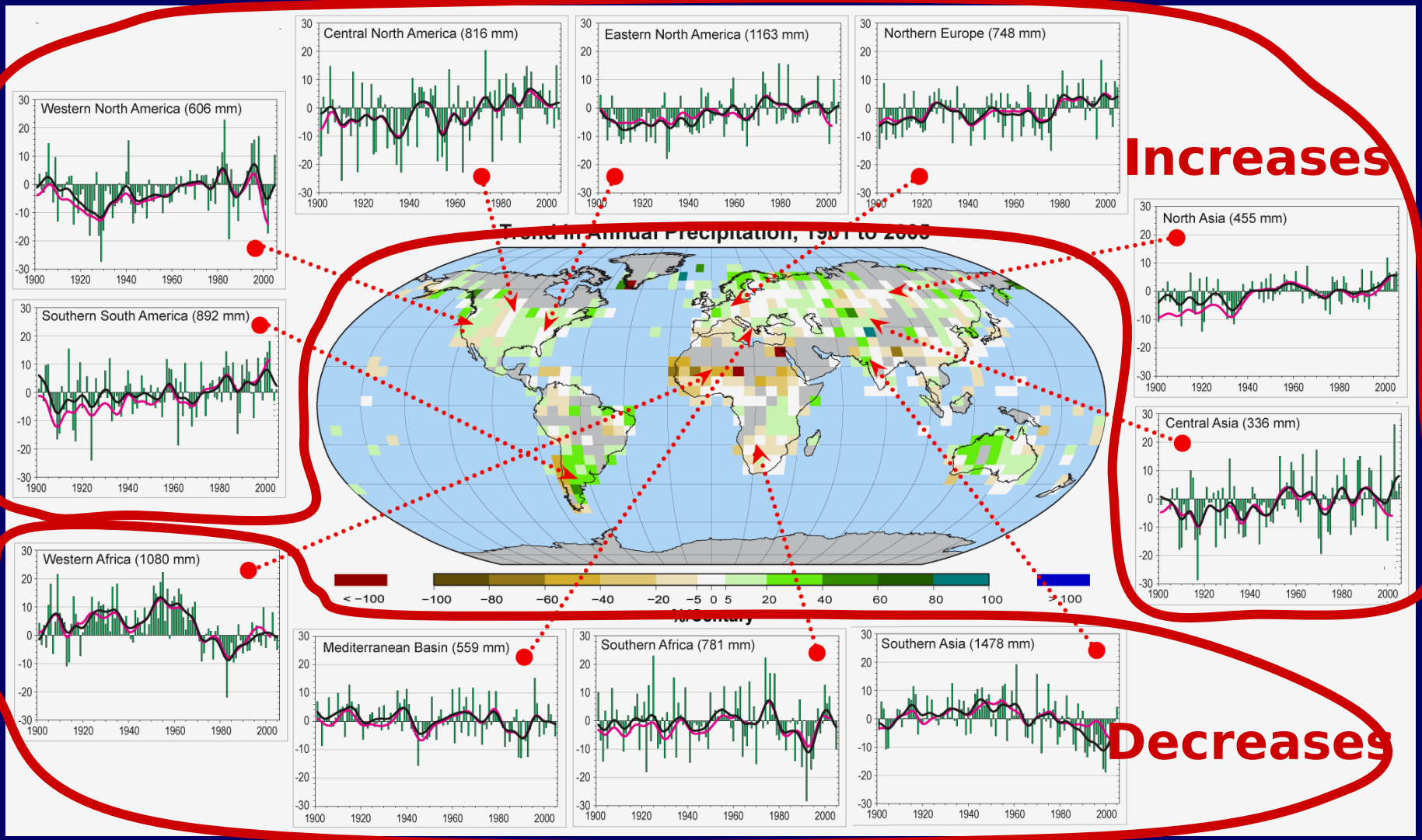
  > seawater expansion and SLR

# Direct Observations of Recent Climate Change

At continental, regional, and ocean basin scales, numerous long-term changes in climate have been observed. These include:

- Changes in Arctic temperatures and ice,
- Widespread changes in precipitation amounts, ocean salinity, wind patterns
- and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones

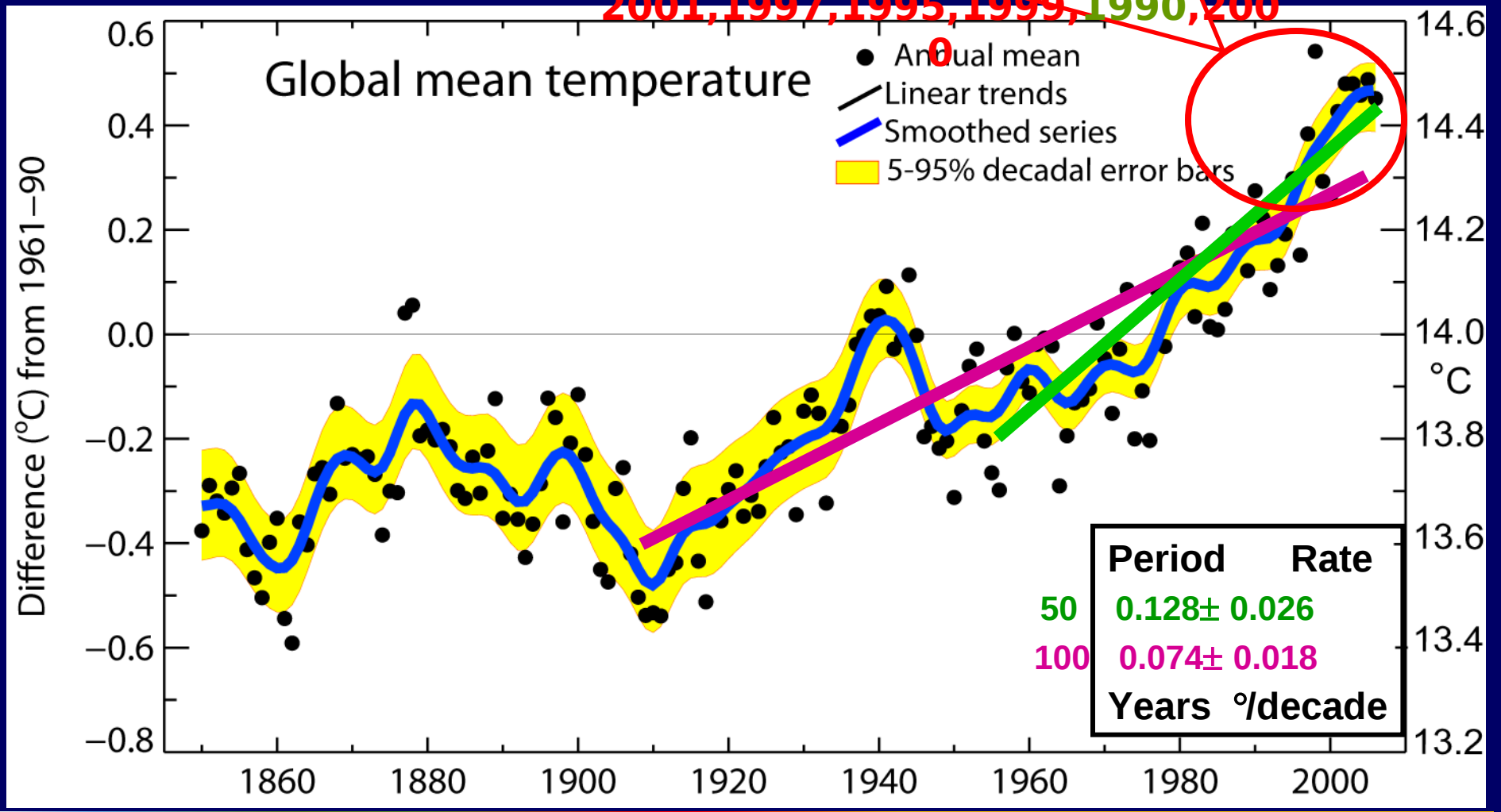
# d precipitation is changing significantly over broad ar



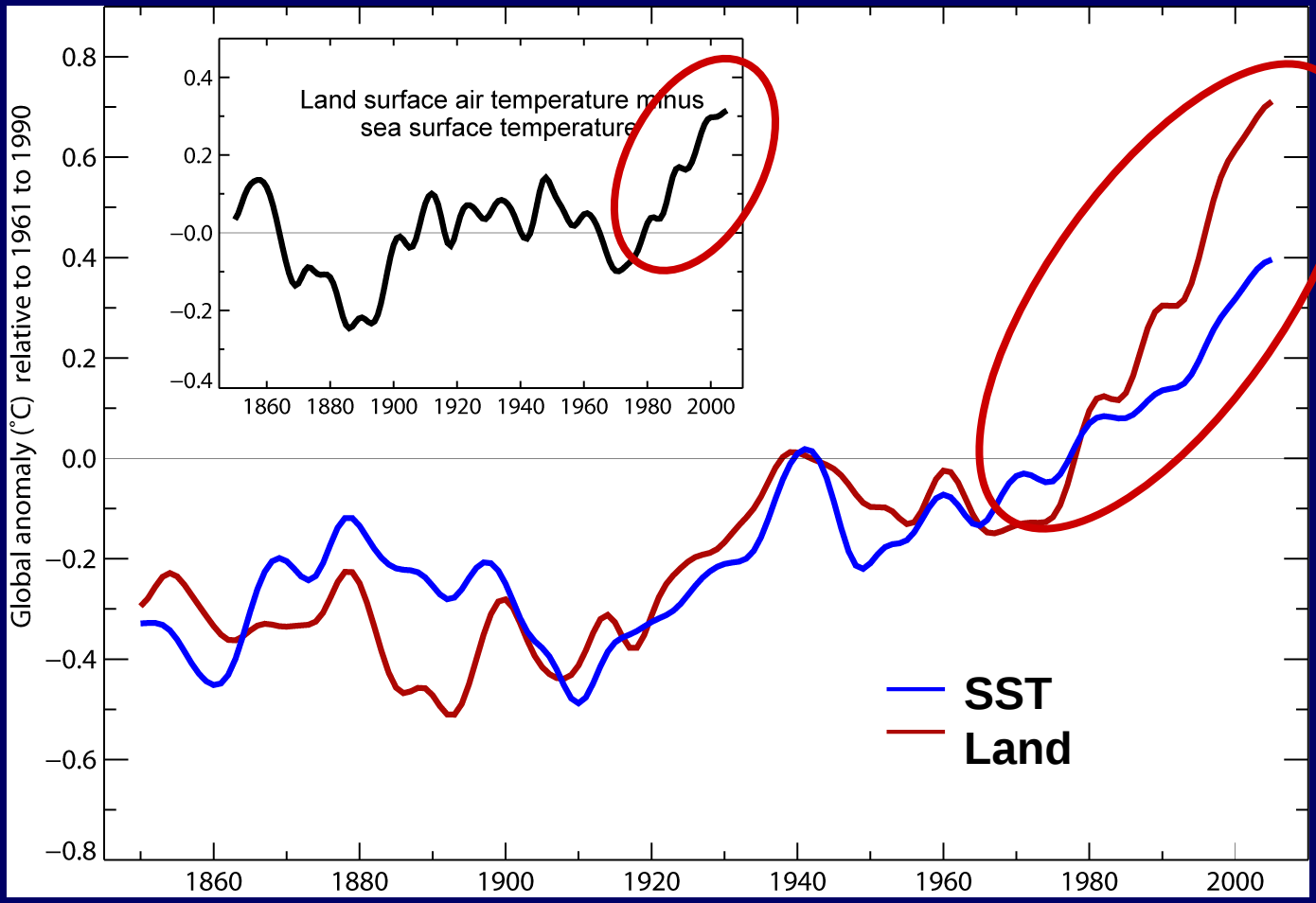

Smoothed annual anomalies for precipitation (%) over land from 1900 to 2005; other regions are dominated by variability

# Global mean temper

**Warmest 12 years:**
**1998,2005,2003,2002,2004,2006,**
**2001,1997,1995,1999,1990,2000**



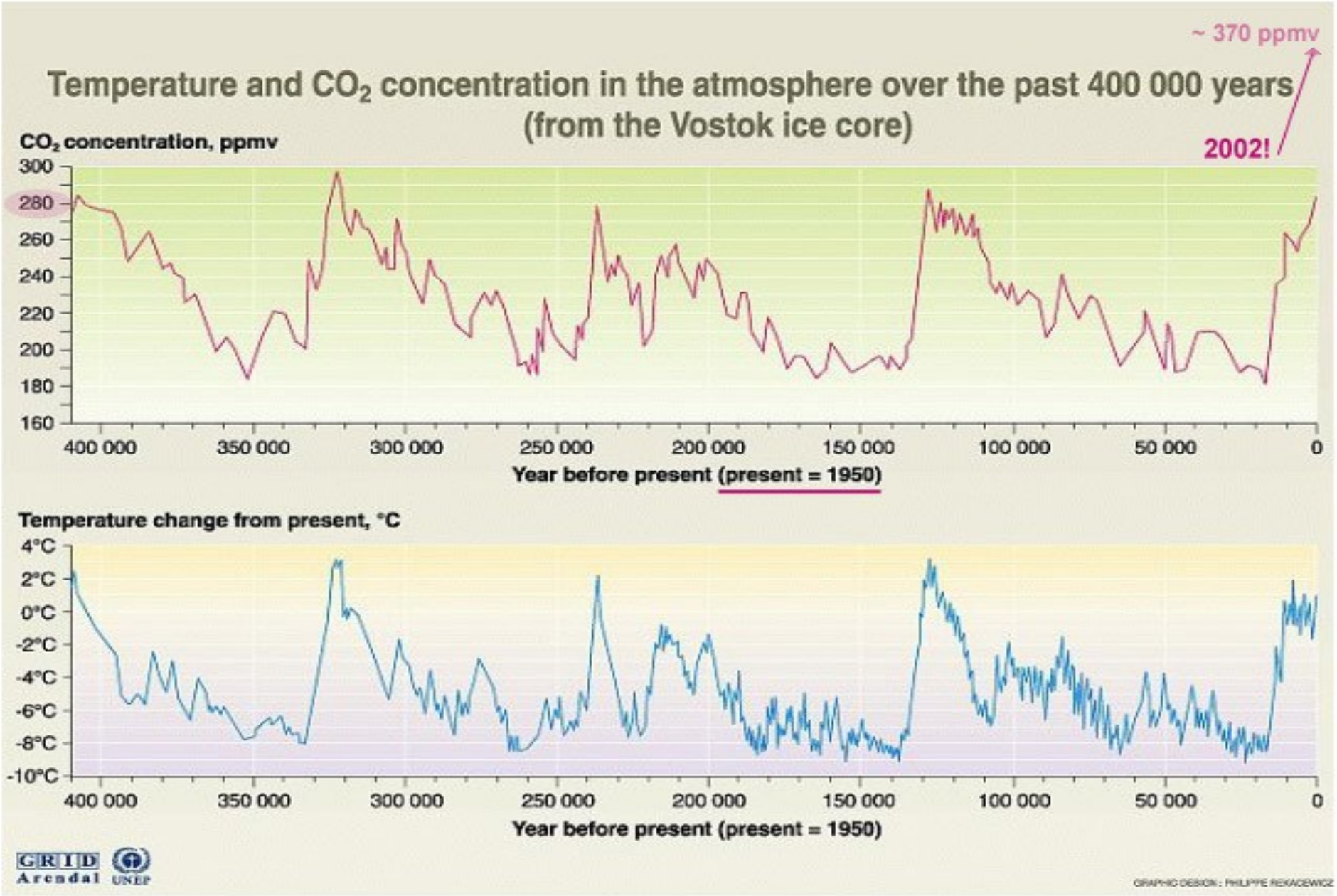
# Land surface temperatures are rising faster than SSTs



# A paleoclimatic perspective

- Paleoclimate information supports the interpretation that **the warmth of the last half century is unusual in at least the previous 1300 years**. The last time the polar regions were significantly warmer than present for an extended period (about 125,000 years ago), reductions in polar ice volume led to 4 to 6 metres of sea level rise.

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




Source: J.R. Petit, J. Jouzel, et al. Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica, Nature 399 (3JUne), pp 429-436, 1999.

(Note: 2002 information added to diagram)

# A climate model:

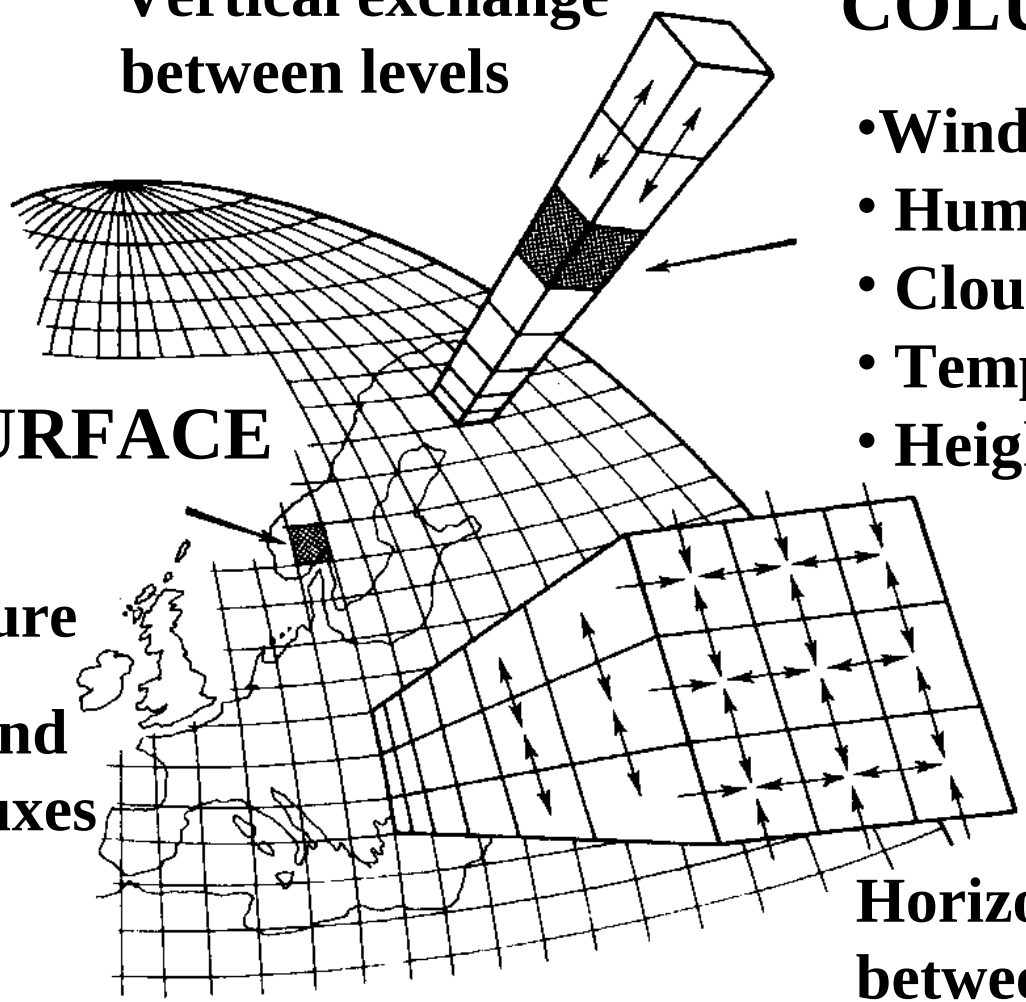
## IN THE ATMOSPHERIC COLUMN

**Vertical exchange between levels**

- **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°**

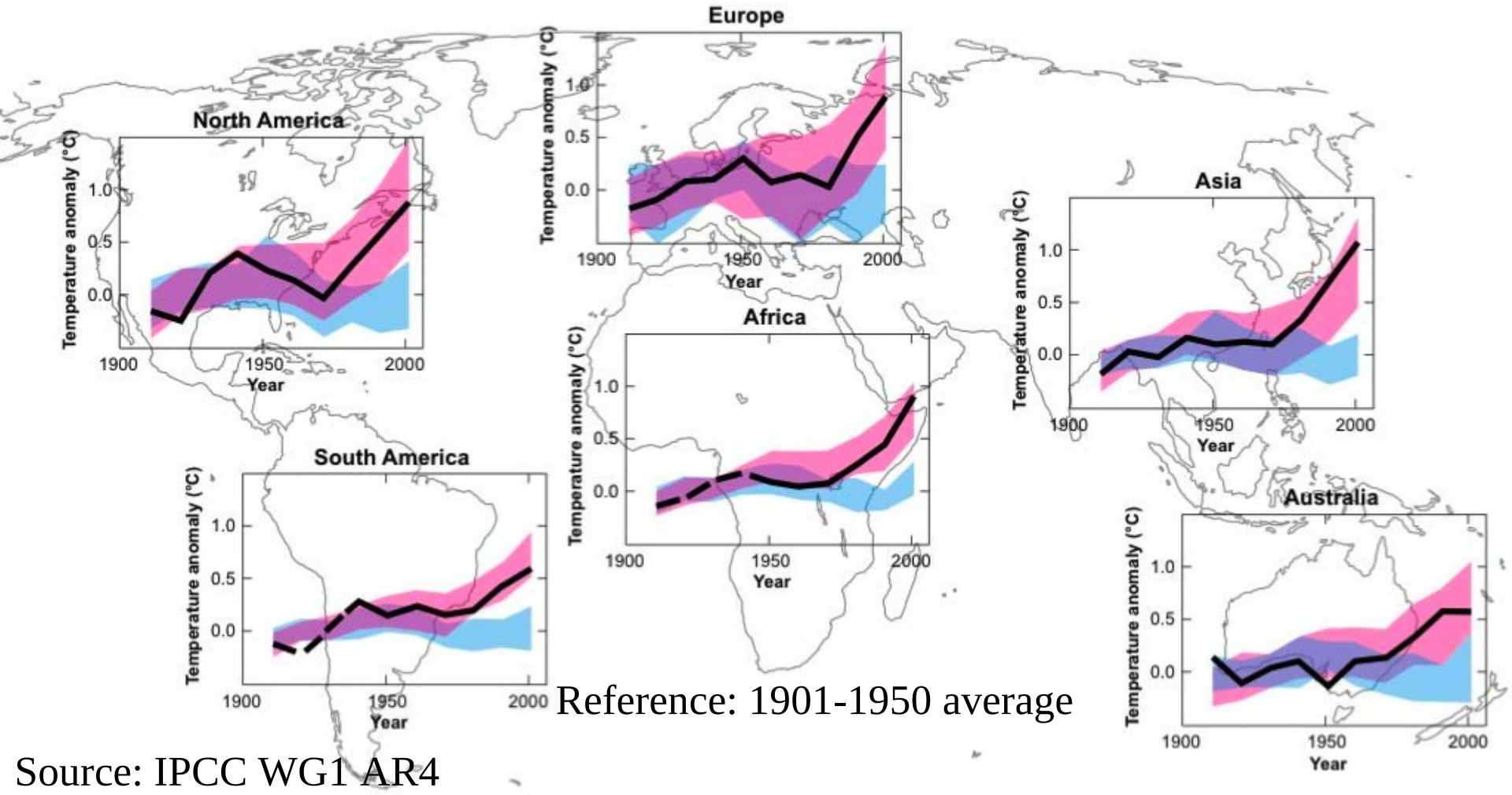
Source: McGuffie & Henderson-Sellers (1997)

# Understanding and attributing climate change

- The equilibrium climate **sensitivity** is a measure of the climate system response to sustained radiative forcing. It defined as the global average surface warming following a **doubling** of carbon dioxide concentrations.
- It is **likely to be in the range 2 to 4.5°C** with a best estimate of about 3°C, and is very unlikely to be less than 1.5°C.
- Values substantially higher than 4.5°C cannot be excluded

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

# Observed Temperature (black line) and simulation with natural+human factors (pink) and only natural factors (blue)




Reference: 1901-1950 average

Source: IPCC WG1 AR4

# Understanding and attributing climate change

- **Most of the observed increase in** globally averaged temperatures since the mid-20th century is **very likely (TAR: likely)** due to the observed increase in **anthropogenic** greenhouse gas concentration
- Discernible human influences now extend to other aspects of climate, including ocean warming, continental-average temperatures, temperature extremes and wind patterns

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

# Projections of future changes in climate

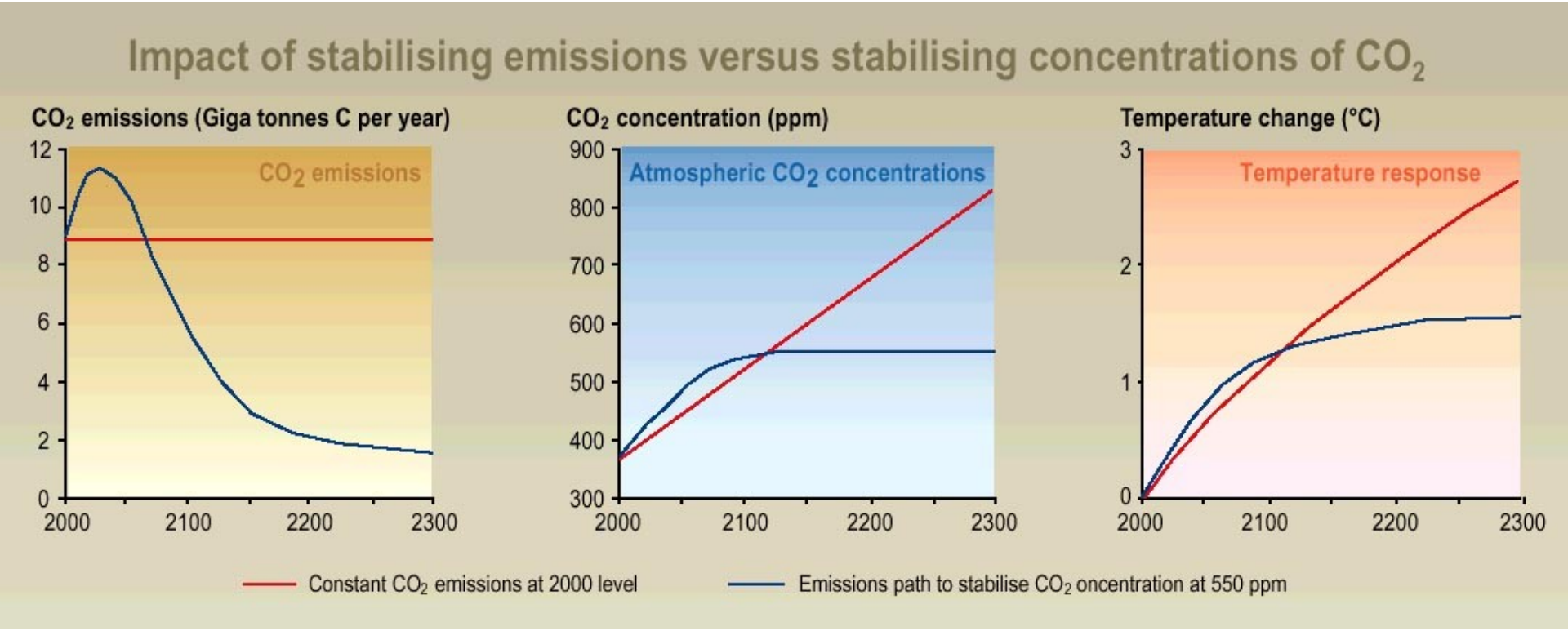
- For the next two decades a warming of about 0.2°C per decade is projected for a range of SRES emission scenarios
- Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected

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

# Projections of future changes in climate

- Since IPCC's first report in 1990, assessed projections have suggested global averaged temperature increases between about 0.15 and 0.3°C per decade for 1990 to 2005. This can now be compared with observed values of about 0.2°C per decade

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




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

IPCC (2001)

# Etapes d'une projection climatique

Scénario socio-économique, production d'énergie

Modèle de cycle du carbone

Modèle climatique

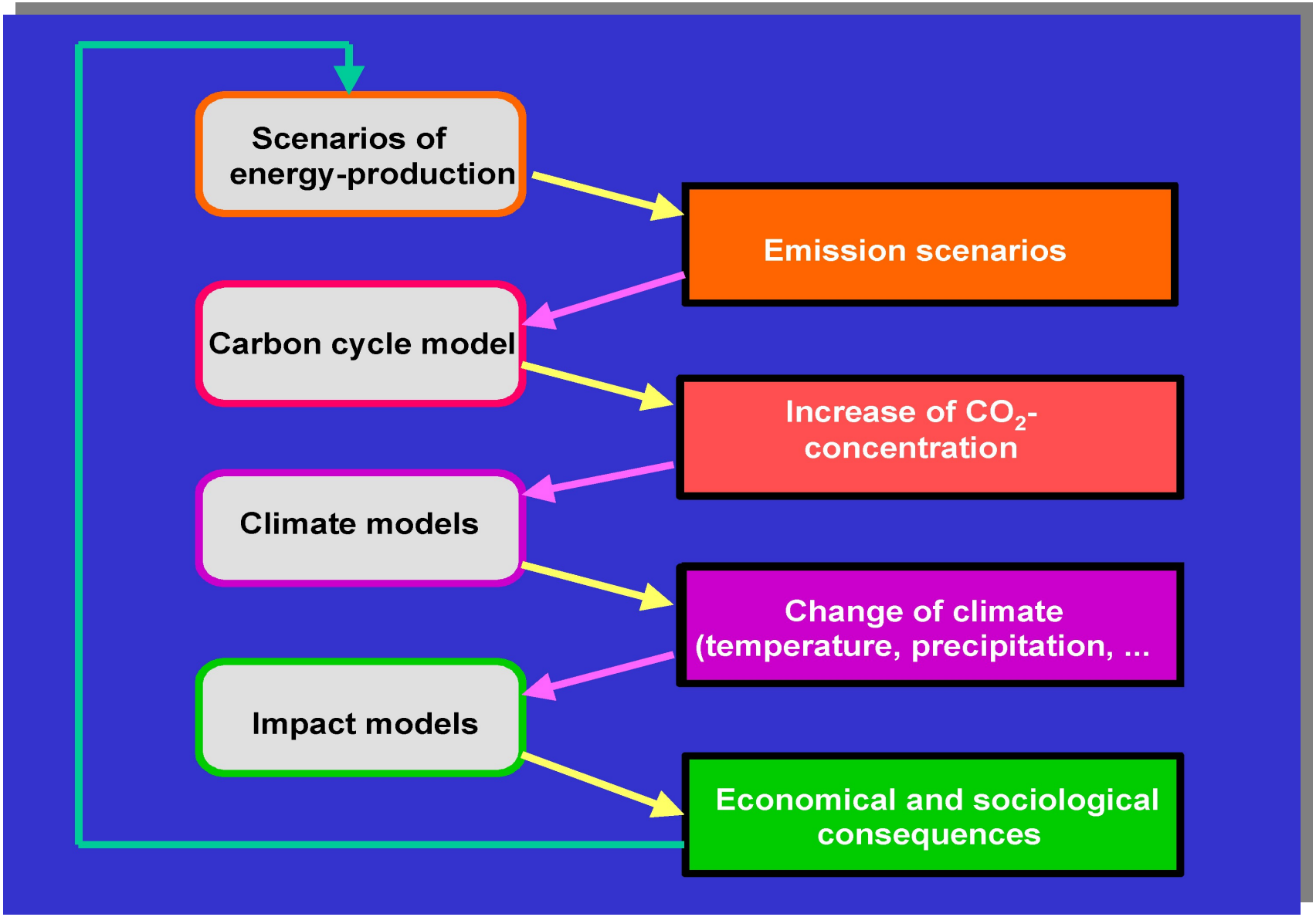
Modèle d'impacts

Scénario d'*émissions* (gaz à effet de serre)

*Concentrations* en gaz à effet de serre

Changements climatiques

Conséquences économiques et sociales




The information chain leading to a climate projection

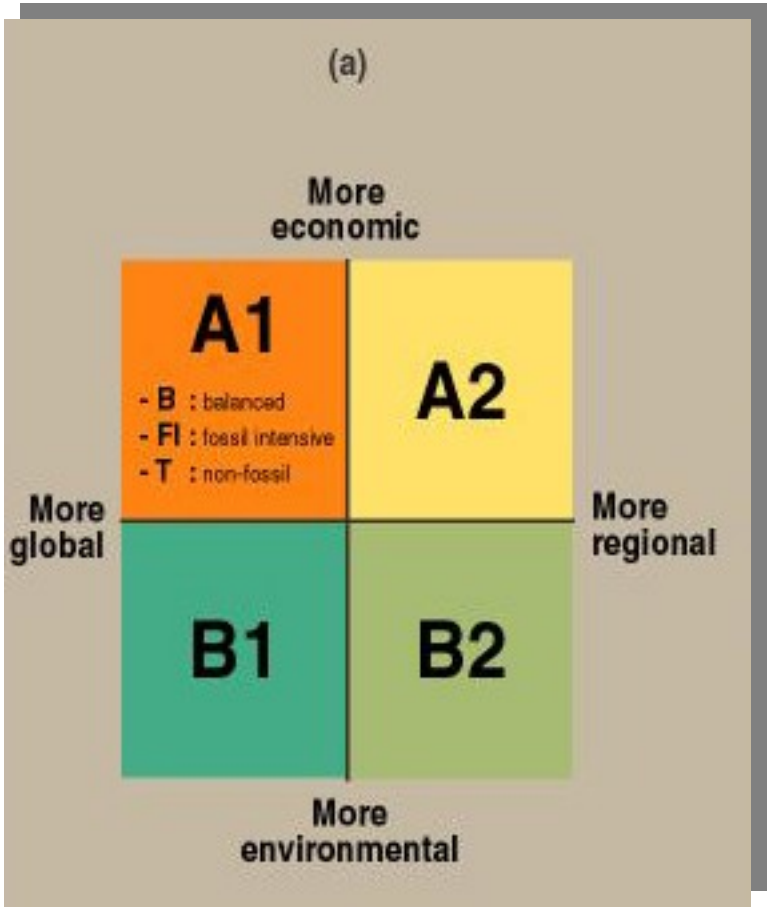
# Scenarios IPCC SRES*

**A1:** A world of rapid economic growth and rapid introductions of new and more efficient technologies

**A2:** A very heterogenous world with an emphasis on familiy values and local traditions

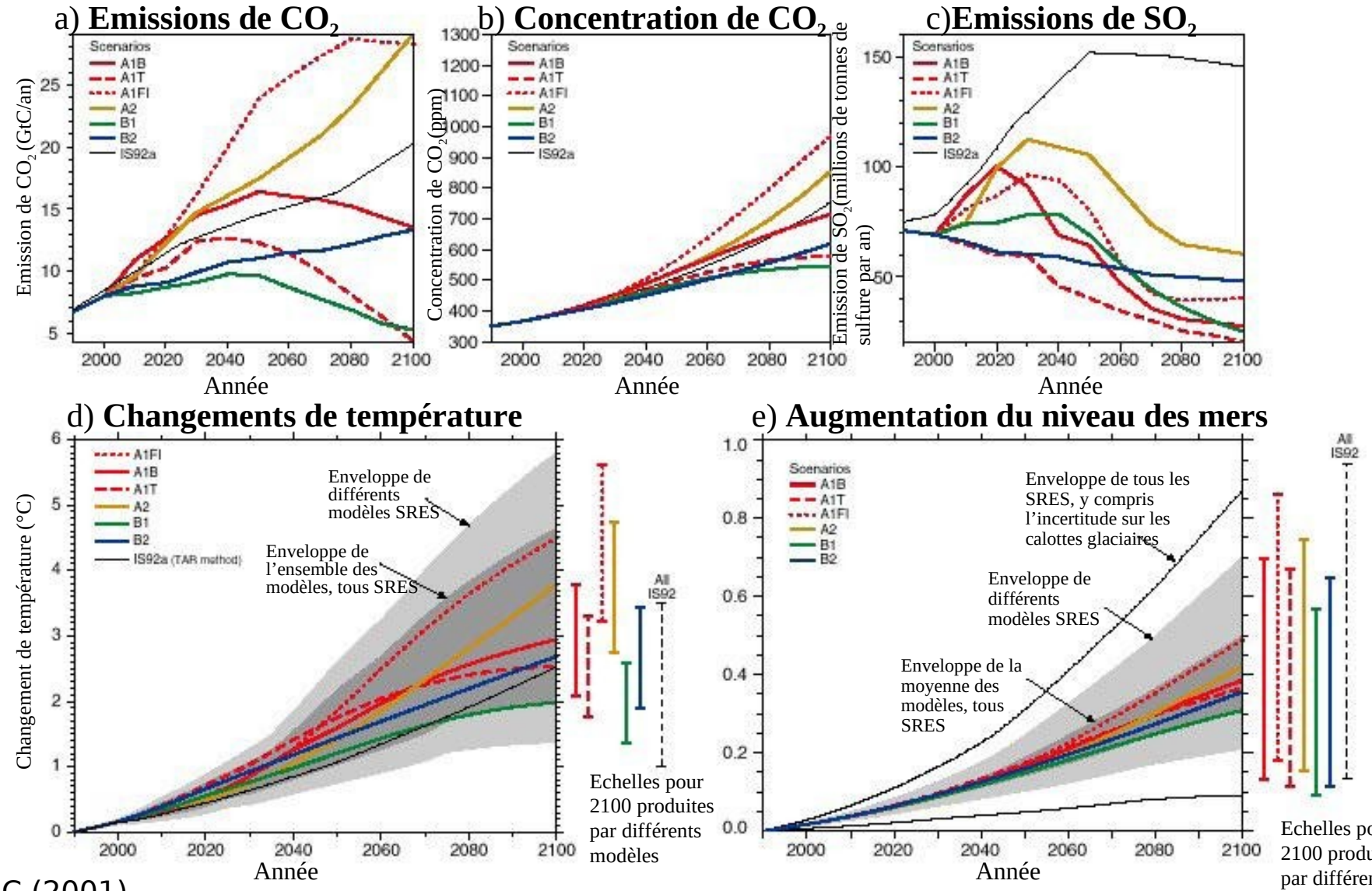
**B1:** A world of „dematerialization“ and introduction of clean technologies

**B2:** A world with an emphasis on local solutions to economic and environmental sustainability



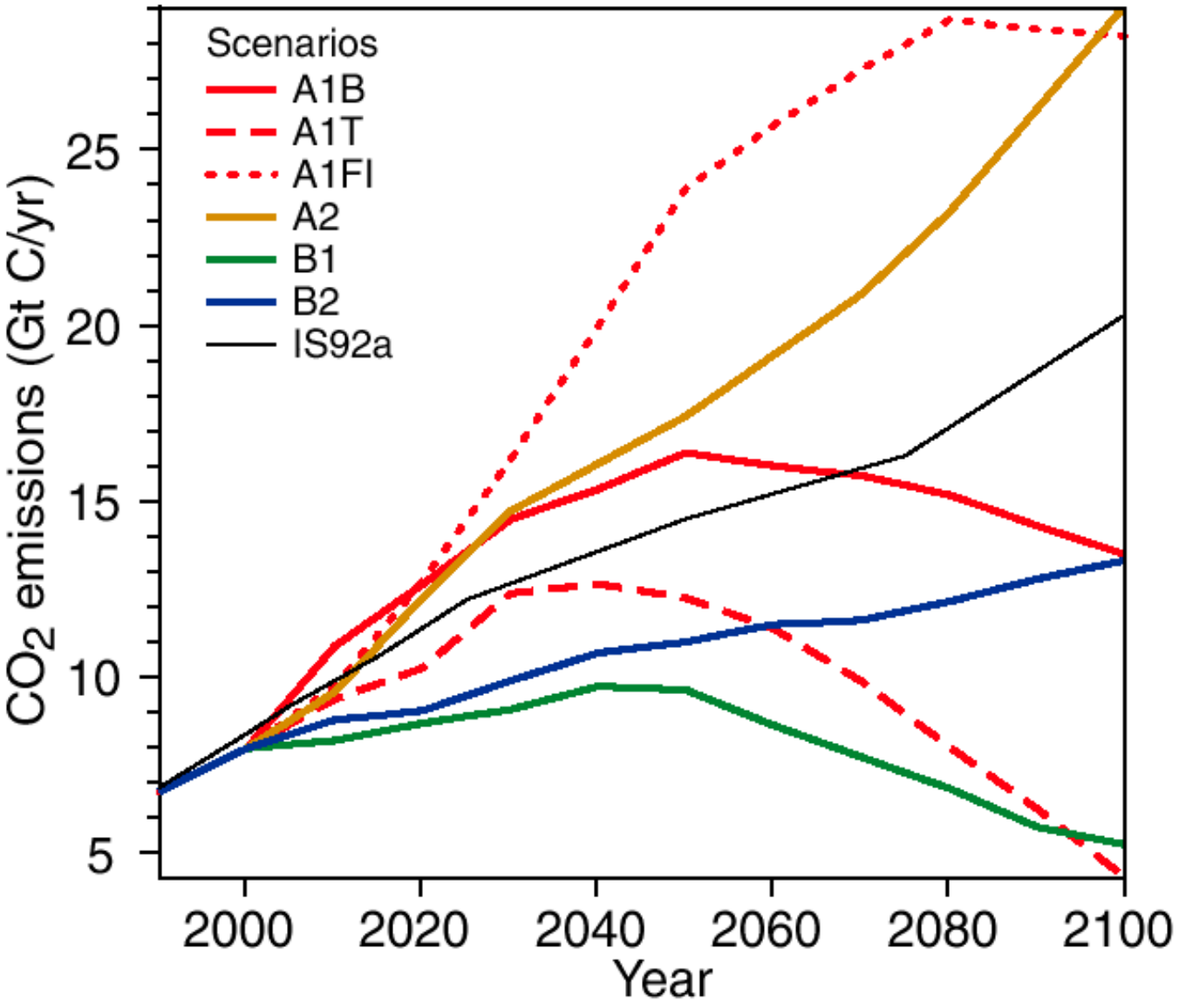

* Special Report on Emissions Scenarios

# Figure 10: On prévoit un changement dans la composition de l'atmosphère, qui impliquera une augmentation de la température et du niveau des mers



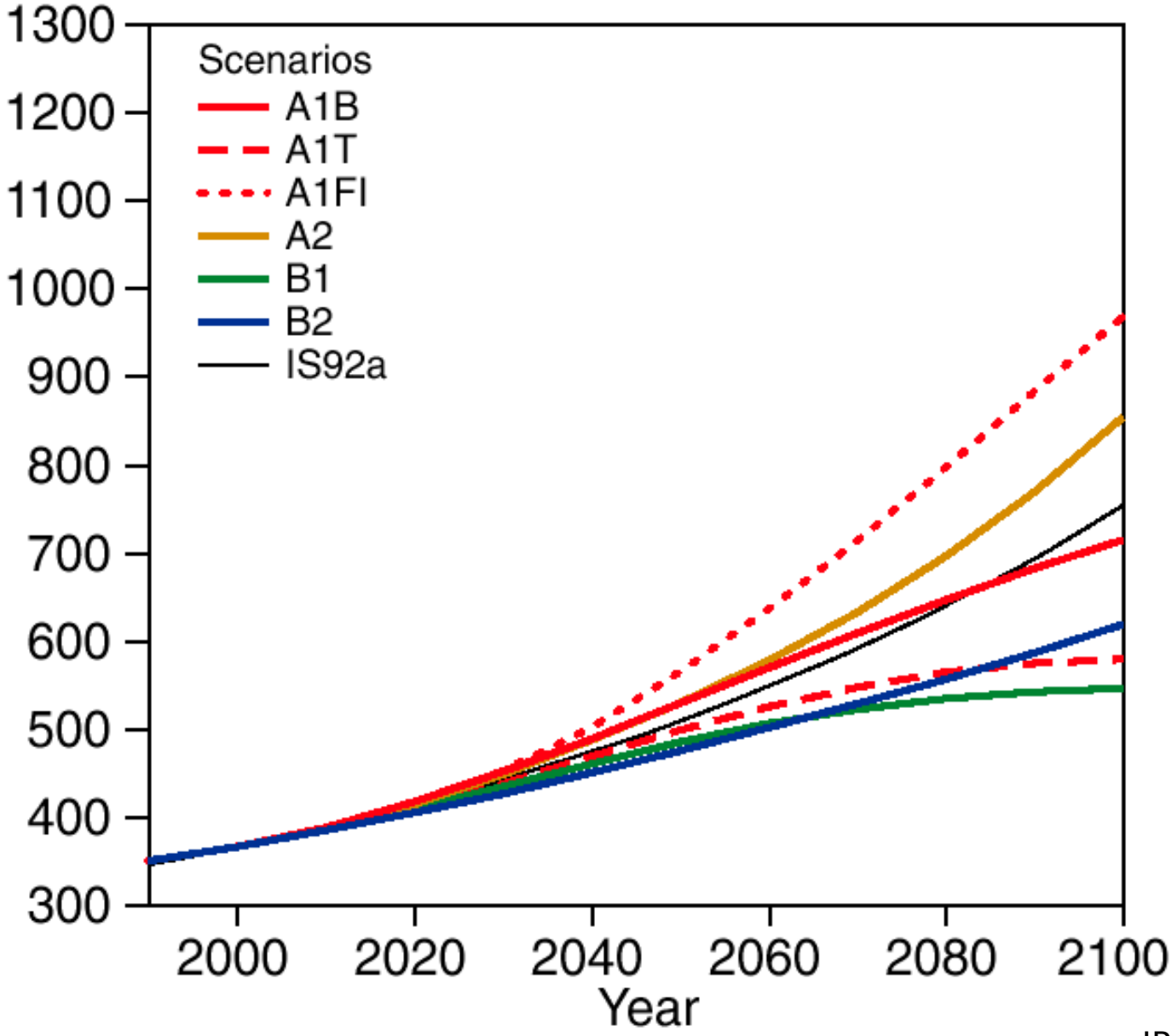

IPCC (2001)

# $CO_2$ emissions



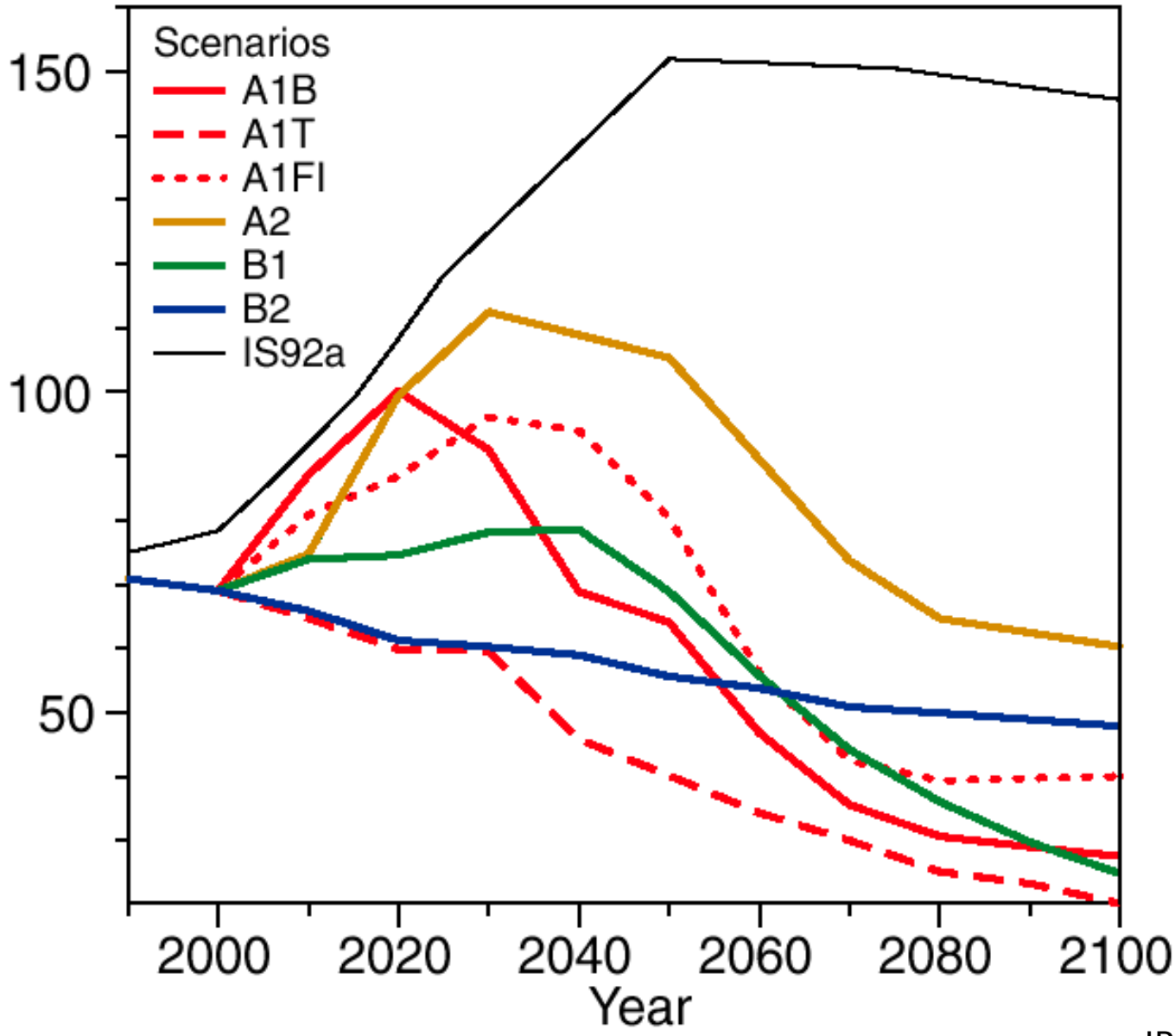

IPCC (2001)

# $CO_2$ concentrations



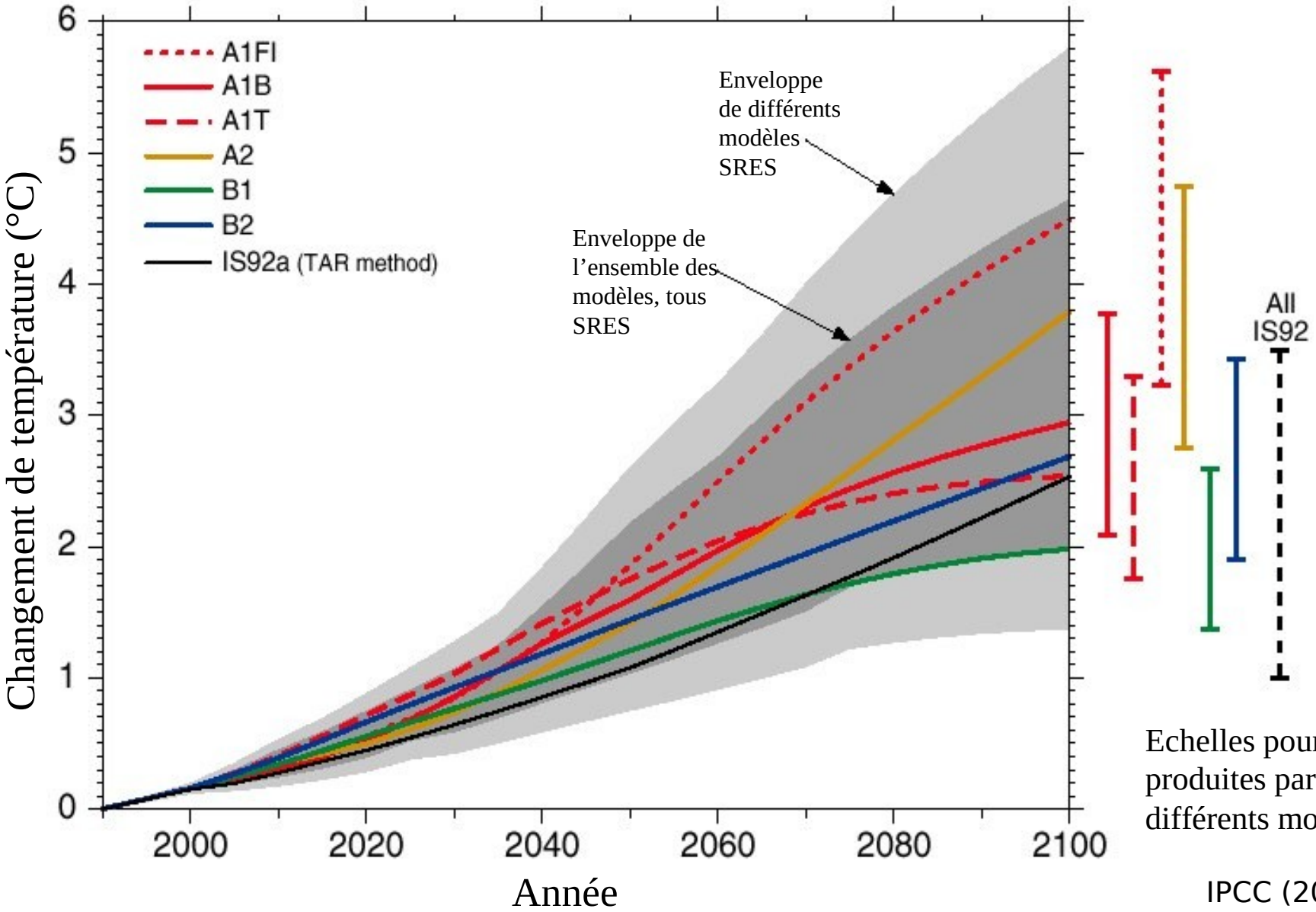

IPCC (2001)

# $SO_2$ emissions




IPCC (2001)

# Figure 11 : On prévoit une augmentation de la température moyenne à la surface du globe pour le 21ème siècle

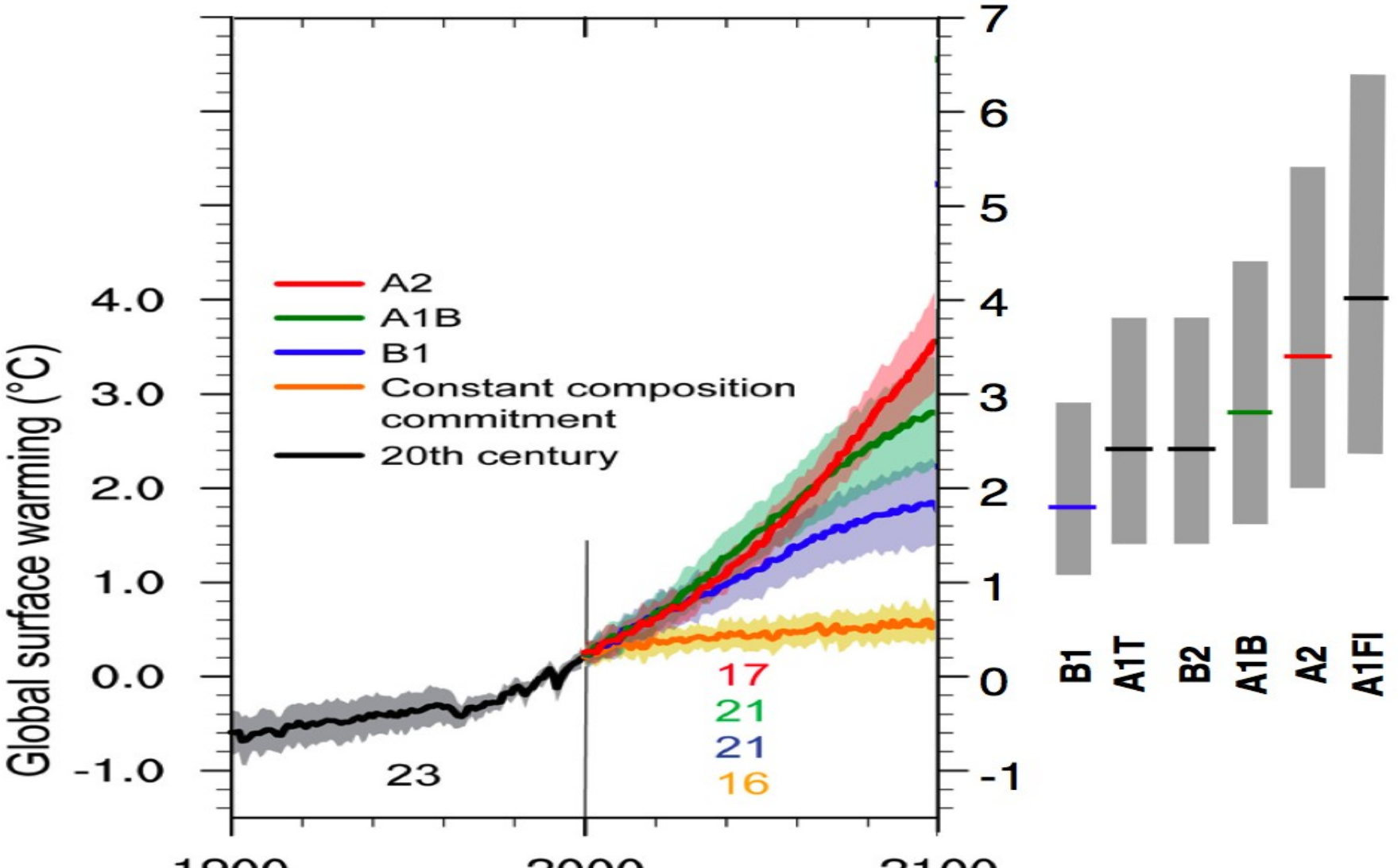



Echelles pour 2100 produites par différents modèles

IPCC (2001)

# *Projections of future changes in climate* (relative to 1980–1999)

**(based on IPCC 2007 SPM draft figure)**



# Projected globally averaged surface warming and sea level rise at the end of the 21st century

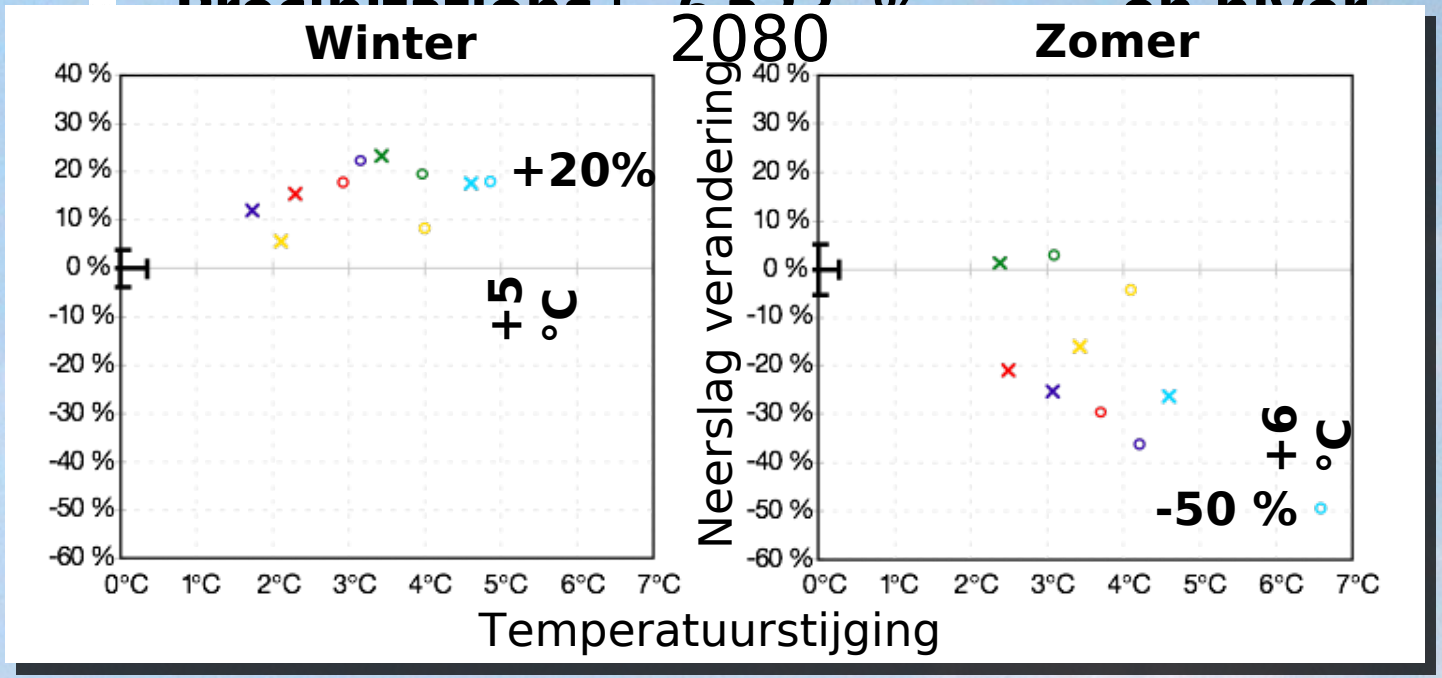
| | Temperature Change (°C at 2090-2099 relative to 1980-1999) [a] | | Sea Level Rise (m at 2090-2099 relative to 1980-1999) |
|---|---|---|---|
| Case | Best estimate | *Likely* range | Model-based range excluding future rapid dynamical changes in ice flow |
| Constant Year 2000 concentrations [c] | 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 |

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

# Changements climatiques (5b)

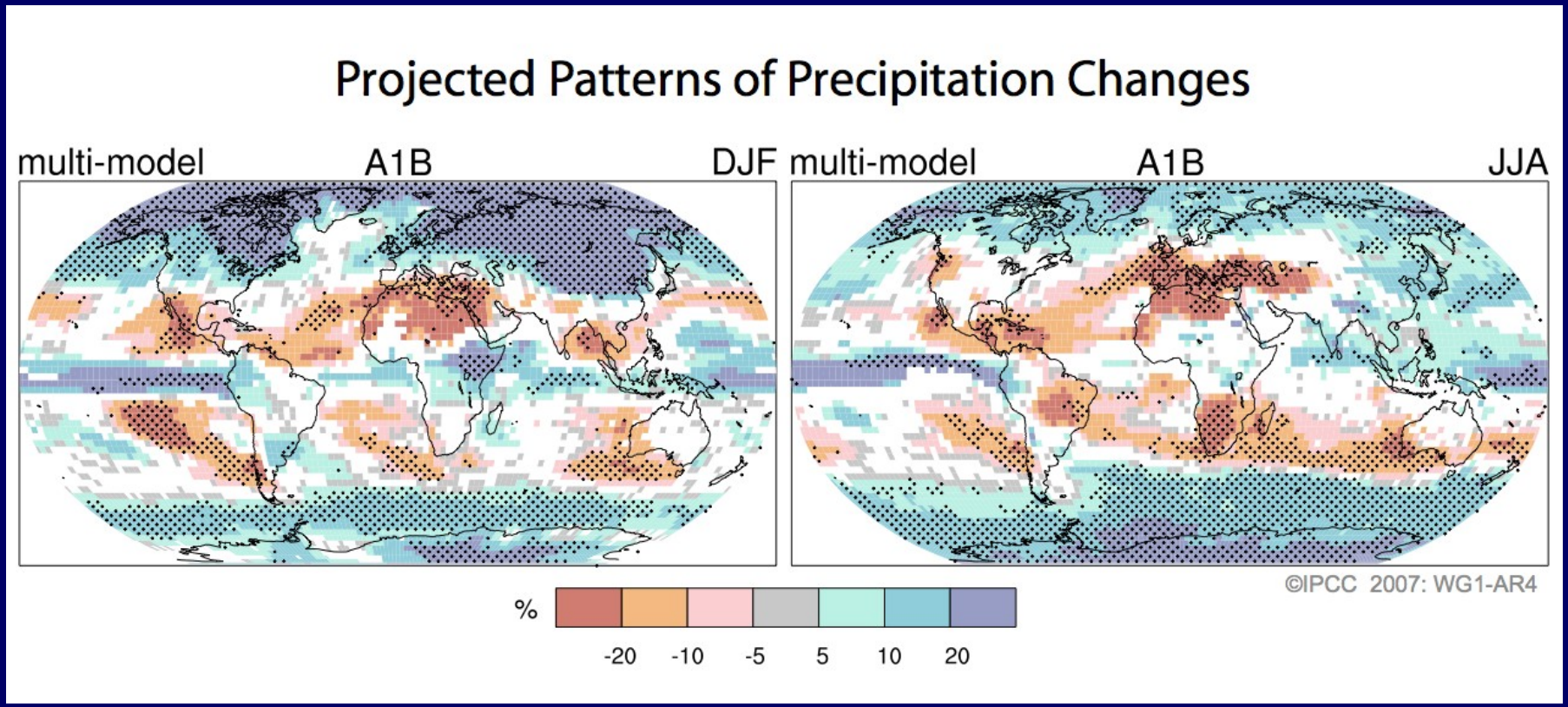
Belgique

- **Augmentation de température importante dès 2050**
- **A la fin du 21ème S, selon scénarios ($CO_2$) et modèles :**
  - **Température +2,4 à 6,6 °C en été**
  - **Précipitations + 6 à 22 % en hiver**




UCL (instit. G. Lemaitre), d'après GIEC : http://ipcc-ddc.cru.uea.ac.uk/

# Projections of Future Changes in Climate




Precipitation increases *very likely* in high latitudes

Decreases *likely* in most subtropical land regions

# Projections of Future Changes in Climate

There is now higher confidence in projected patterns of warming and other regional-scale features, including changes in wind patterns, precipitation, and some aspects of extremes and of ice.

# PROJECTIONS OF FUTURE CHANGES IN CLIMATE

- Snow cover is projected to contract
- Widespread increases in thaw depth most permafrost regions
- Sea ice is projected to shrink in both the Arctic and Antarctic
- In some projections, Arctic late-summer sea ice disappears almost entirely by the latter part of the 21st century

# PROJECTIONS OF FUTURE CHANGES IN CLIMATE

- *Very likely* that hot extremes, heat waves, and heavy precipitation events will continue to become more frequent
- *Likely* that future tropical cyclones will become more intense, with larger peak wind speeds and more heavy precipitation
  - less confidence in decrease of total number
- Extra-tropical storm tracks projected to move poleward with consequent changes in wind, precipitation, and temperature patterns

# PROJECTIONS OF FUTURE CHANGES IN CLIMATE

- 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.

# 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.

# IPCC WG-II (Impacts) (2) 2001
(426 authors, 440 reviewers)

- Some natural systems may undergo significant and irreversible damage:
  - glaciers
  - coral reefs & atolls
  - mangroves
  - boreal & tropical forests
  - polar & alpine ecosystems
  - prairie wetlands
  - remnant native grasslands

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

# IPCC WG-II (Impacts) (3) 2001
(426 authors, 440 reviewers)

- Human systems that are sensitive to climate change include mainly:
  - water resources
  - agriculture (especially food security) and forestry
  - coastal zones and marine systems (fisheries)
  - human settlements
  - energy and industry
  - insurance, financial services

# IPCC WG-II (Impacts) (5) 2001
(426 authors, 440 reviewers)

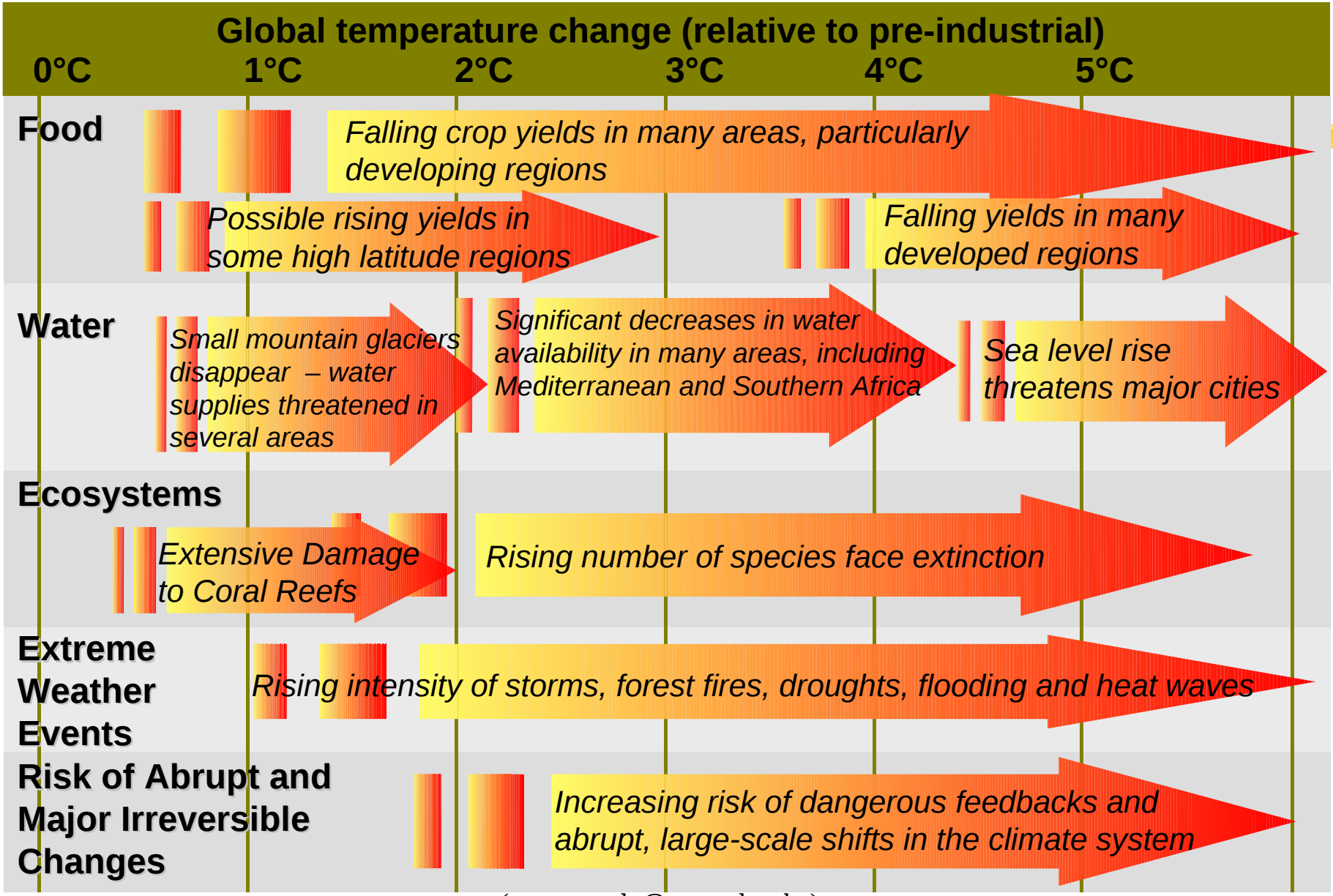
- Projected *beneficial* impacts include:
  - **Increased potential *crop yield* in some mid-latitude regions for increases in T of less than a few degrees C**
  - **Potential increase in global *timber* supply from appropriately managed forests**
  - **Increased *water* availability for populations in some water scarce regions, for example in parts of South East Asia**
  - **Reduced *winter mortality* in mid- and high-latitudes**
  - **Reduced *energy demand* for space heating due to higher winter temperatures**

# IPCC WG-II (Impacts) (4) 2001
(426 authors, 440 reviewers)

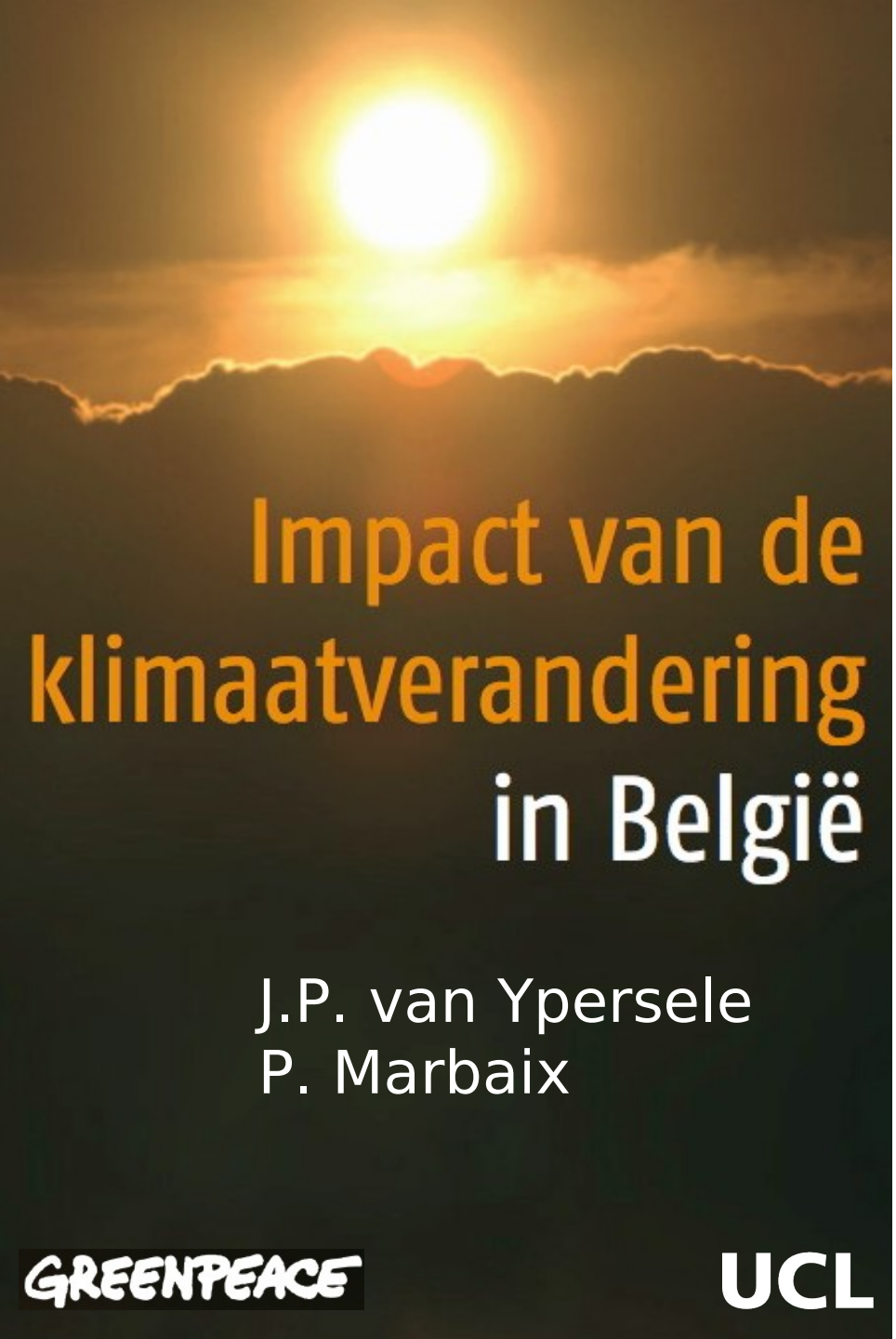
- Projected *adverse* impacts include:
  - **General reduction in potential *crop yields* in most tropical and sub-tropical regions**
  - **Decreased *water* availability for populations in many water scarce regions (esp. sub-tropics)**
  - **Increase in the number of people exposed to *diseases* such as malaria and cholera, and an increase in *heat stress mortality***
  - **Widespread increase in the risk of *flooding* for many human settlements from both increased heavy precipitation events and sea-level rise**

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

# Projected impacts of climate change




(vanypersele@astr.ucl.ac.be)




**Available on**
**www.greenpeace.be and**
**www.climate.be/impacts**

# Impacts des changements climatiques en Belgique

P. Marbaix
J.P. van Ypersele

Université catholique de Louvain

# Present situation: blue=land under the average sea-level

## (not flooded because of protection)


Source: N. Dendoncker (Dépt de Géographie, UCL), J.P. van Ypersele et P. Marbaix (Dépt de Physique, UCL)

# 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)

# With 8 metre sea-level rise: 3700 km² below sea-level in Belgium

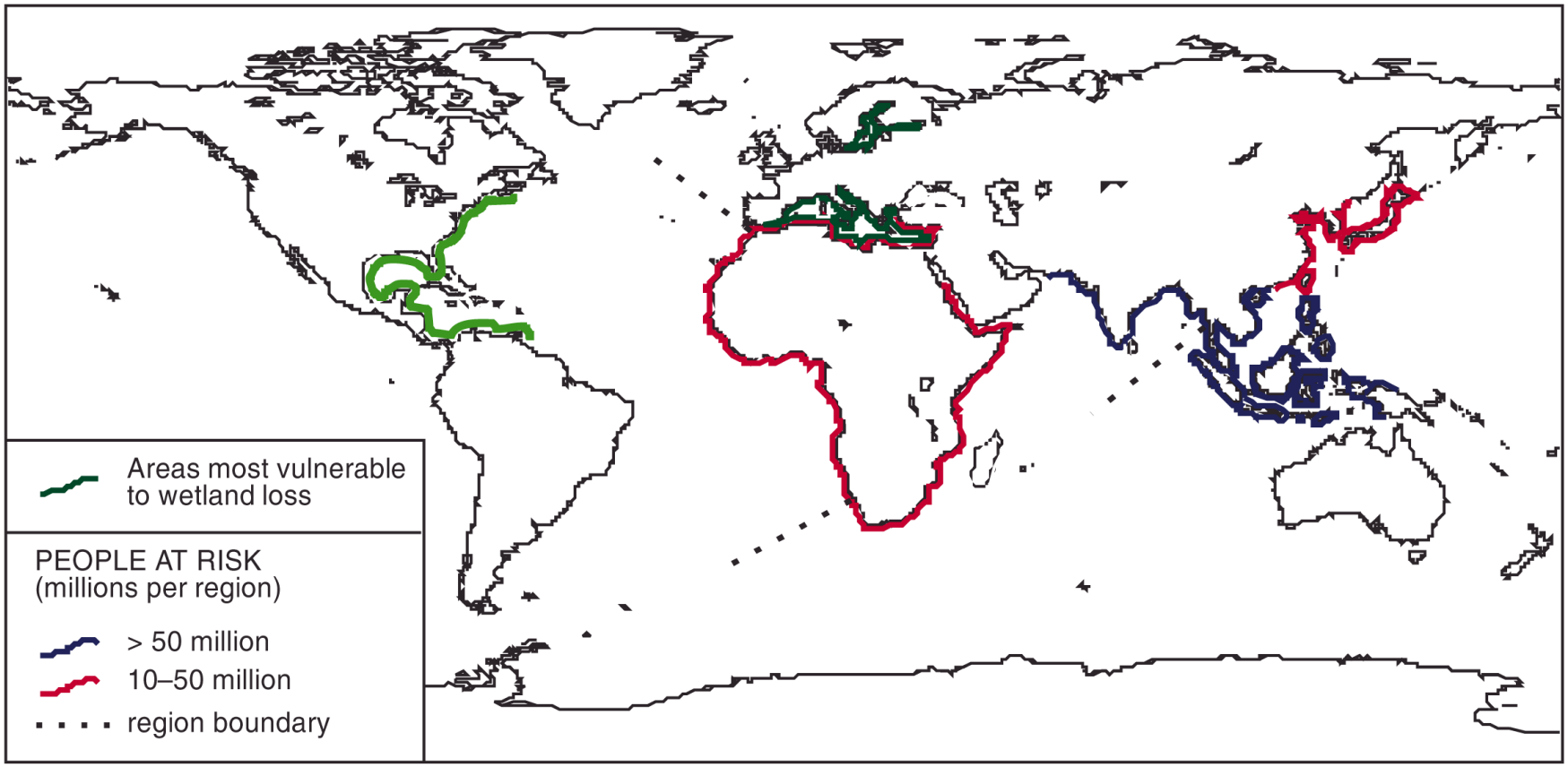
## (very possible in year 3000)

## (NB: flooded area depends on protection)


Source: N. Dendoncker (Dépt de Géographie, UCL), J.P. van Ypersele et P. Marbaix (Dépt de Physique, UCL)

# 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.*

# ENVIRONMENTAL REFUGEES IN A GREENHOUSE-AFFECTED WORLD

| Country or Region | Total of Refugees Foreseen (millions) |
|---|---|
| Bangladesh | 15 |
| Egypt | 15 |
| Deltas and other coastal zones | 70 |
| Agriculturally dislocated areas | 50 |
| Total | 150 |

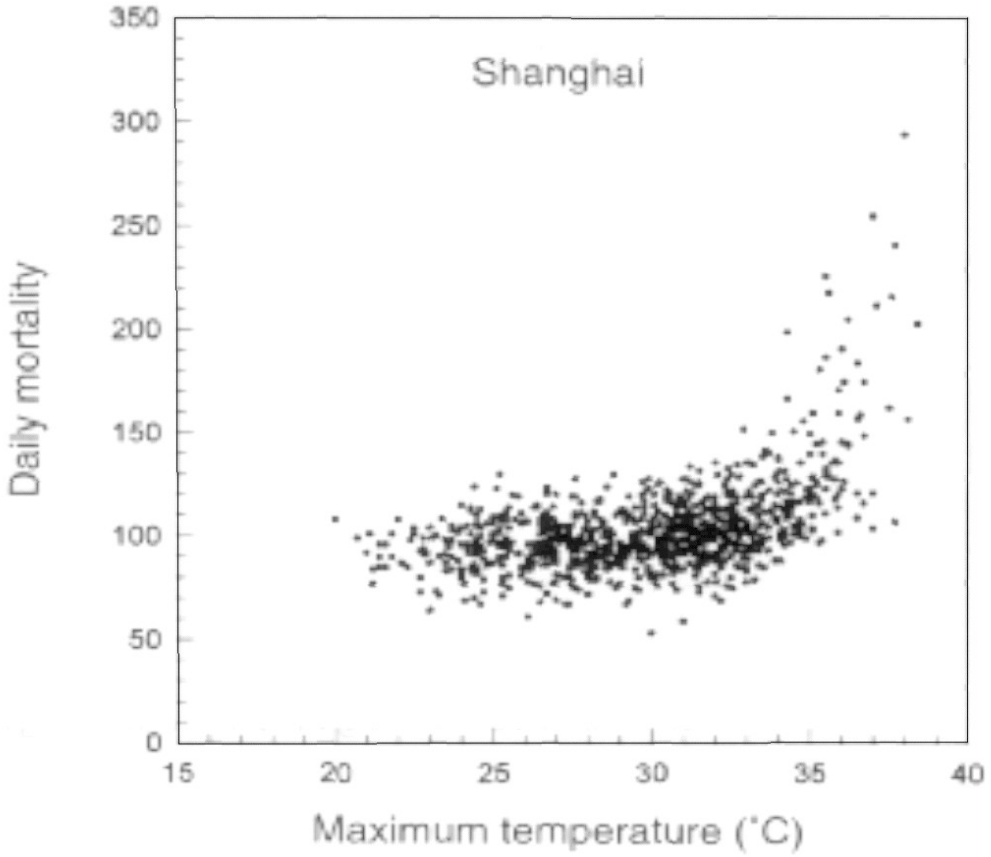
Source: Myers (1993)

## Effects on human health…

**Reduced winter mortality in mid- and high-latitudes**

**Increased incidence of heat stress mortality, and the number of people exposed to vector-borne diseases, such as malaria and dengue and water-borne diseases such as cholera, especially in the tropics and sub-tropics**

# Relationship between maximum temperature and mortality in Shanghai, China, 1980-89



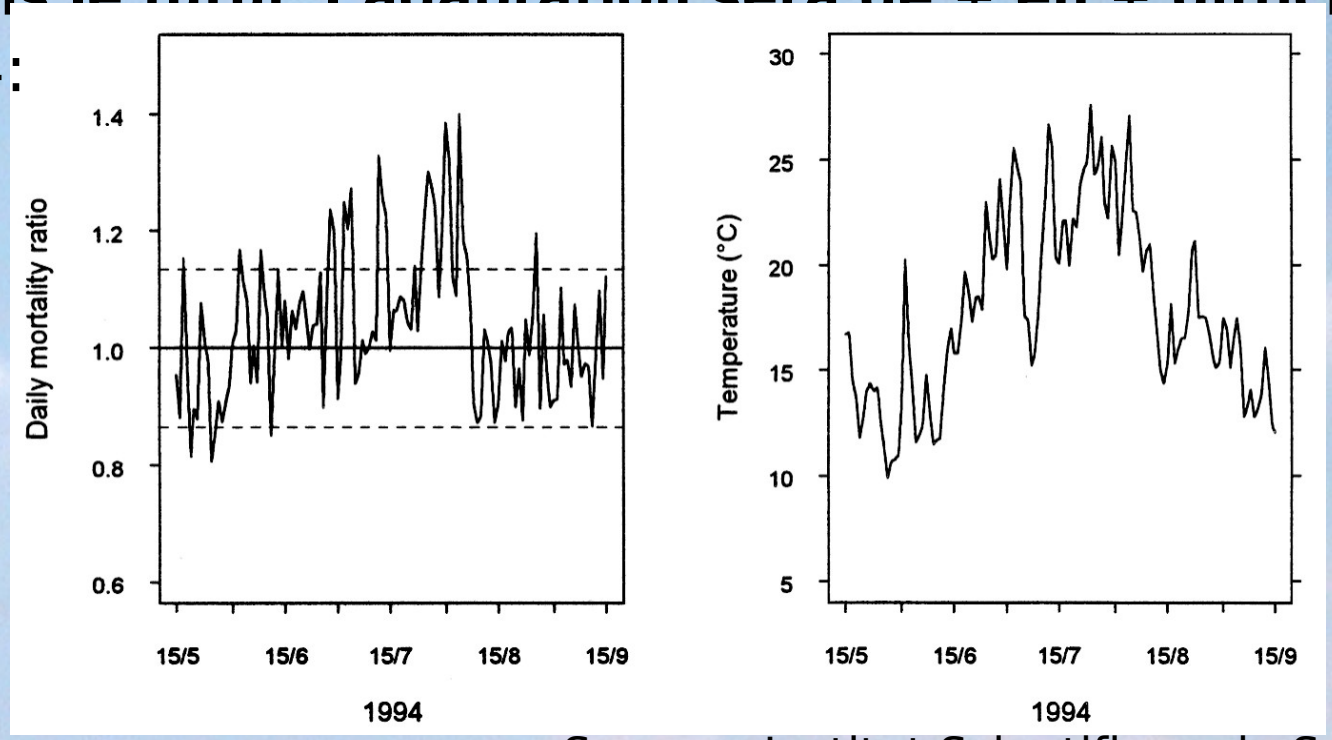

Jean-Pascal van Ypersele
(vanypersele@astr.ucl.ac.be)

McMichael & al., 1996

# Effets sur la santé

- **Dépend de la vulnérabilité, capacité d'adaptation -> pays développés moins touchés, mais…**
- **Vagues de chaleur :**
  **effets bien étudié chez nous par l'ISP pour les étés 1994 et 2003: chaleur + ozone ->  excès de ~ 1250 décès**
- **Dans le futur, l'adaptation sera de + en + difficile**

Été 1994:




Source : Institut Scientifique de Santé

# Santé: d’autres effets sont possibles

- Contribution possible du réchauffement à la propagation de la maladie de Lyme propagées par les tiques (photo) (corrélation entre leur nombre et la chaleur des hivers)
- Diminution de la mortalité cardio-vasculaire en hiver
- Infections facilitées par l

# The climate challenge is underestimated

- Impacts of unmitigated CC are huge
- Sensitivity of climate to greenhouse gases might be higher than anticipated
- Inertia of climate system is huge
- Decisions we take (or not) today have long-term climate consequences

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

# Conférence de Toronto, 1988

- **“ L’humanité se livre sans frein à une expérience qui touche l’ensemble du Globe et dont les conséquences définitives ne seraient dépassées que par celles d’une *guerre nucléaire mondiale* ”**

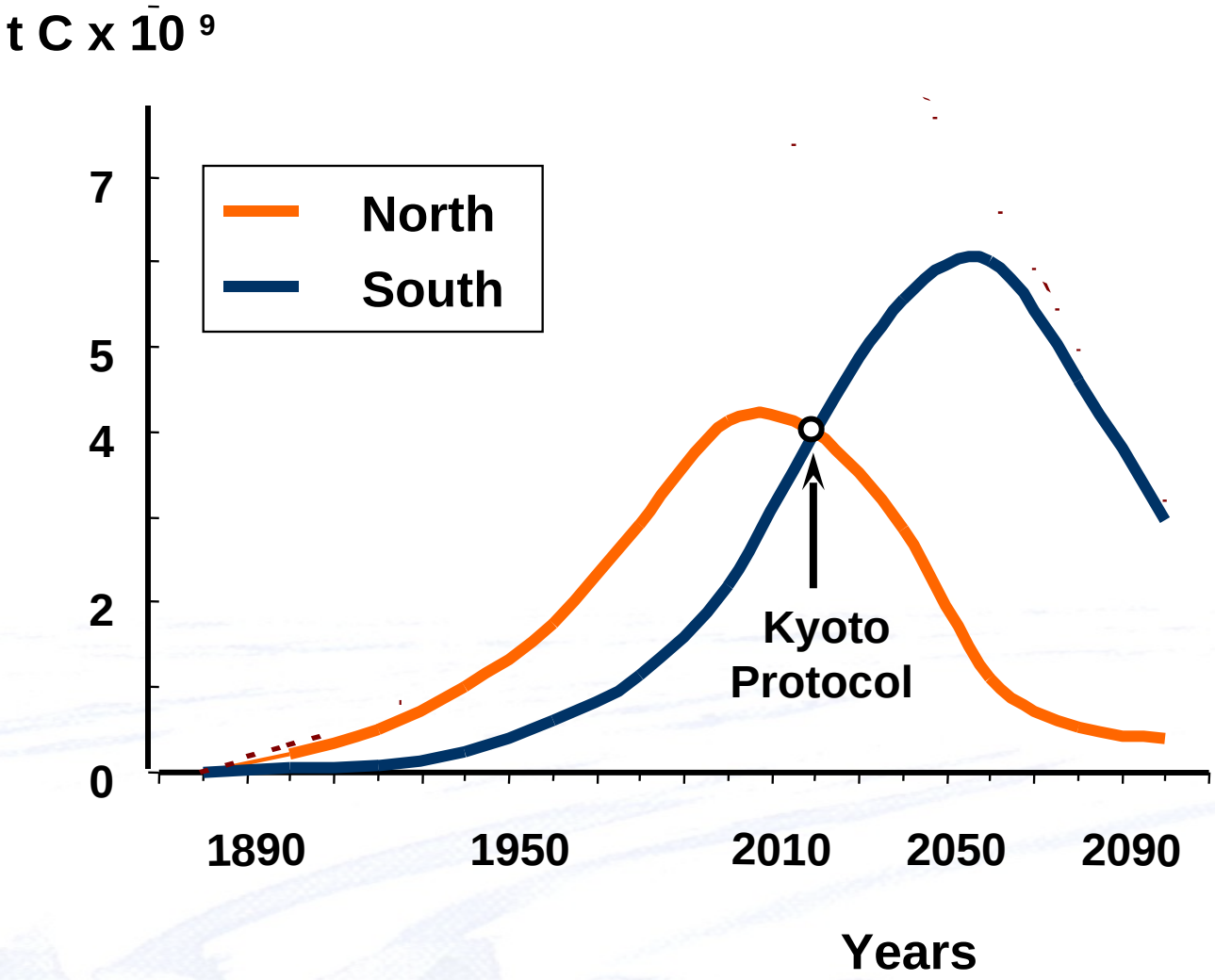
Jean-Pascal van Ypersele
(vanypersele@astr.ucl.ac.be)

# Kyoto is only a first step

- Goal: -5% for developed countries emissions
- Far from enough to avoid the «  bath tub  » to overflow…

North
+
South
carbon
emissions

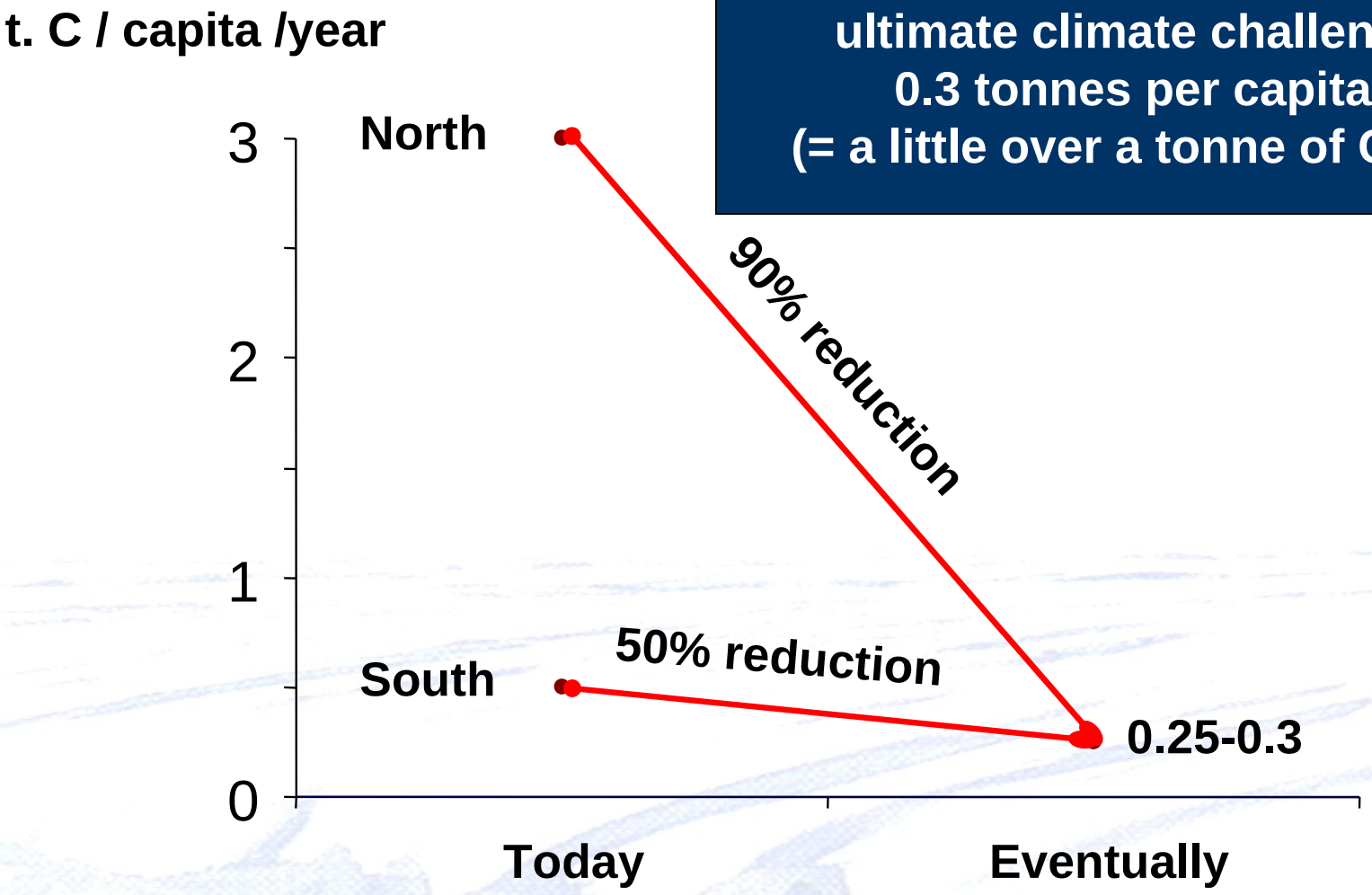
450 ppmv
stabilization
scenario




Source : *Sivan Kartha et al,* 1998

## carbon emissions

**ultimate climate challenge**
**0.3 tonnes per capita**
**(= a little over a tonne of $CO_2$)**




Source : *Sivan Kartha et al,* 1998

**- Climate is changing**
**-Humans are mostly responsible**
**-Exact future behaviour uncertain**

**-More than enough is known to justify further emission reductions**

Unicef

# References

- www.climate.be : ASTR-UCL
- www.ipcc.ch : IPCC
- www.unfccc.int : Convention & Protocol

- jcm.chooseclimate.org : interactive model by Ben Matthews, developed at UCL with support from BELSPO
- www.sternreview.org.uk : Stern review