“In and Out Air Strategies. From Climate Change to Microclimate. Library, Archives and Museum Preservation Issues”

5-6 March 2009

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Global Climate Change

What *has* changed.

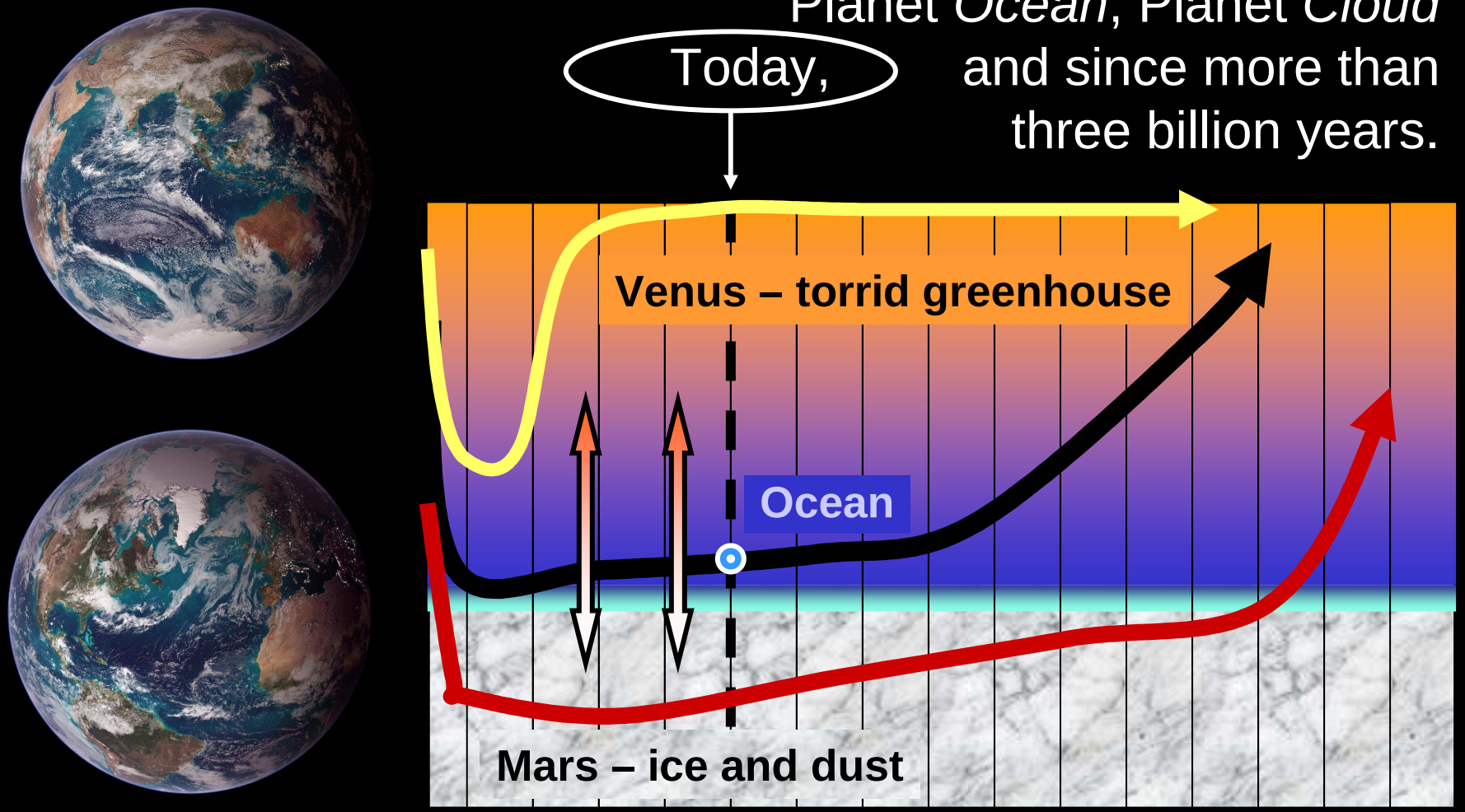
What *will* change.

What *must* change *quickly* !

Robert Kandel
Laboratoire de Météorologie Dynamique
Institut Pierre Simon Laplace
Ecole Polytechnique, Palaiseau, France

The state of the planet ?

Planet Earth ? … or rather
Planet *Ocean*, Planet *Cloud*
Today, and since more than
three billion years.

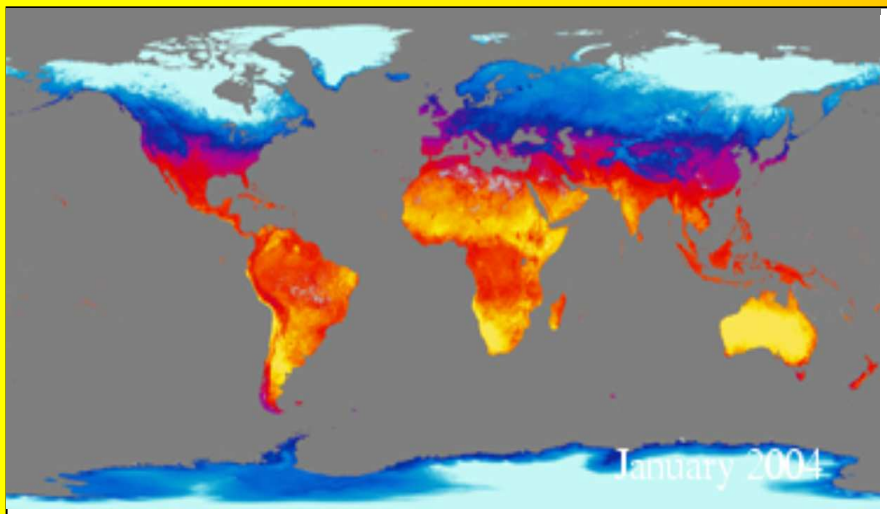


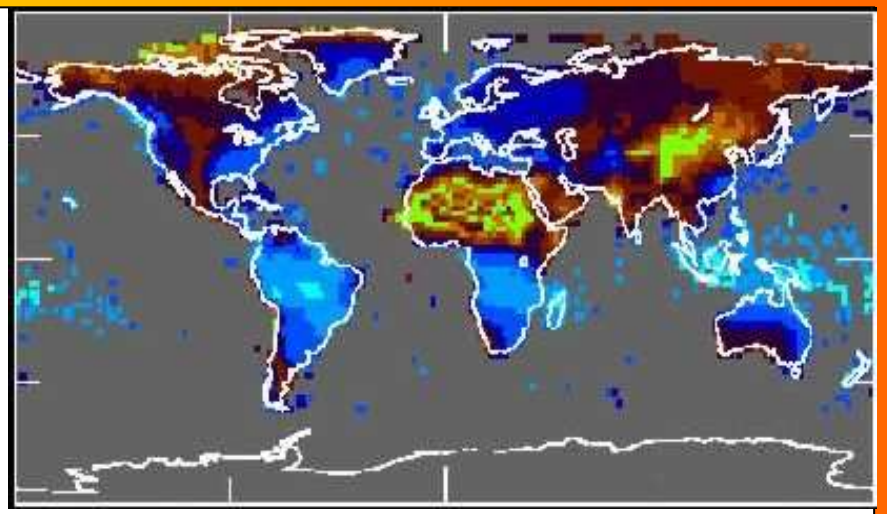
Global Climate Change

Climate determines the possibilities of *life* on the planet

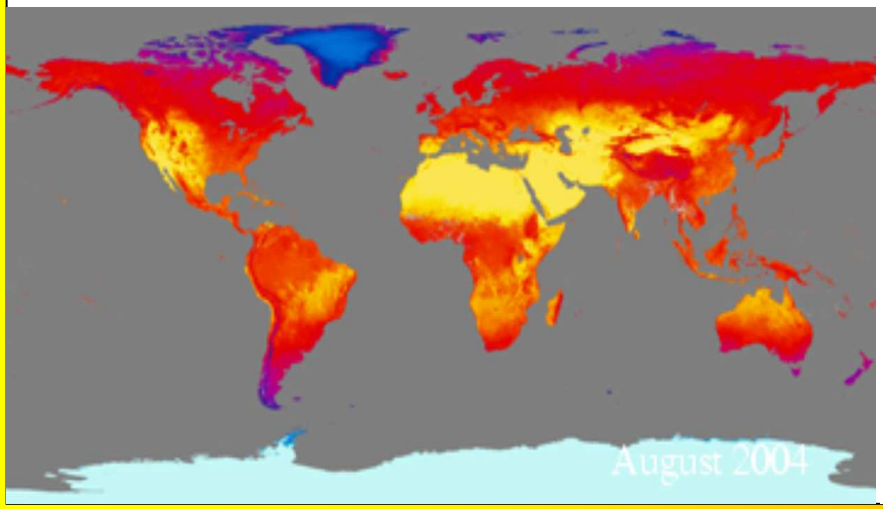
Climate

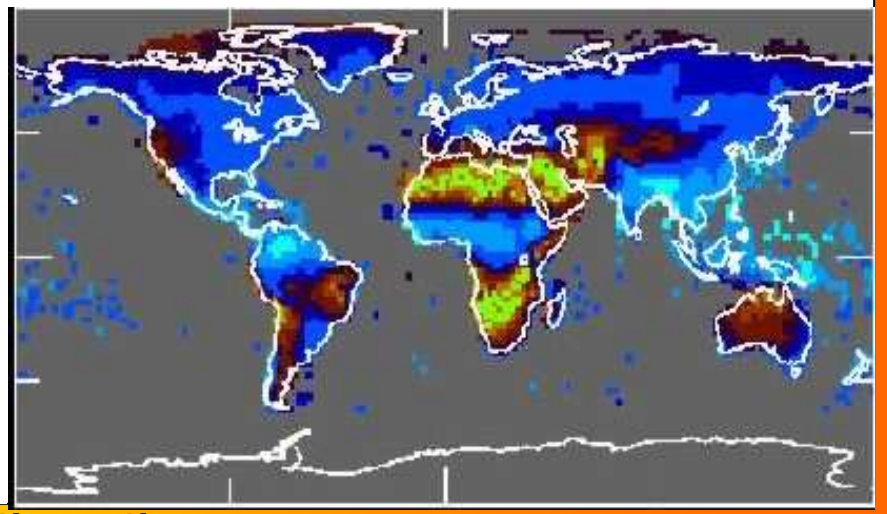
temperature *and* precipitation





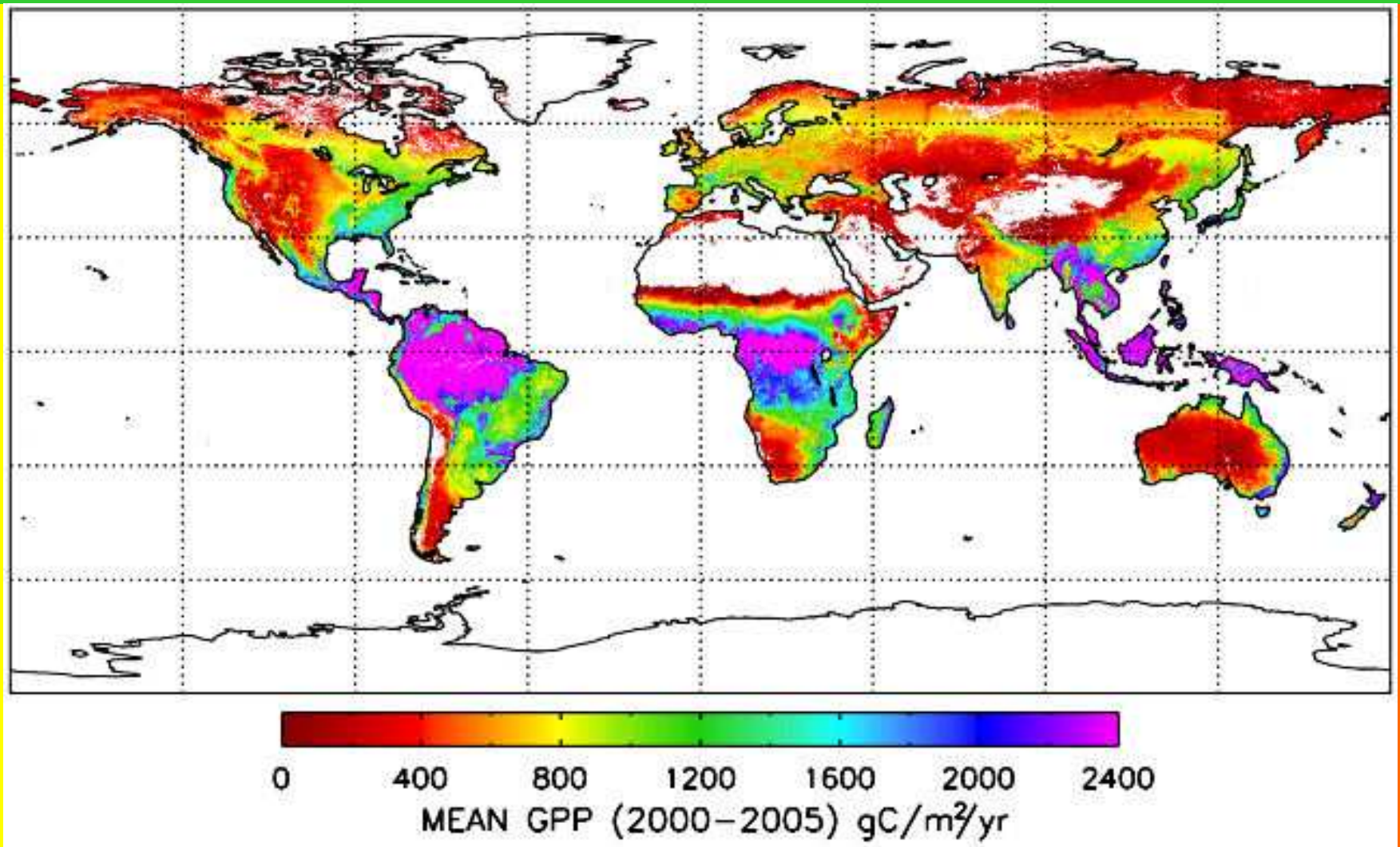
January





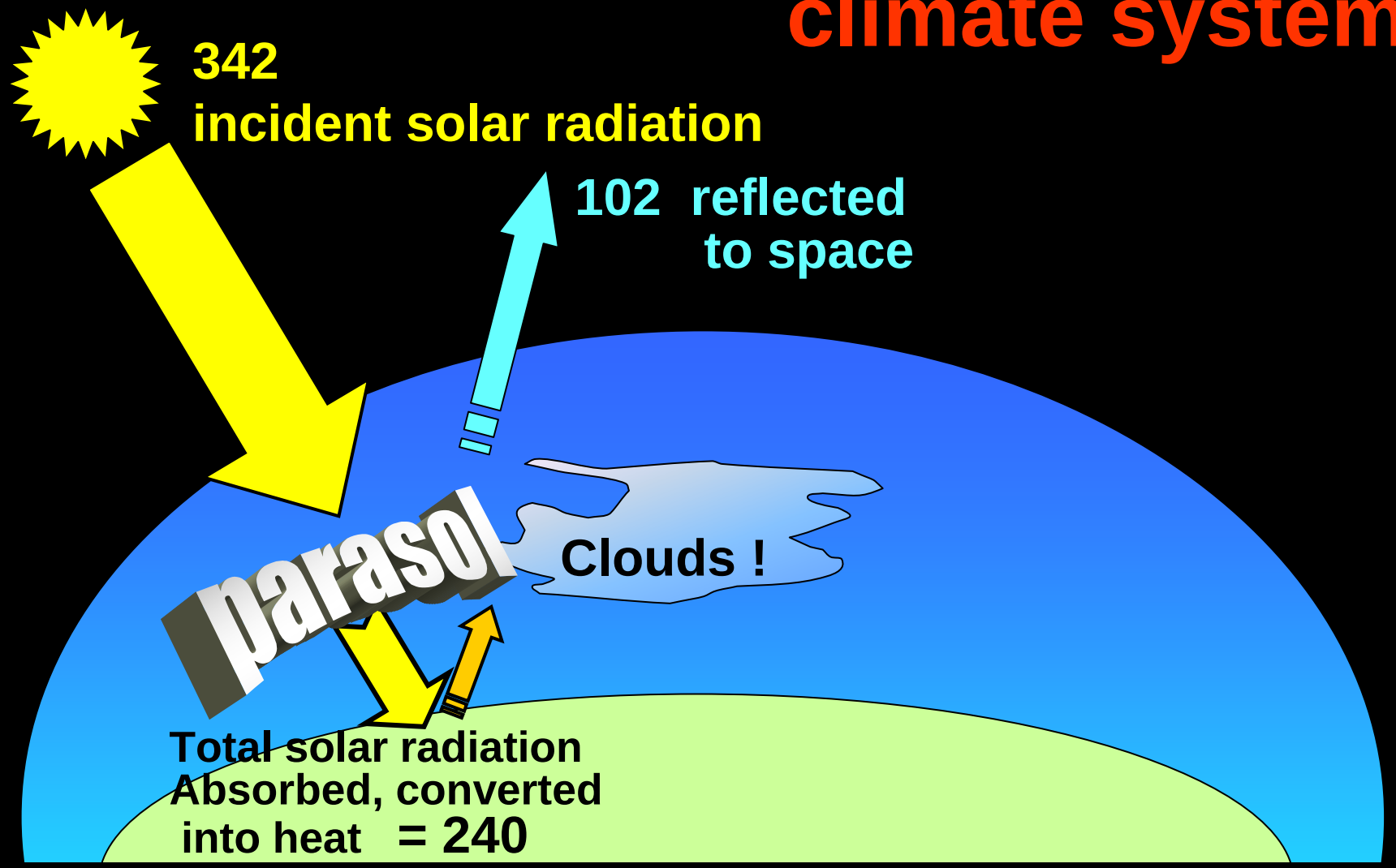
July

Life on Land – Gross Primary Production



Physics of the atmosphere and climate

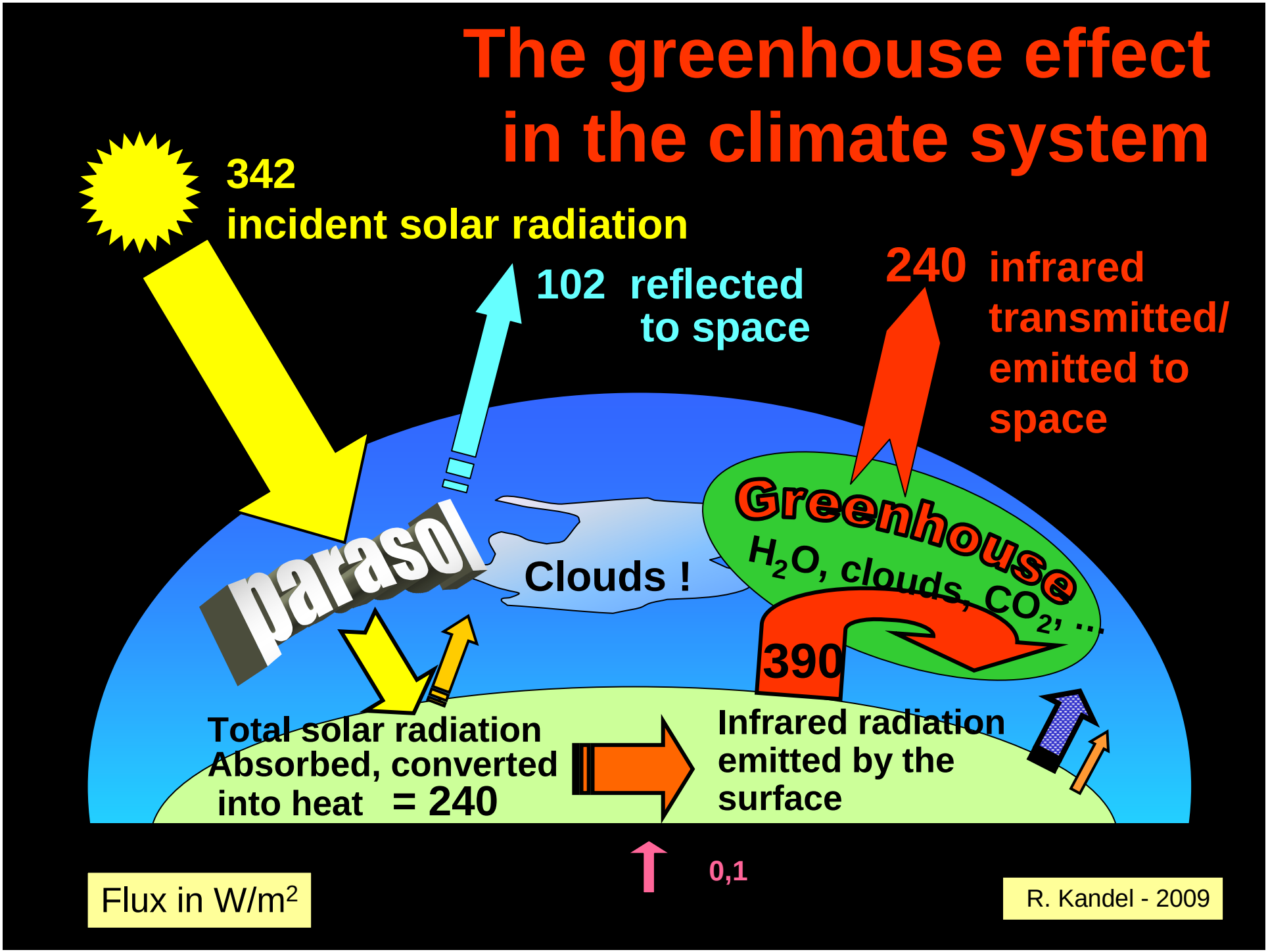
Energy input to the climate system



Flux in W/m^2

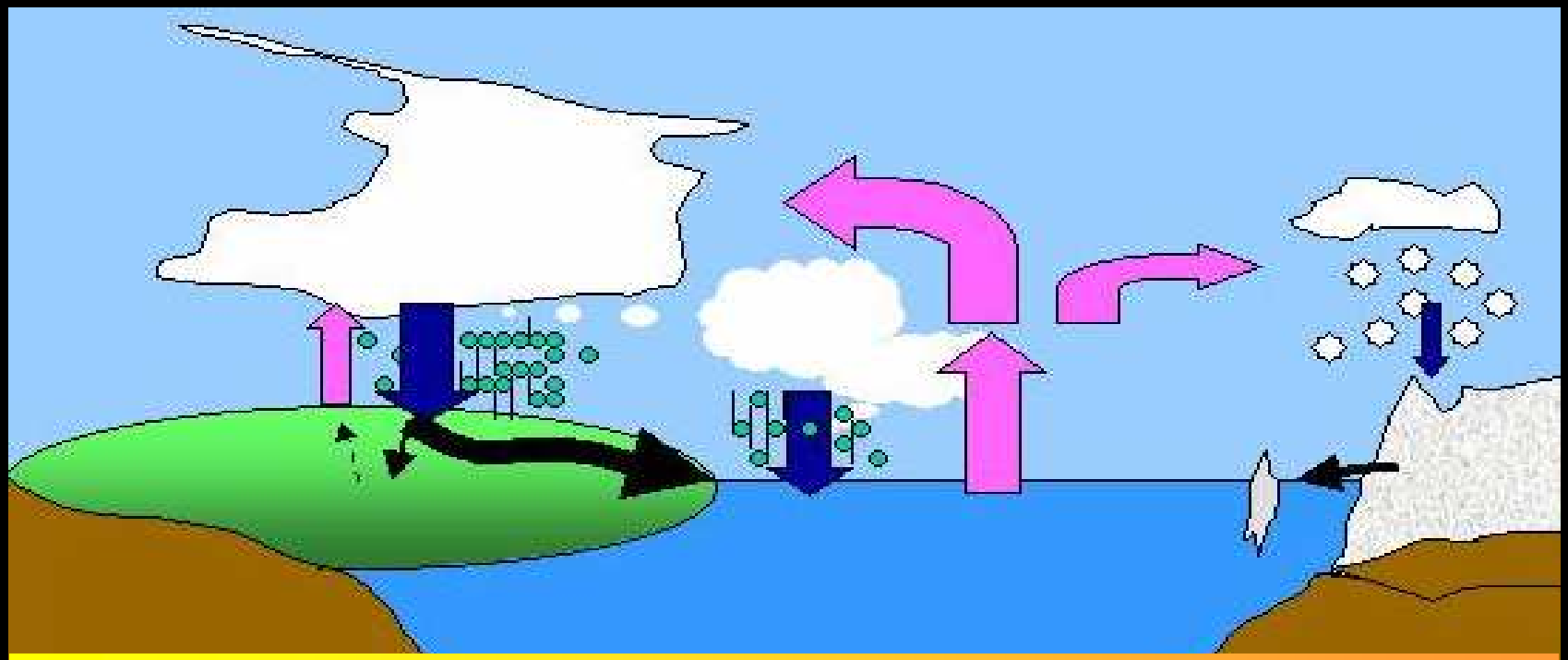
R. Kandel - 2009

The greenhouse effect in the climate system



Physics of the atmosphere and climate

The water cycle



Climate change (« glàbal warming ») necessarily entails changes in the water cycle

Evaporation, Precipitation, Runoff

« Global » Climate
Sun, Parasol, Greenhouse

Sun

- *Human activities have **no** effect*
- Does solar activity affect climate ?

Parasol

- Clouds, snow, ice
- Volcanic eruptions
- *Visible Pollution*

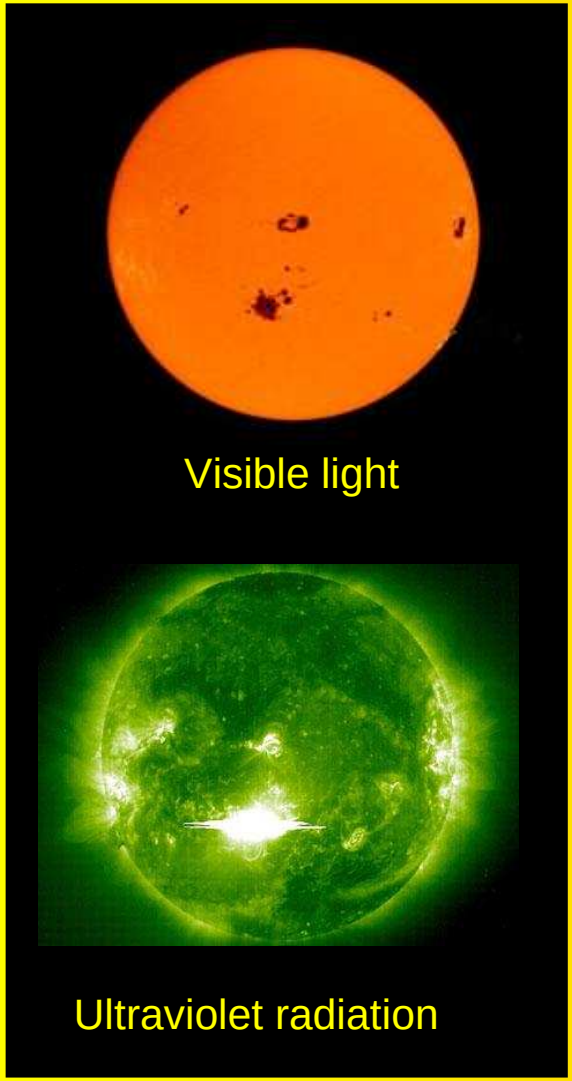
Greenhouse !

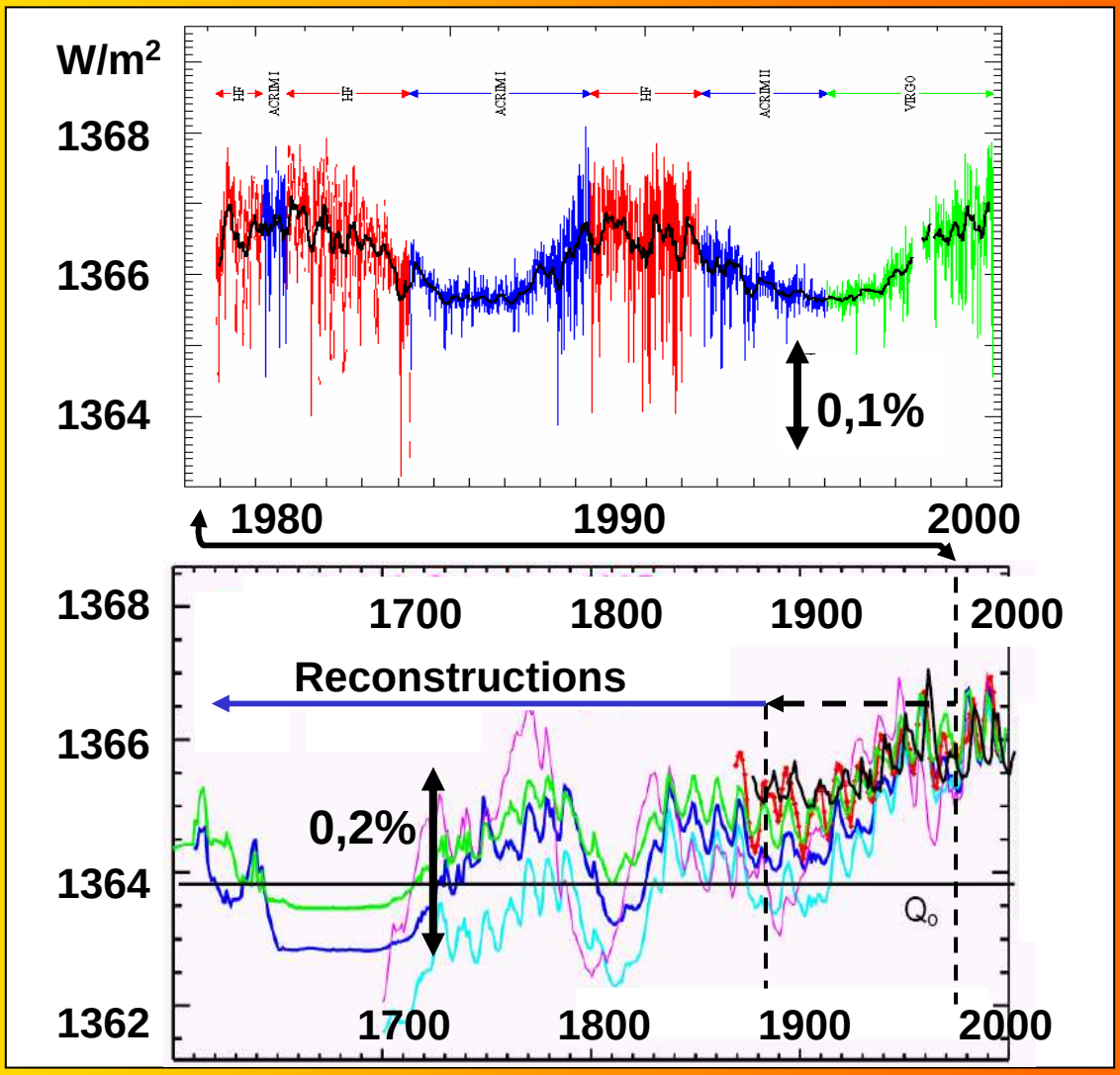
- Invisible Pollution !

- Anthropogenic emissions of CO_2 and other gases

- Anthropogenic Perturbation of the Water Cycle

The Sun – spectacular activity but nearly ***constant*** irradiance





Reinforcement of the Parasol ?

Aerosols (solid particles or liquid droplets suspended in the air)

Volcanic Aerosols

1-2 years residence in the stratosphere (10-20 km altitude)
→ temporary global cooling, or a pause in the warming

Anthropogenic aerosols (pollution)

in the troposphere (0 – 10 km altitude)

Short residence times – regional effects

- Reflecting aerosols cool the surface
- Black aerosols (soot...), warm the air but reduce sunlight reaching the surface
- *Indirect effects on clouds ?!*

Intensification of the greenhouse effect

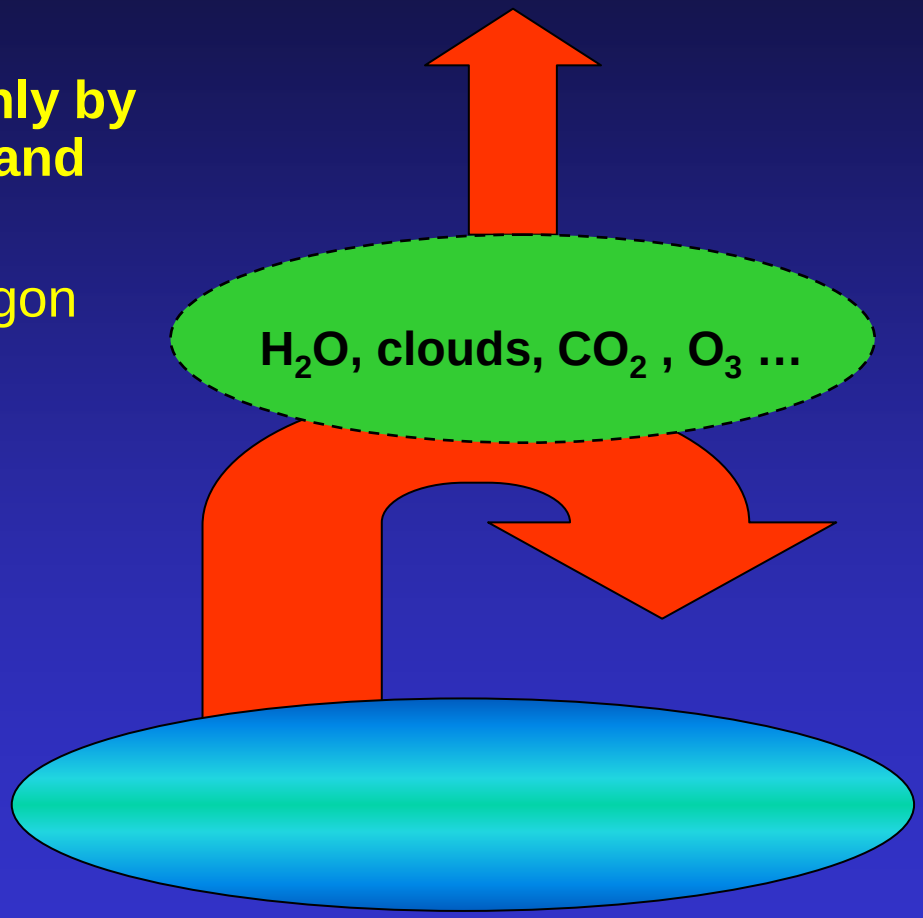
Controls the escape of energy (heat) to space by infrared radiation.

Infrared absorption/emission only by the air's *poly*atomic molecules and clouds.

Nitrogen (N_2), oxygen (O_2) and argon (99% of the air) play no role.

Infrared radiation *downward* warms the surface of the globe and the lower atmospheric layers.

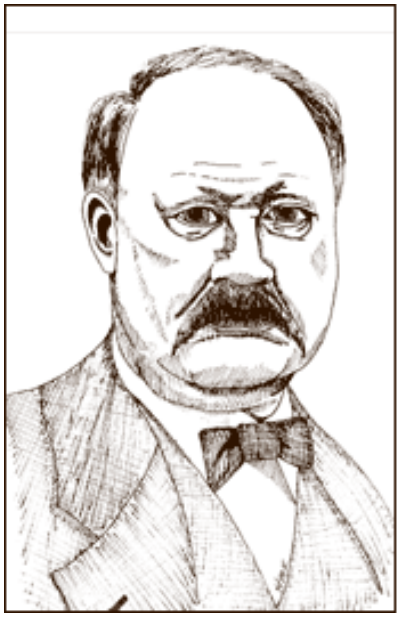
Adding CO_2 molecules to the atmosphere *intensifies* the greenhouse effect.

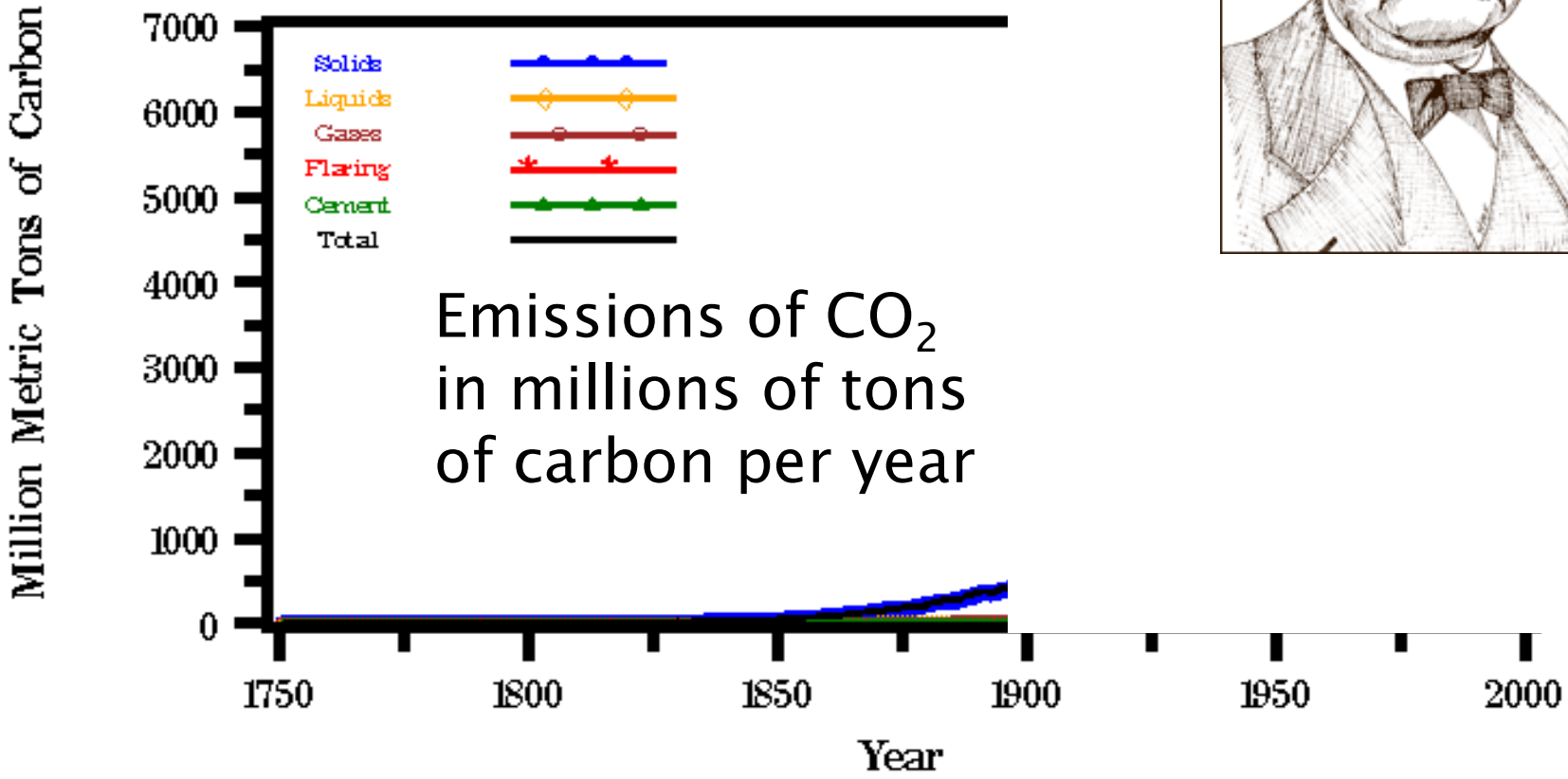


Anthropogenic alteration of the atmosphere

A prophecy from 1896

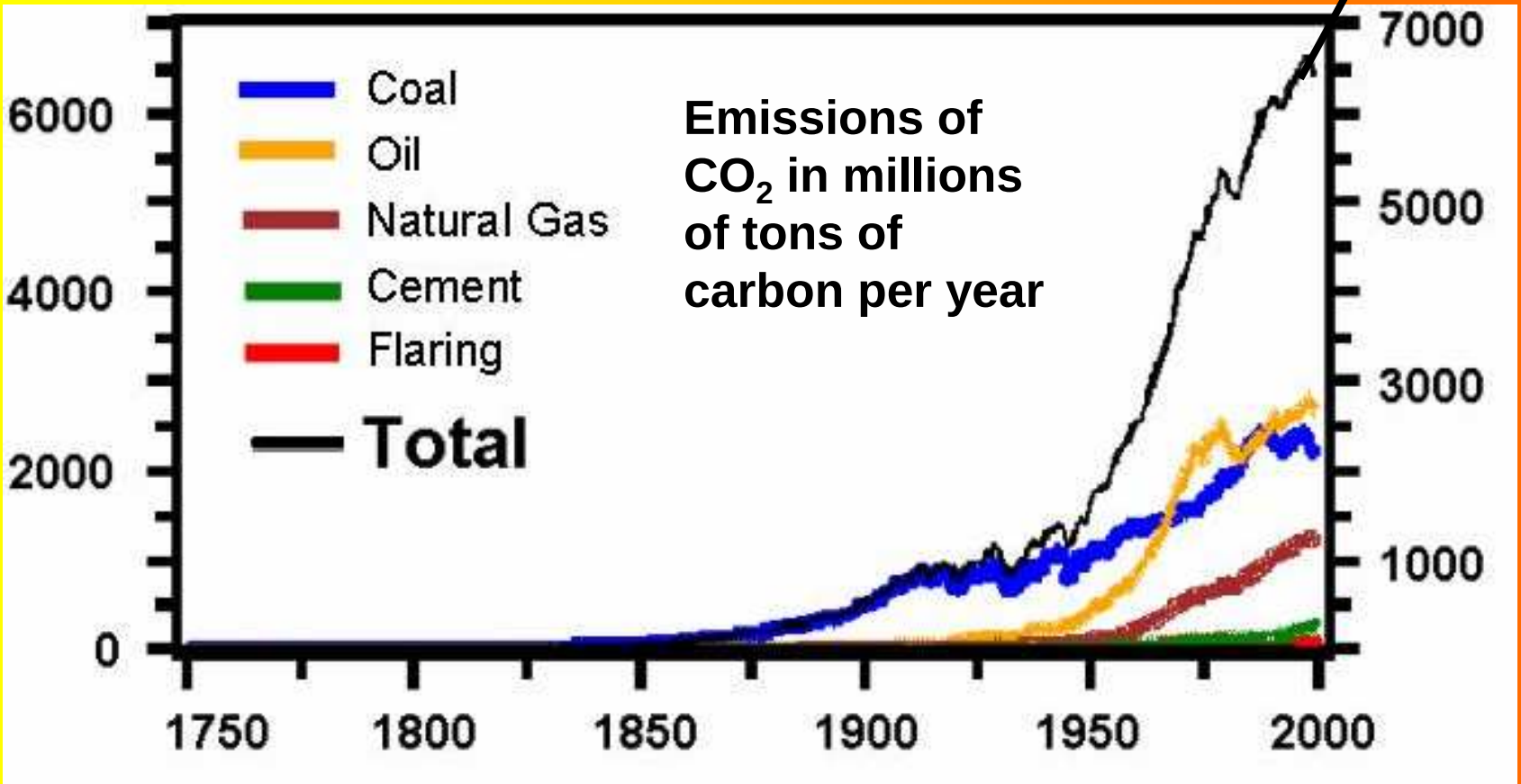
Swedish scientist Svante Arrhenius :
If humans continue to burn more and more coal, CO_2 in the atmosphere will eventually double, and the world will warm up by 4℃.



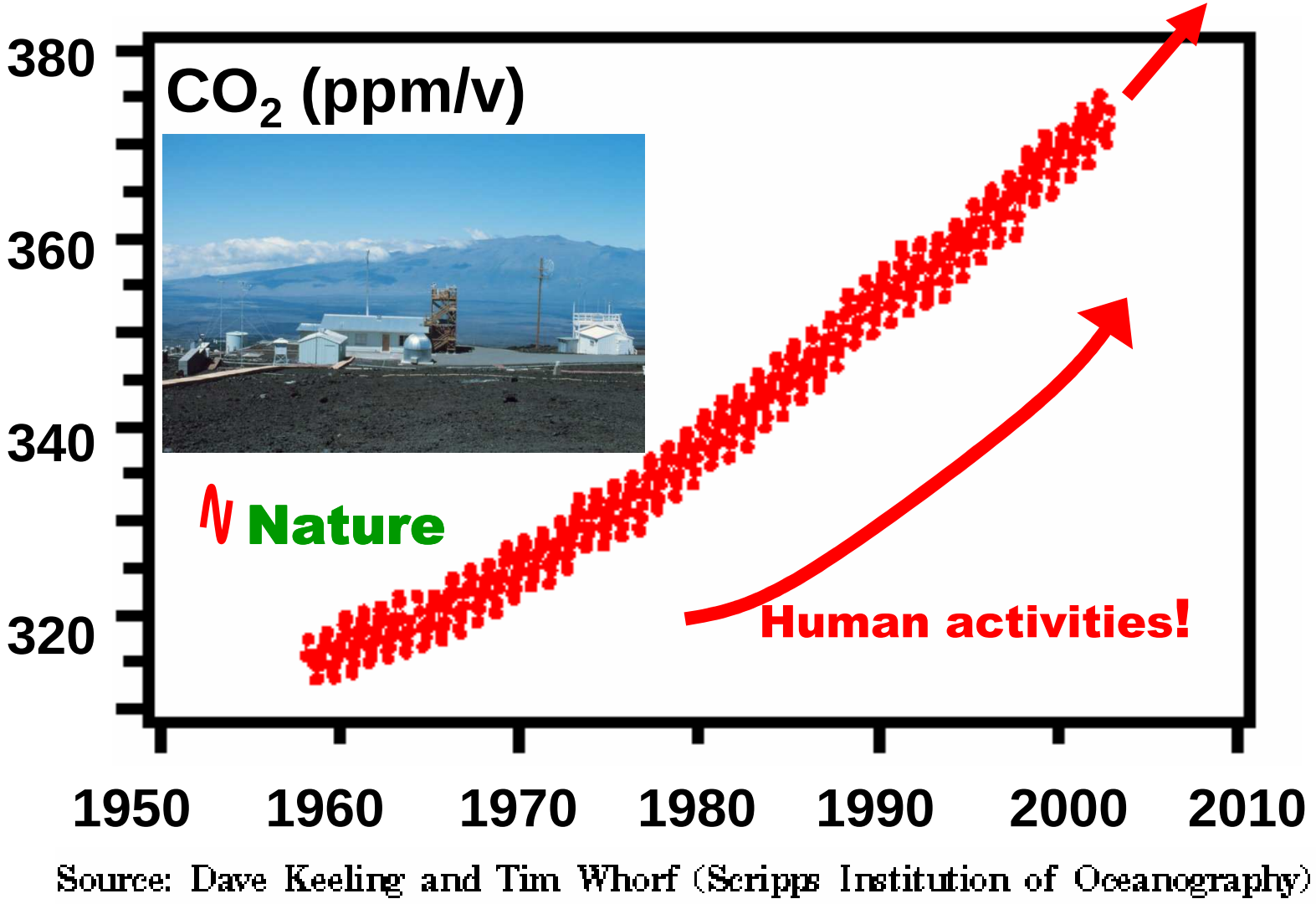


Global CO_2 emissions have risen, by nearly a factor 15 since 1896 !

But does the amount of CO_2 in the air rise ?



Increasing CO_2 *in the global atmosphere*

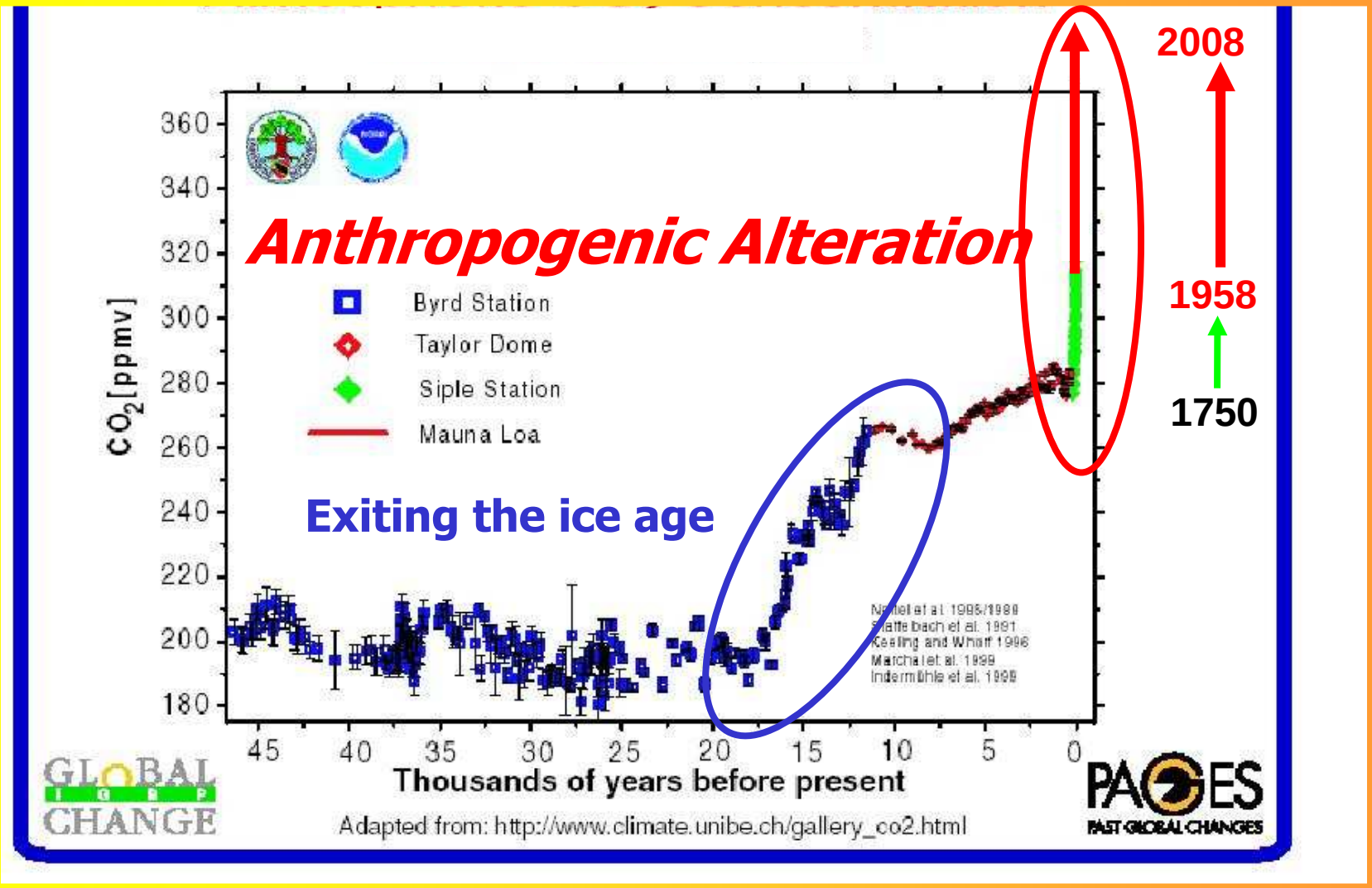


How does this compare to *natural* changes of the recent past ?

Since 1958, enormous increase in our knowledge of the past, recorded in the ice

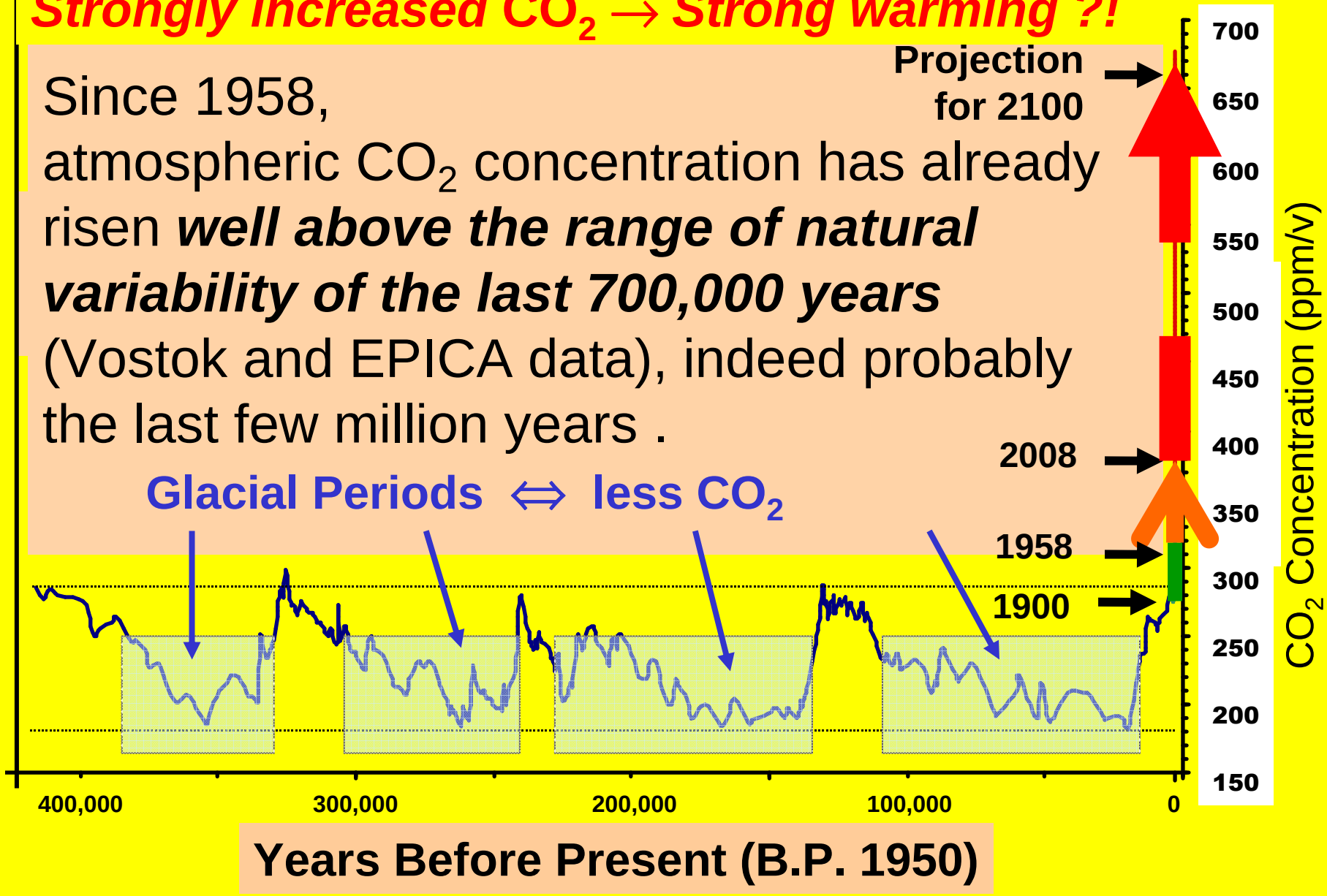
- Access to Greenland, Antarctica
  - the post-IGY Antarctic Treaty signed in 1959
- Development of tools using isotope ratios to determine temperatures of the past
- Extraction and analysis of air trapped in the snow and ice up to 700,000 years ago

Atmospheric CO_2



Strongly increased CO_2 → Strong warming ?!

Since 1958, atmospheric CO_2 concentration has already risen ***well above the range of natural variability of the last 700,000 years*** (Vostok and EPICA data), indeed probably the last few million years .



Global Climate Change

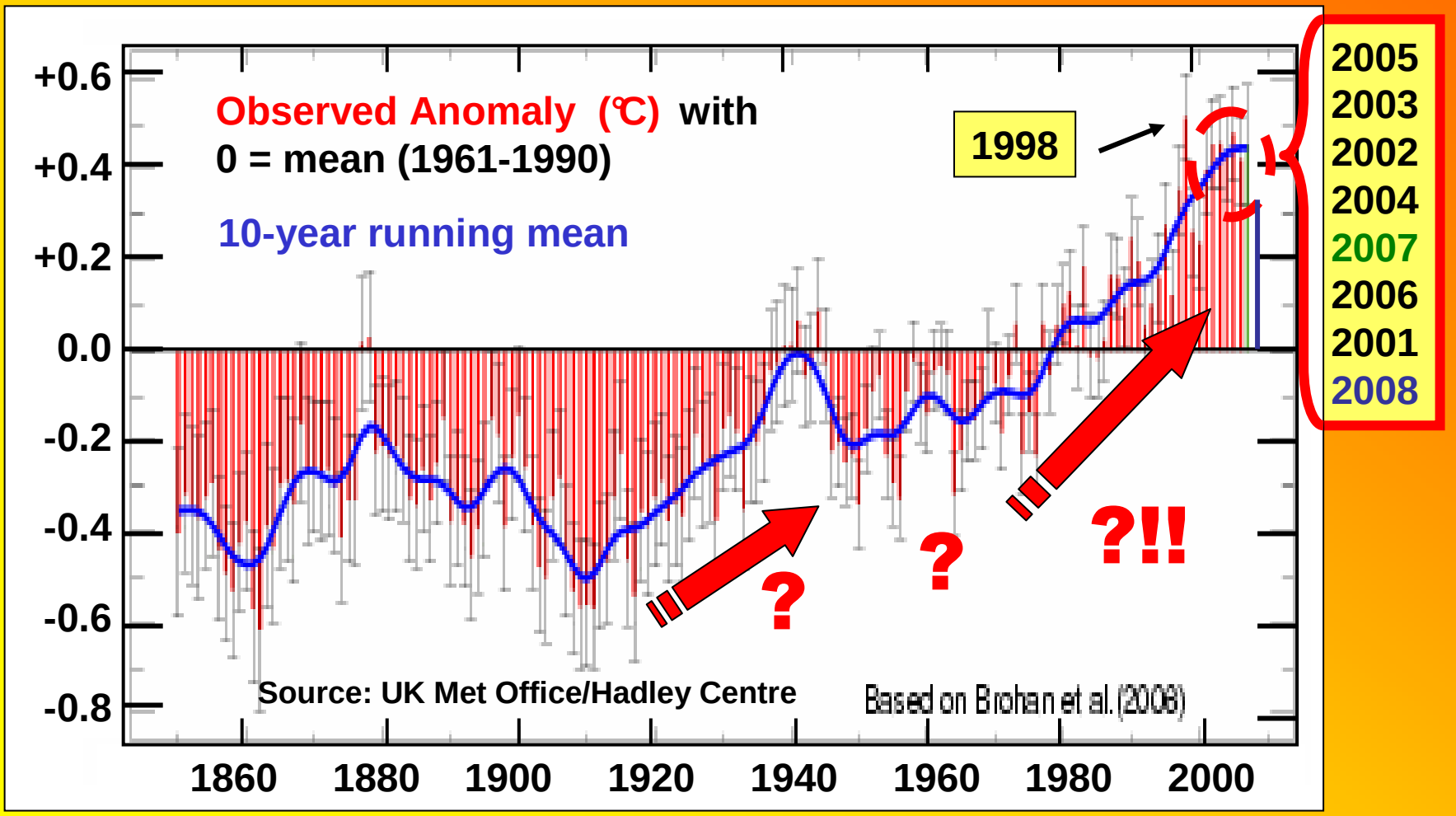
The climate is warming.

This results from anthropogenic greenhouse intensification.

Converging proof.

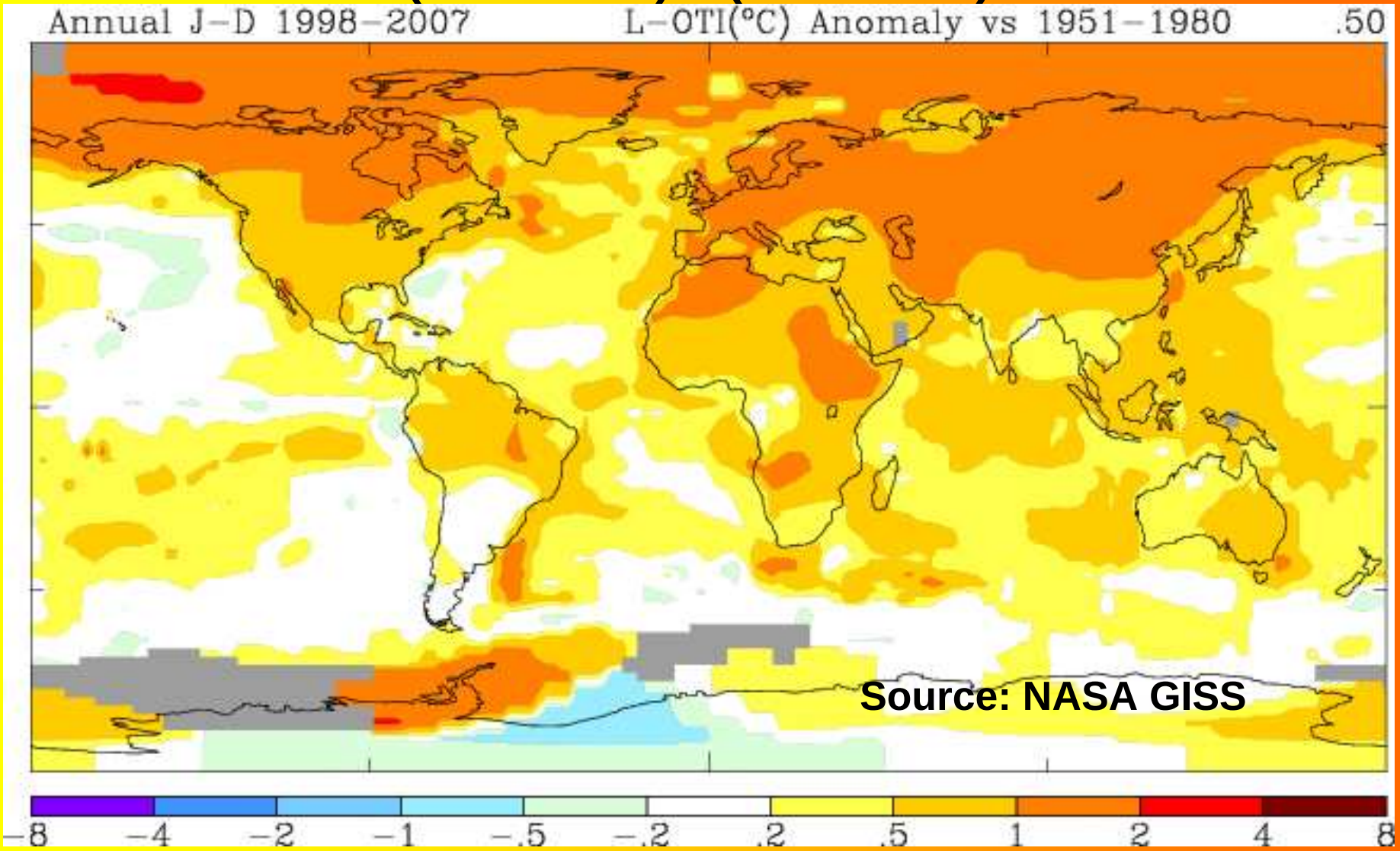
Observed global warming

average air temperature at the Earth's surface

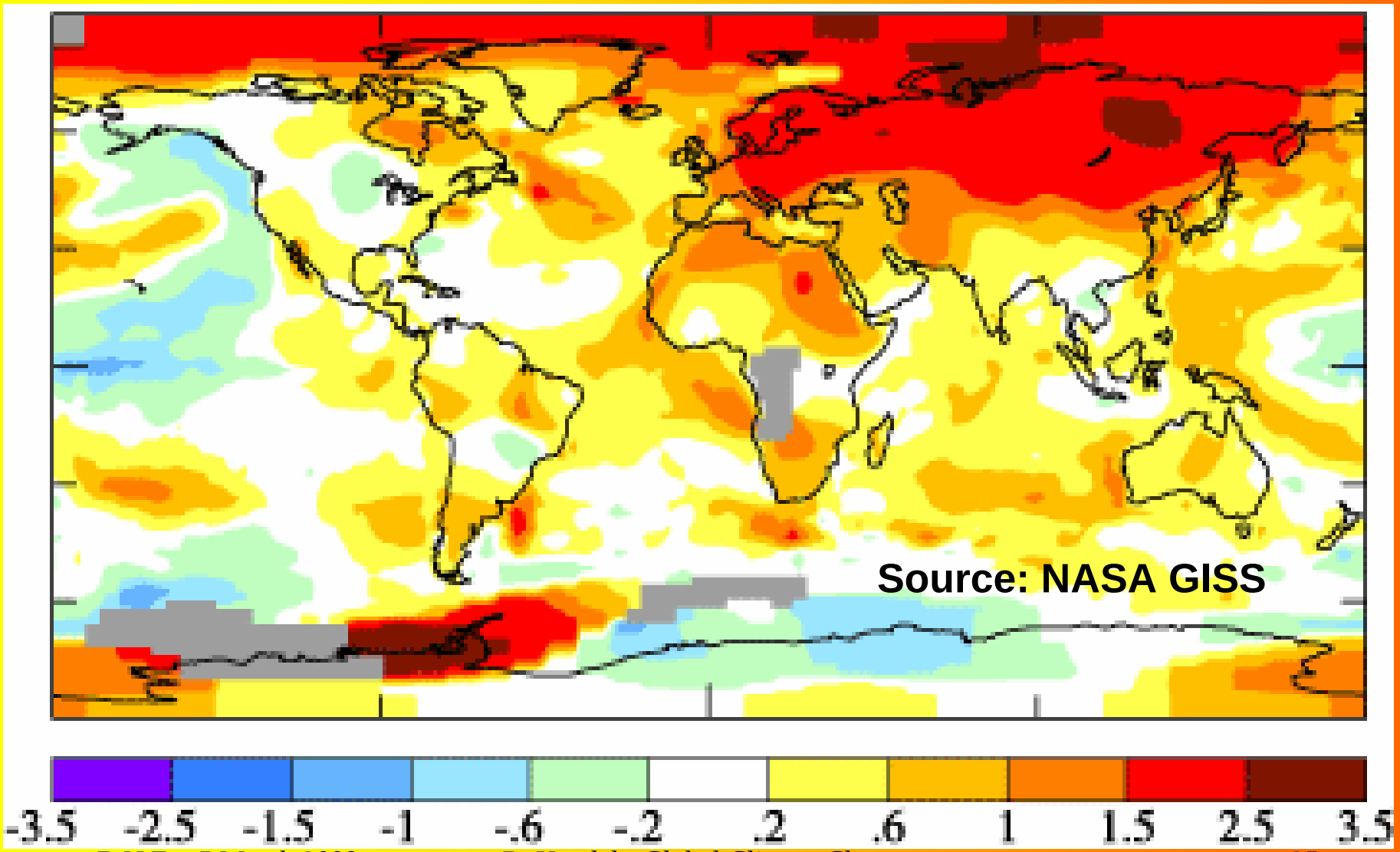


Warming over practically the entire globe

(1998-2007) – (1951-1980)

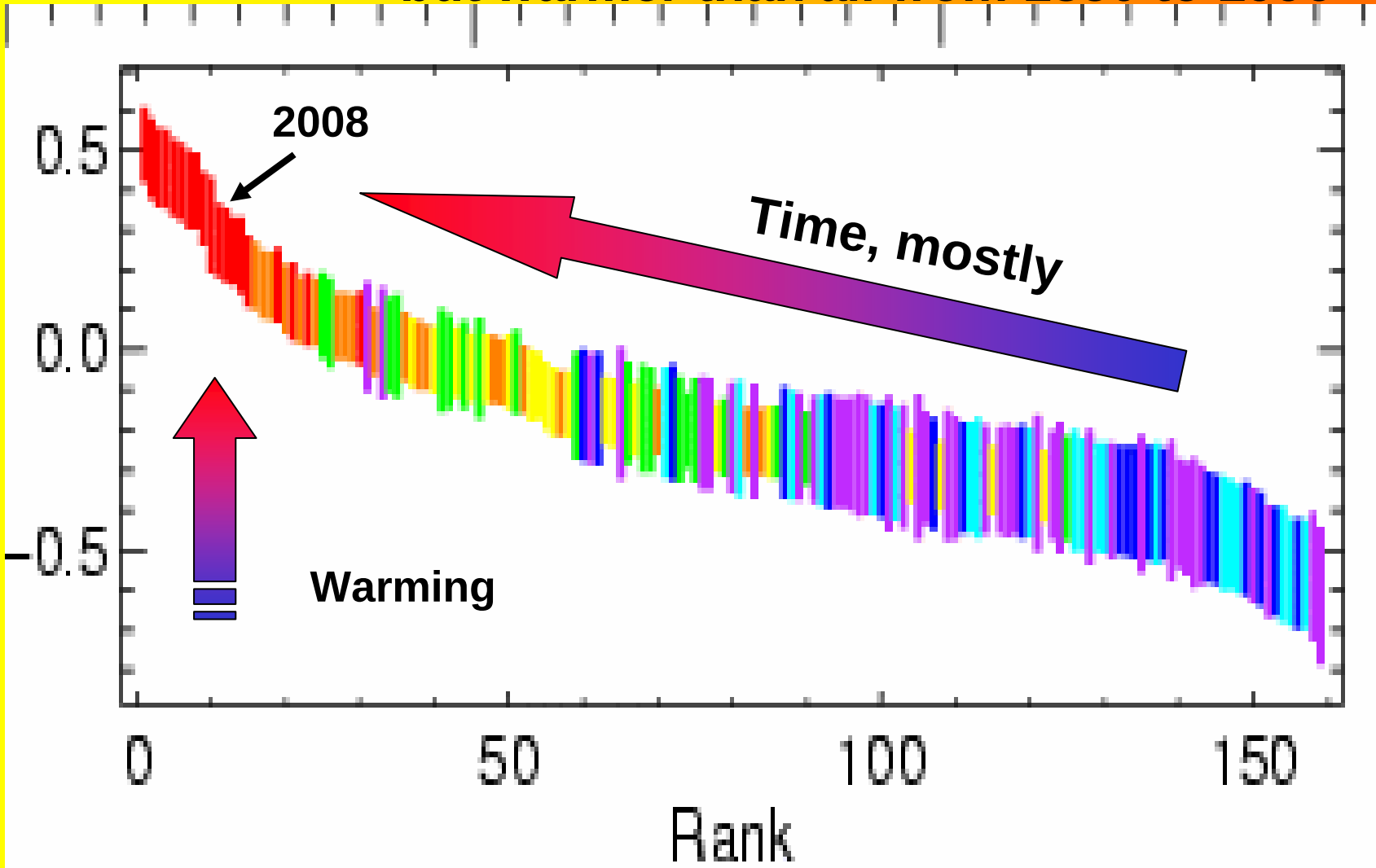


Temperature in 2008
compared to (1951-1980)



2008 – the coolest since 1997 –

but warmer than *all* from 1850 to 1996



The Scientific Analysis Today

- **Human activities, *especially the burning of fossil fuels*, cause the observed strong rapid increase in concentrations of CO_2 and other greenhouse gases in the global atmosphere.**

- **The resulting intensification of the natural greenhouse effect is now the *strongest* factor forcing climate change.**

- **Observations from space, in the air, on land and sea, and in the ice and sea, together with model simulations based on physical law, *all confirm that this explains most recent global warming*.**

Converging proof

The observed changes in climate result principally from anthropogenic intensification of the greenhouse effect

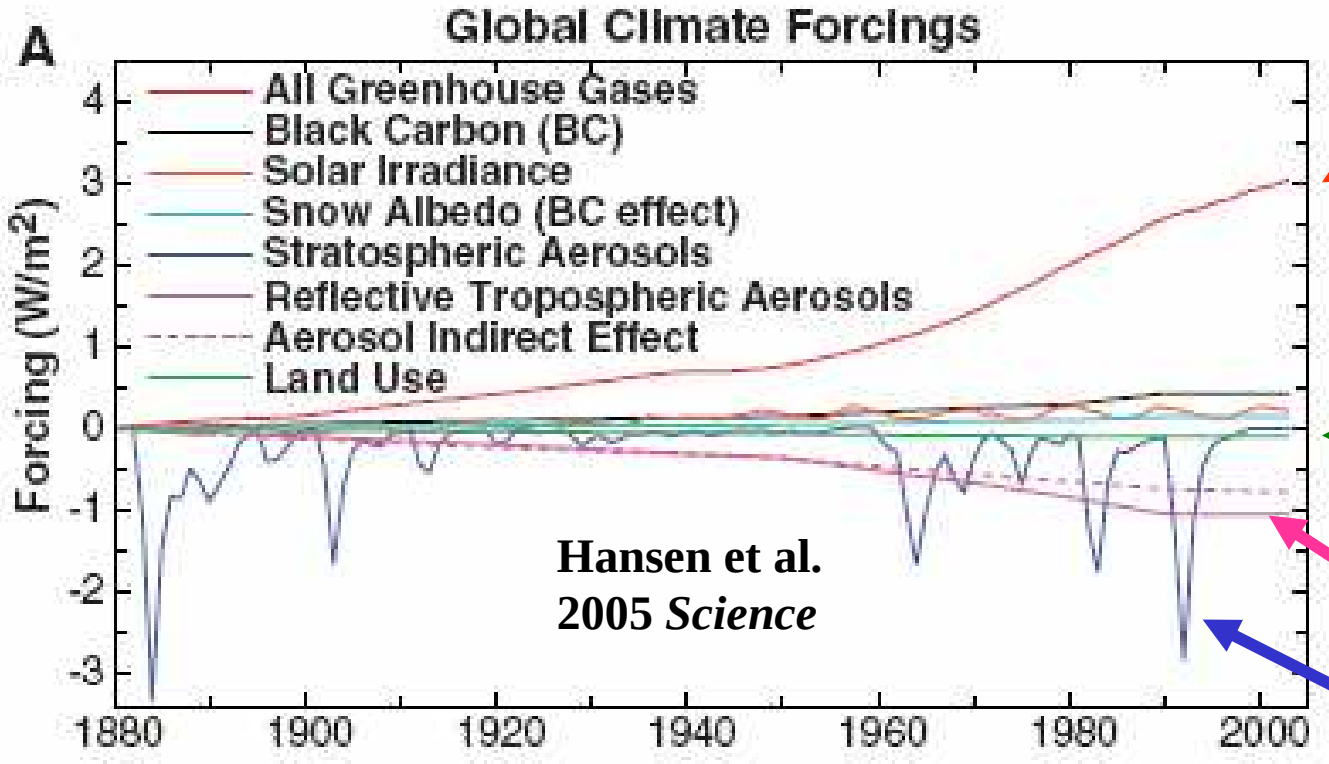
1) This « forcing » is the strongest

2) Predicted changes are observed :

- Warming at the surface of the globe
- Warming of the lower atmosphere
- Cooling of the stratosphere
- Warming of the ocean
- Melting of the ice

Climate change is now mainly driven by *anthropogenic* forcing factors

Solar variations play but a *minor* role,
effects of volcanic eruptions are ephemeral.



CO_2 CH_4 etc.

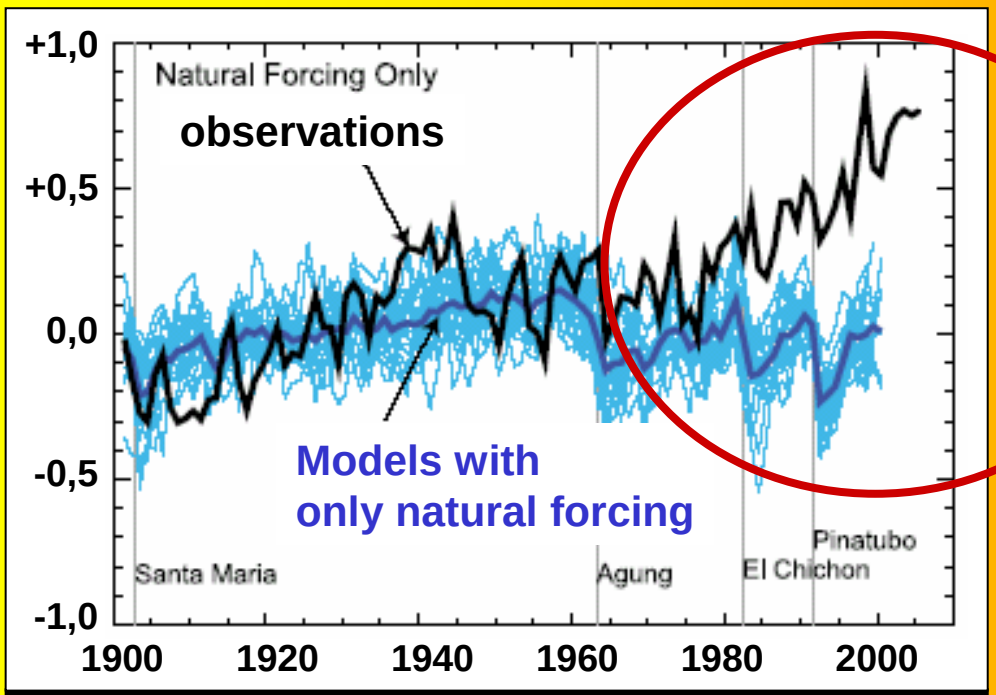
Sun ?

Land Use ?

Aerosols

Volcanoes

Physically based climate models give the observed warming *only* if anthropogenic forcing is included



!

Natural Forcing
Solar Fluctuations
Volcanic Eruptions

Physically based climate models give the observed warming *only* if anthropogenic forcing is included

Natural Forcing

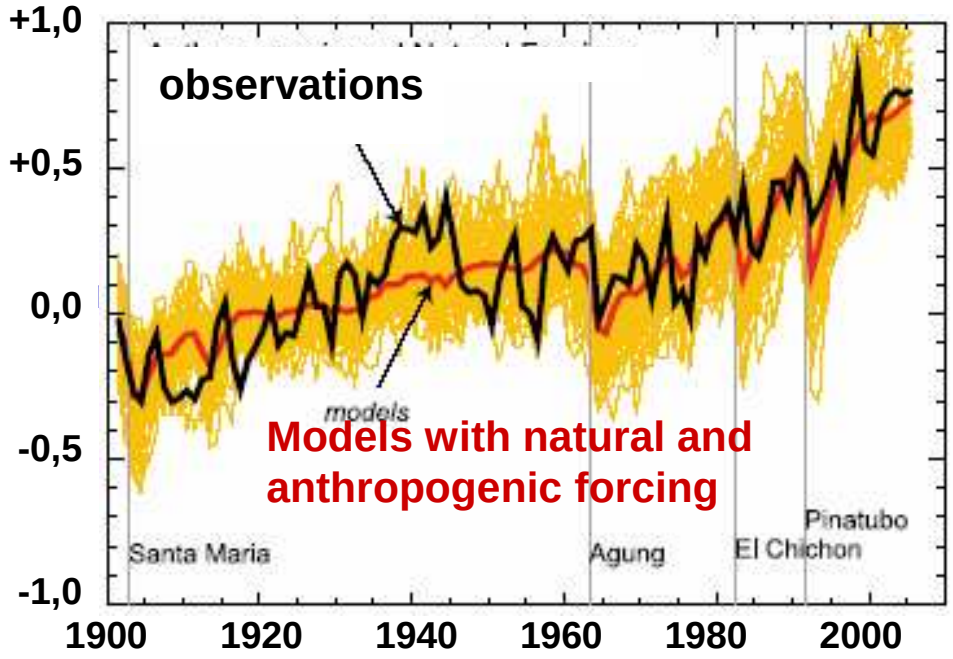
Solar Fluctuations

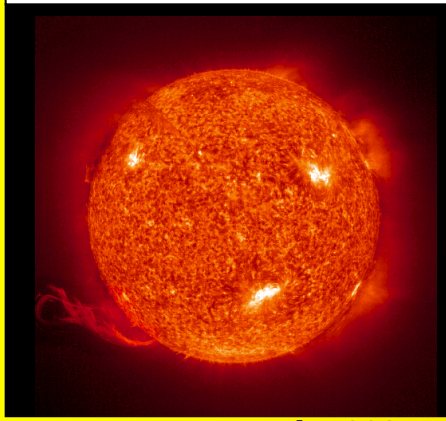
Volcanic Eruptions

+ anthropogenic forcing factors

CO_2 CH_4 … ↑

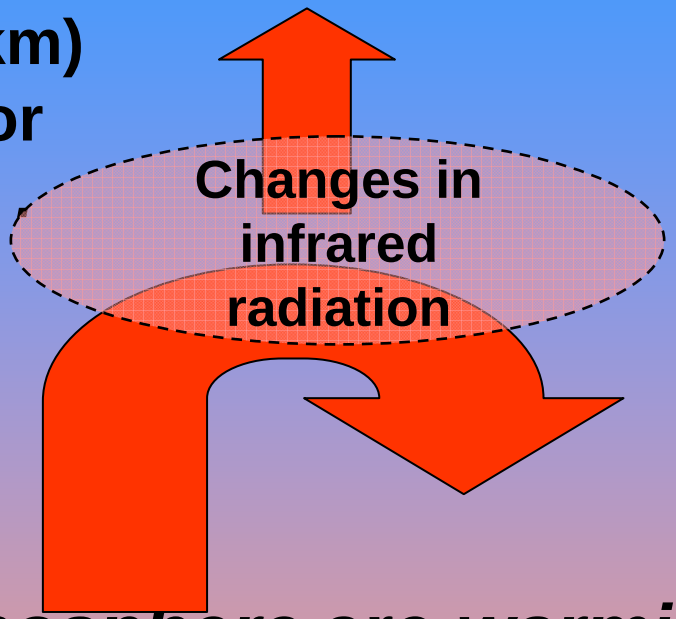
SO_2 … ↓





Converging proof

The stratosphere (15-50 km) is *cooling*, as predicted for added greenhouse gases

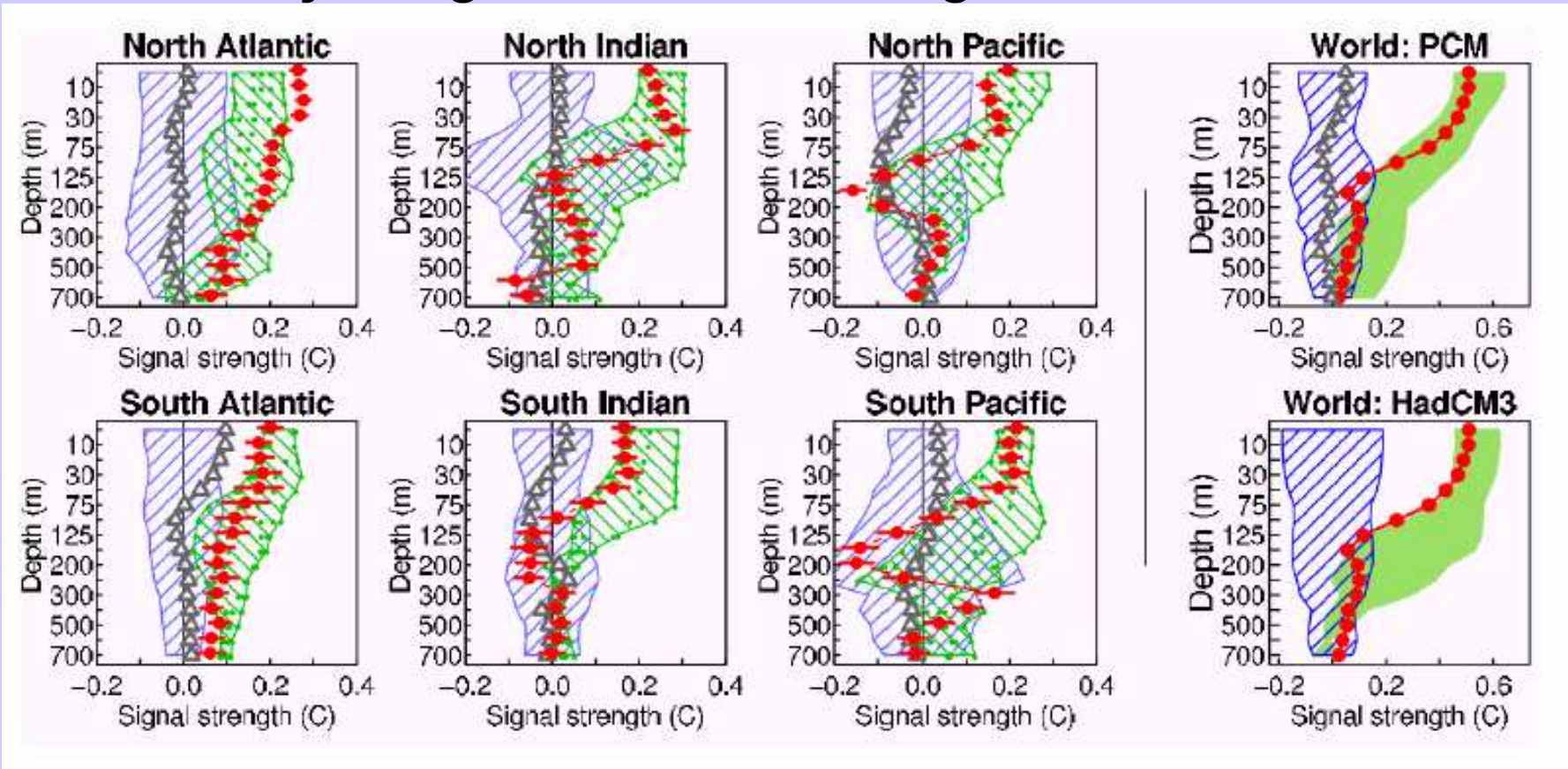


Surface and *lower atmosphere* are *warming,* as predicted for added greenhouse gases.

Satellite observations also show that the atmosphere is becoming more humid as it warms, i.e. it contains more water in the gaseous state. This acts as a *positive feedback*, i.e. an *amplifying* factor.

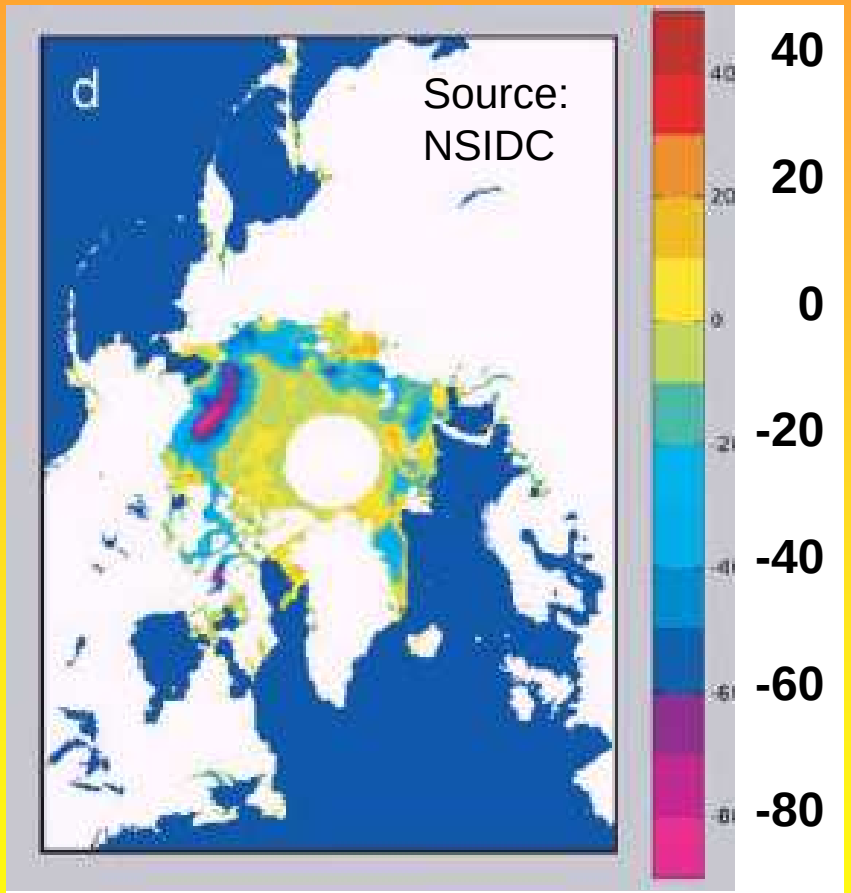
The oceans are warming

and only the greenhouse forcing can account for it



Observations **Natural Variability** **Forced warming**

Thickness and surface area of the ice floating on the Arctic Ocean have decreased.



End-summer Trend (%)
(Septembers, 1978 – 2003)

<1992-2006> **2005** **2007**

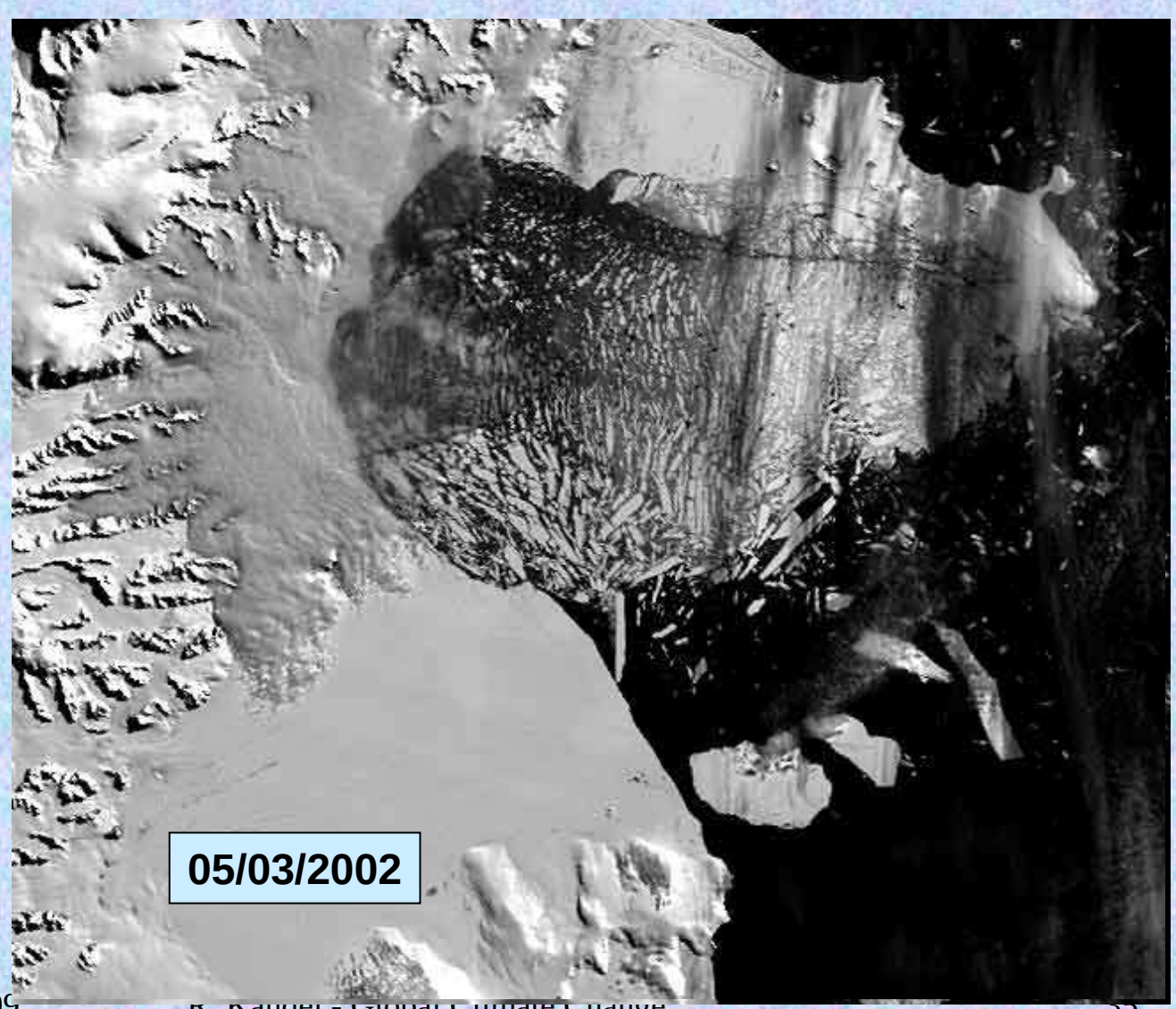
Toward an ice-free Arctic Ocean in September 2050 ?

Disintegration of Antarctic ice shelves

Larsen B ice shelf

Loss of 3250 km^2

Images MODIS/ Terra (NASA EOS)



Most mountain glaciers are retreating.

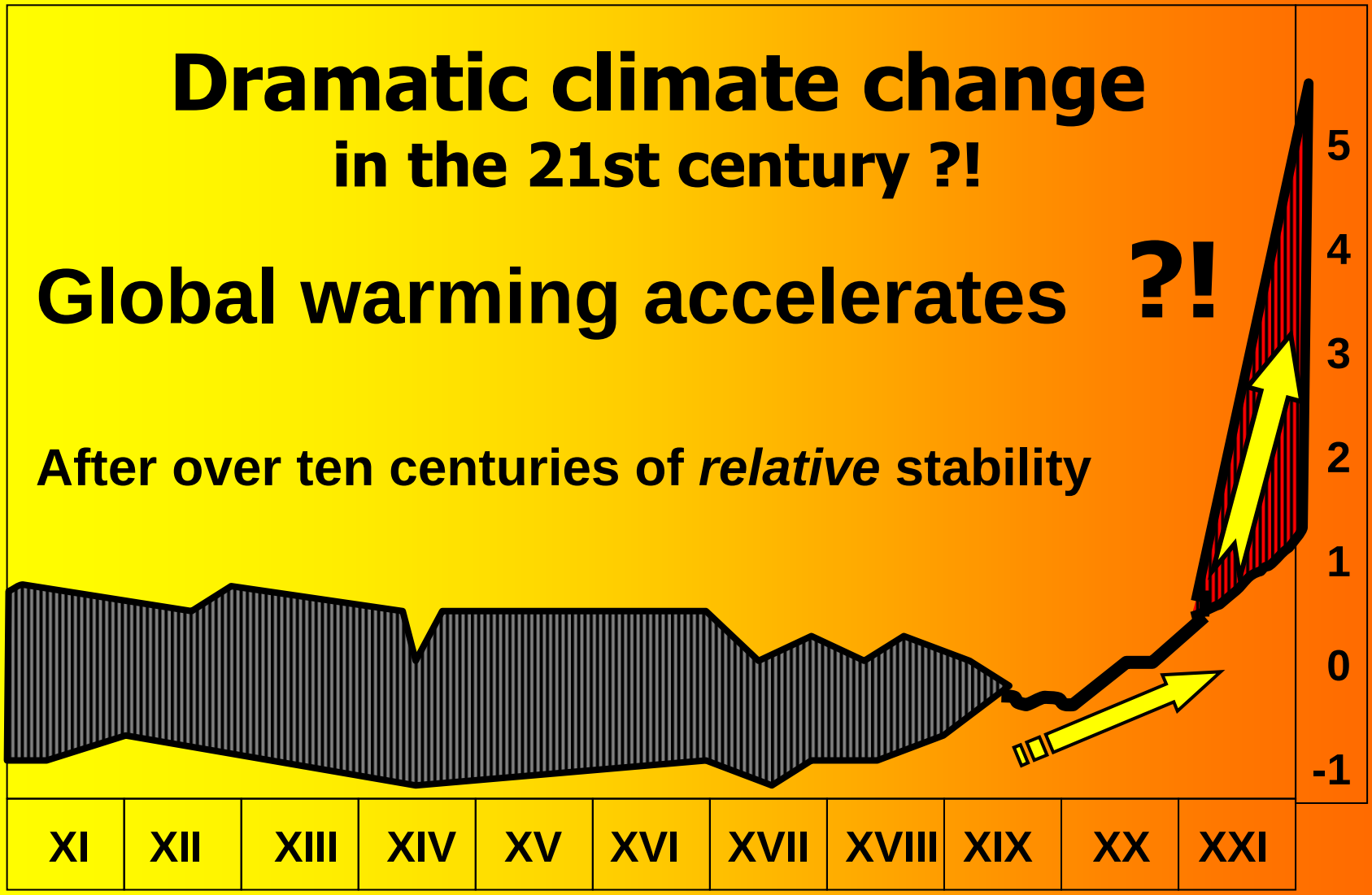
Global Climate Change

The risks of *major* climate change in coming decades

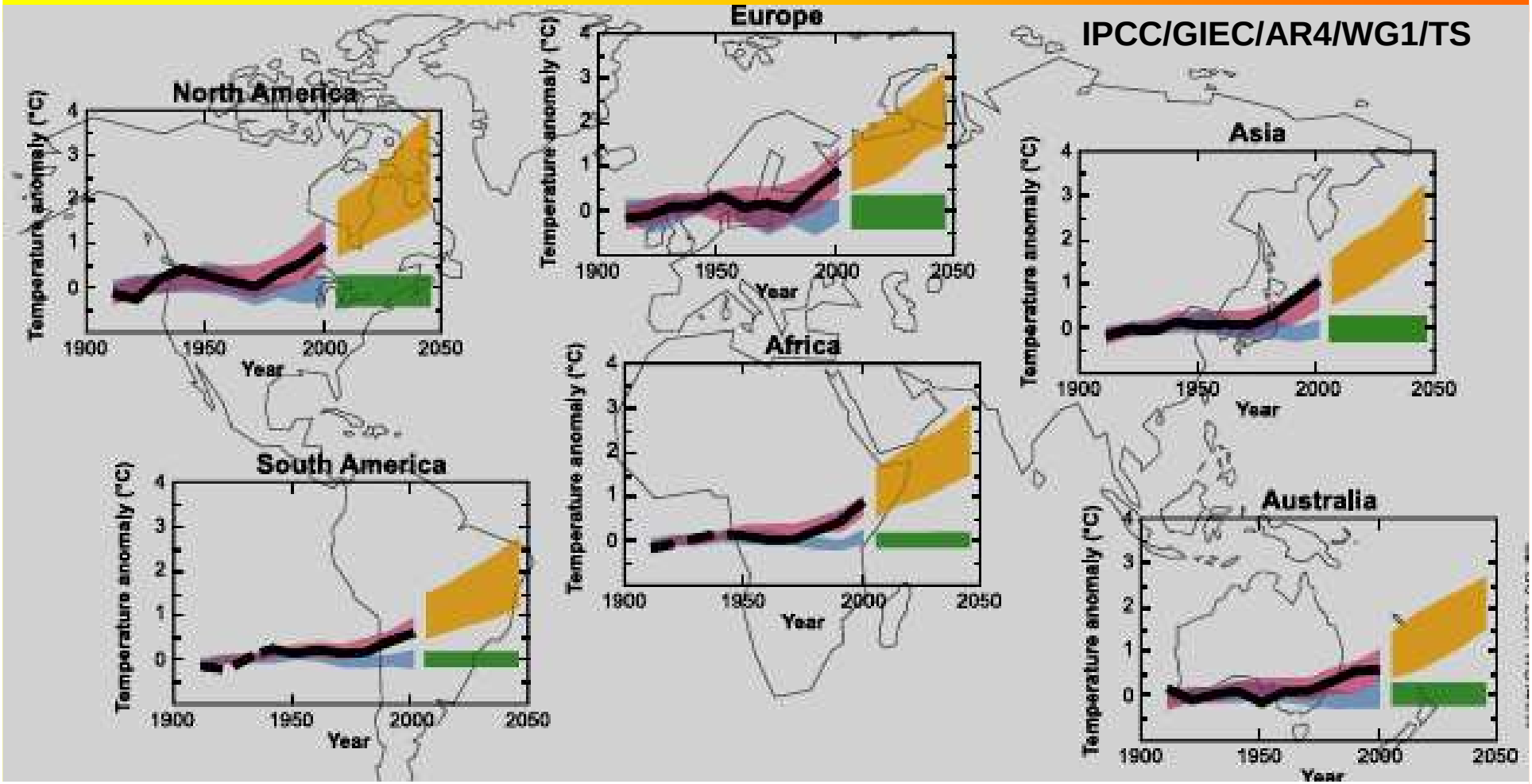
Dramatic climate change
in the 21st century ?!

Global warming accelerates ?!

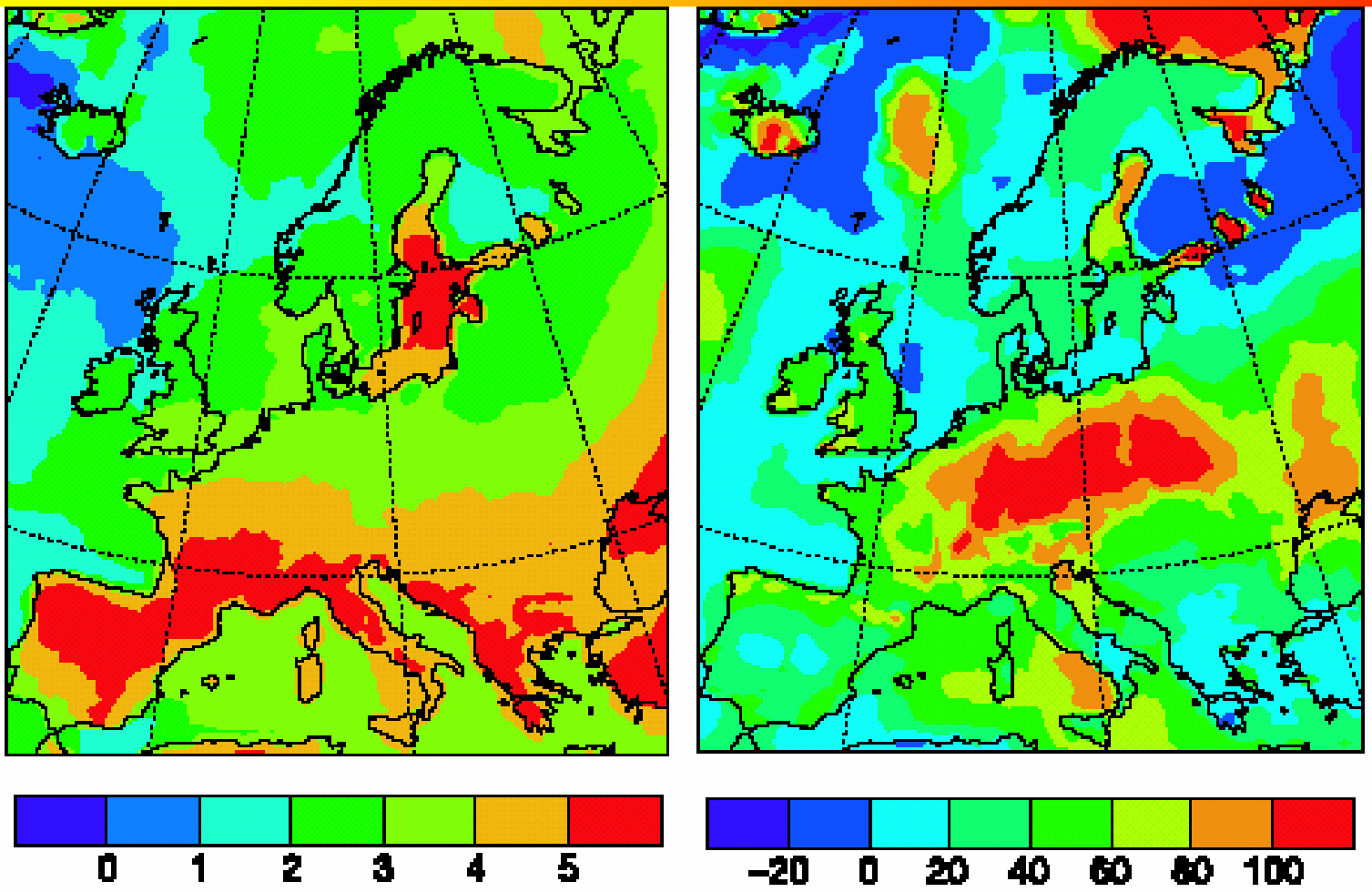
After over ten centuries of *relative* stability



Warming 1900 - 2000 - 2050



Europe in 2071-2100 ?



Source : Schär et al. *Nature*, 2004

Risks of greenhouse effect intensification

Not only Global *Warming*
But also, and rapidly,

***Modification* of the water cycle**
and a new distribution of fresh water

Consequences :
Changed *risks* of:
- **prolonged drought**
- **strong rainfall, floods**
- **violent storms**
- **tropical cyclones**

Consequences for :

- **Agriculture**
- **Water supply for people**
- **Hydroelectric resource**
- **The natural biosphere**

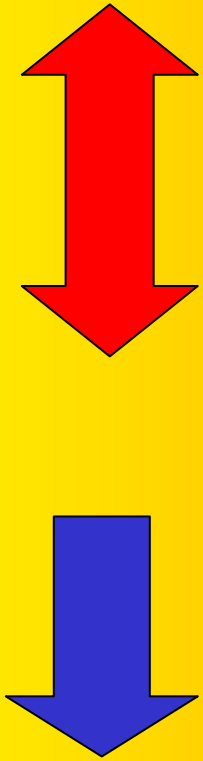
Intensification of the water cycle

rapidly

The warming climate

rapidly

New distribution Of fresh water



Consequences :
Increased variability ?
Modification of the *distribution* of *risks* for

- **heat waves, drought**
- ***torrential rain, floods***
- **storms and cyclones**

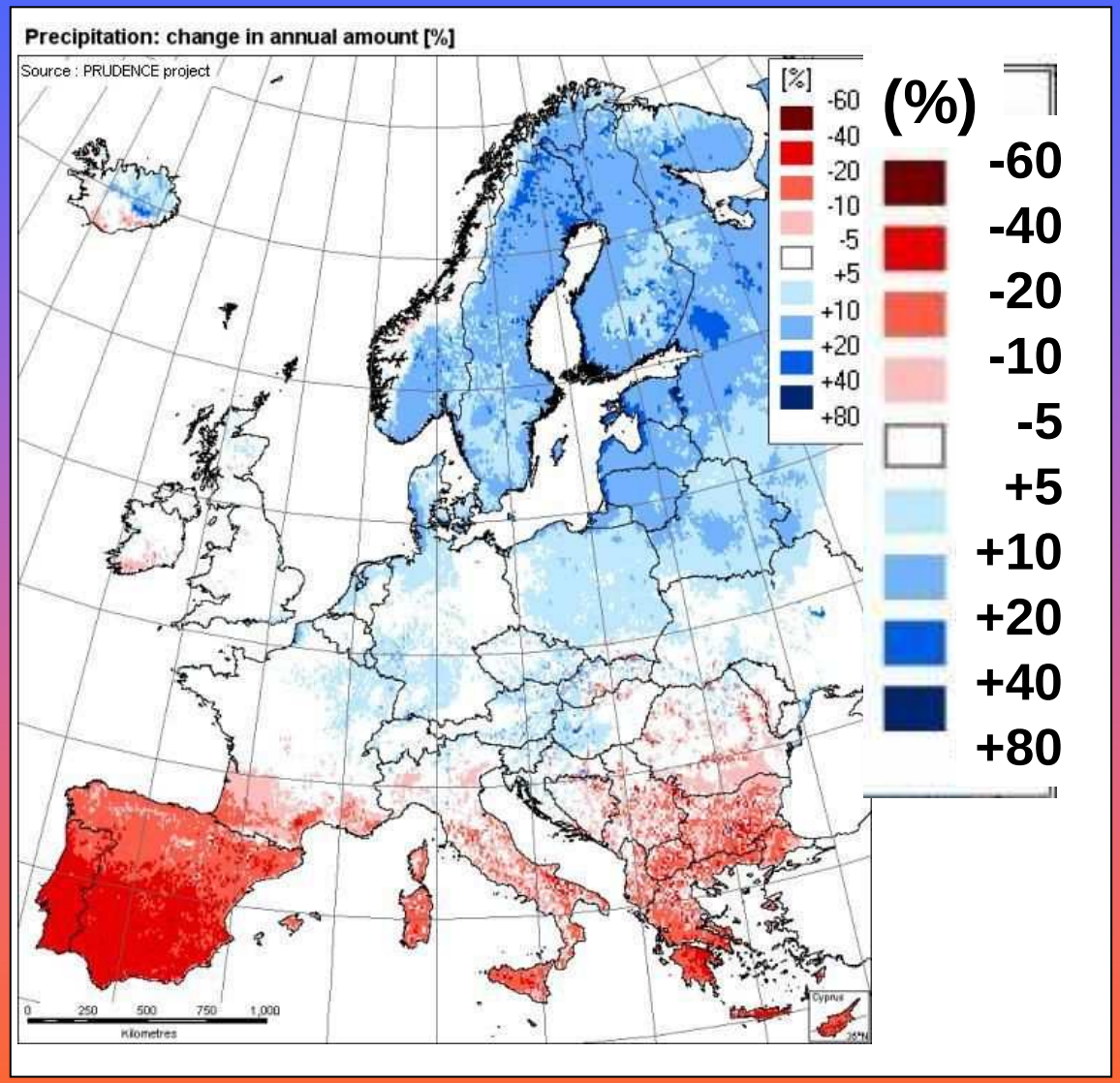
Consequences pour :

- agriculture and forestry
- hydroelectric resource
- water supply
- the natural biosphere

Precipitations en Europe

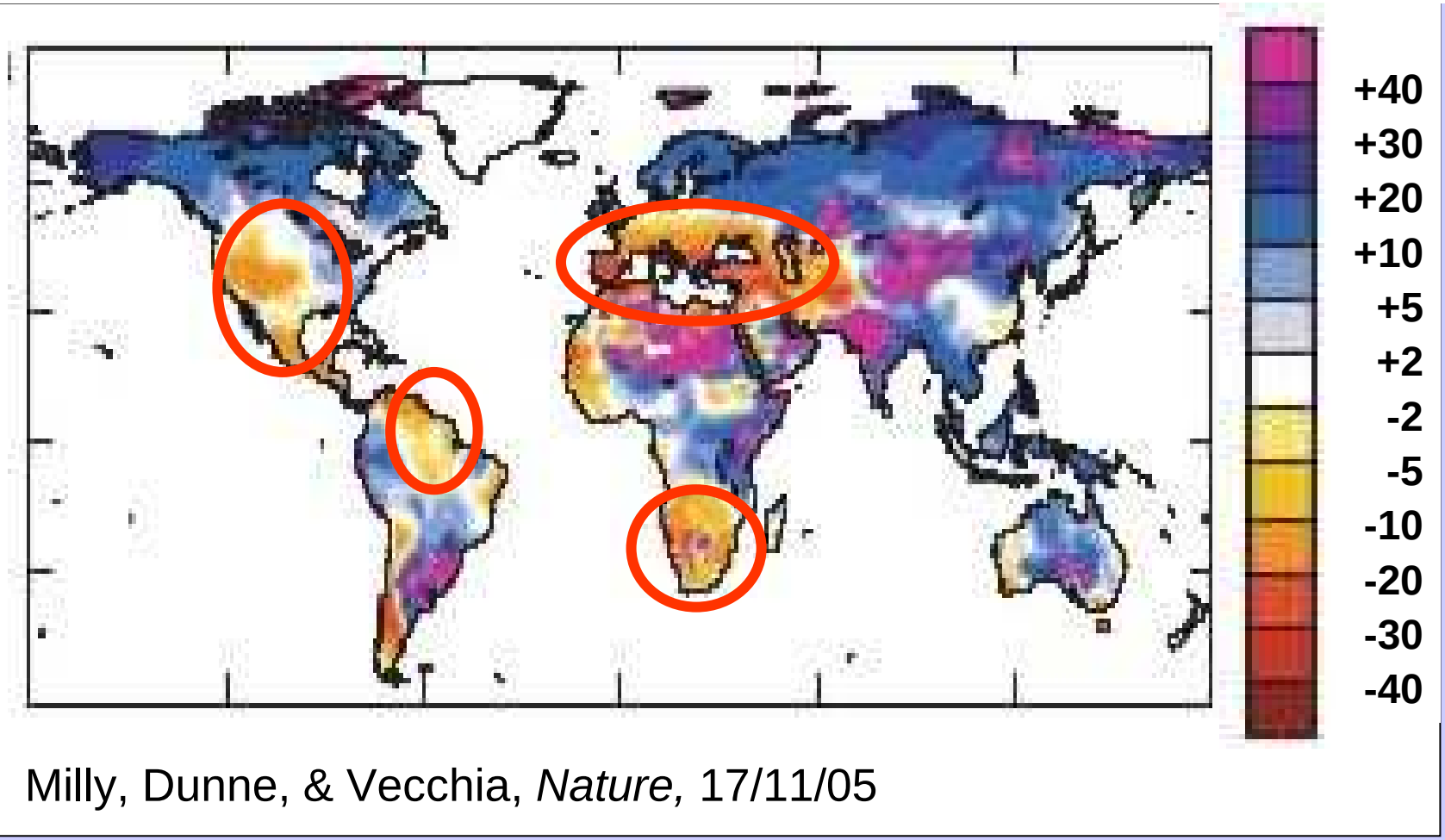
More in the North

Less in the South



Changes in runoff – available fresh water

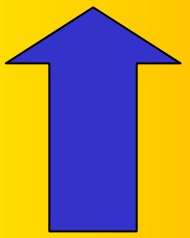
Scenario A1B : (2041-2060) – (1900-1970)



Milly, Dunne, & Vecchia, *Nature,* 17/11/05

Rising sea level

More or less slowly



The warming climate

Factors involved:

Thermal expansion of seawater

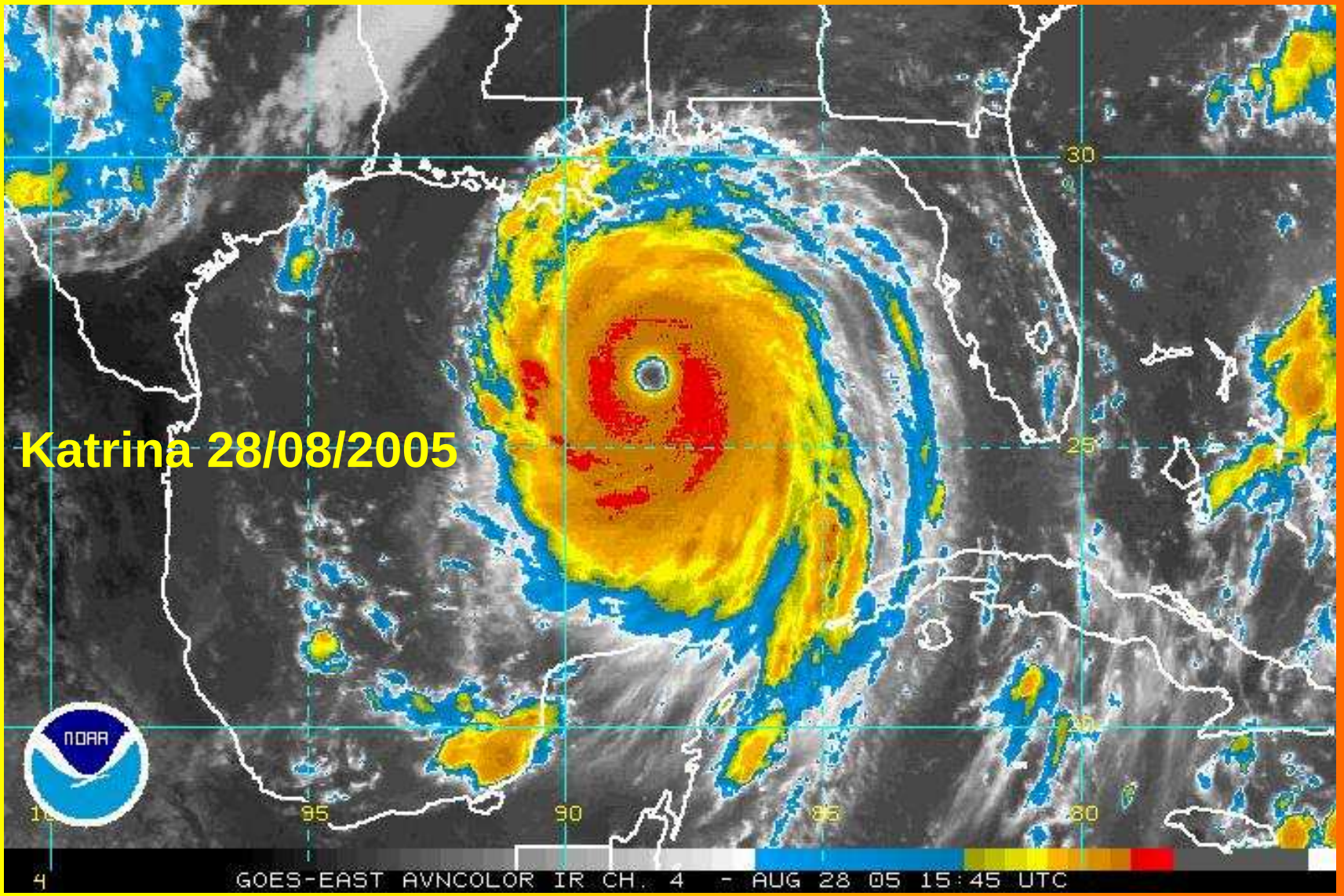
Land ice melting faster than it accumulates

Underground water ?

Consequences : +20 ou +60 cm SLR by 2100 ?
Or more ? … and after 2100 ?

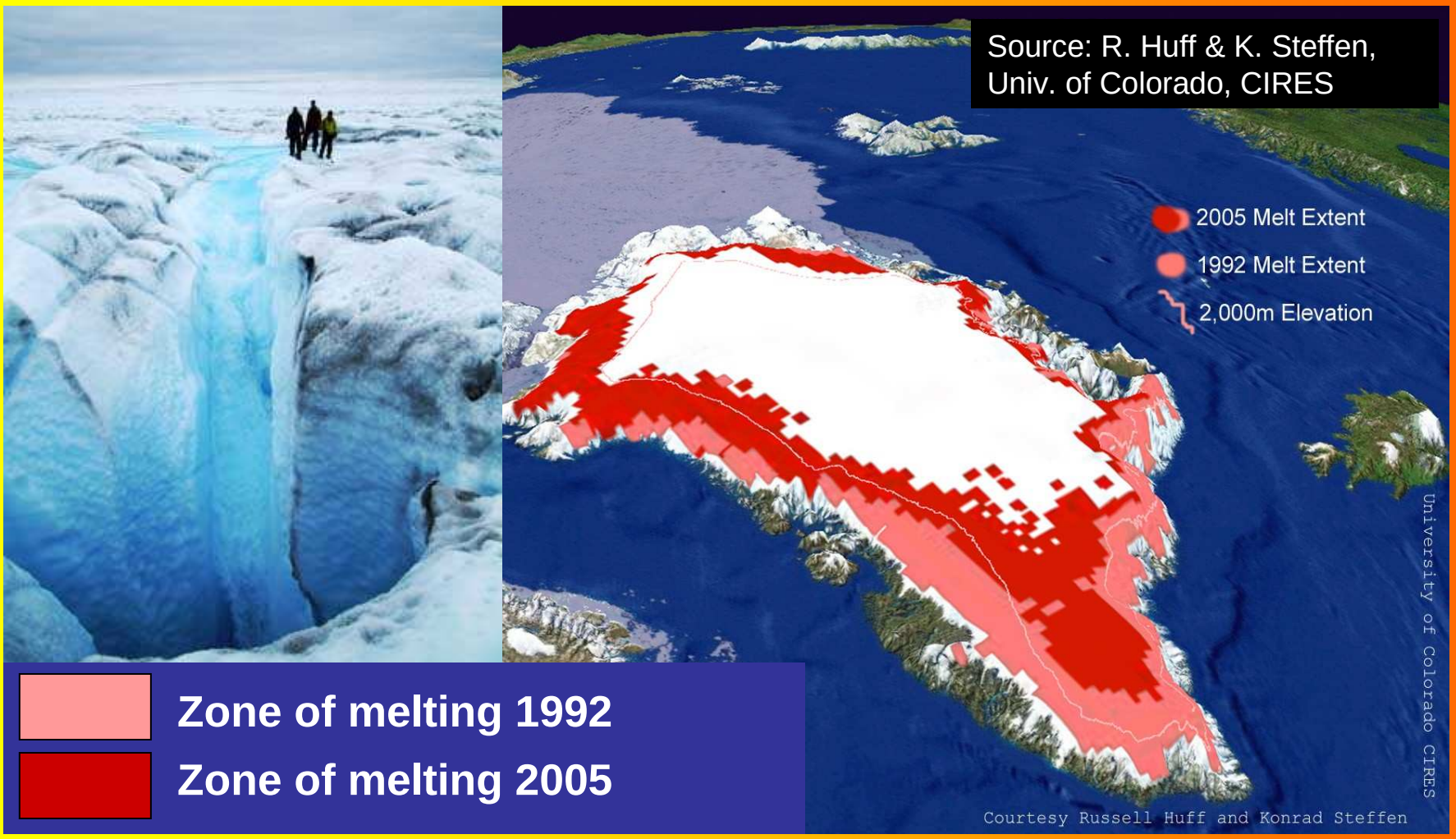
- ***stronger storm surge risk along coasts***
- flooding of coastal plains and wetlands
- infiltration of coastal aquifers

Increased risk from storms




HELP!

Accelerated melting in Greenland ?!
More rapid sea-level rise ?



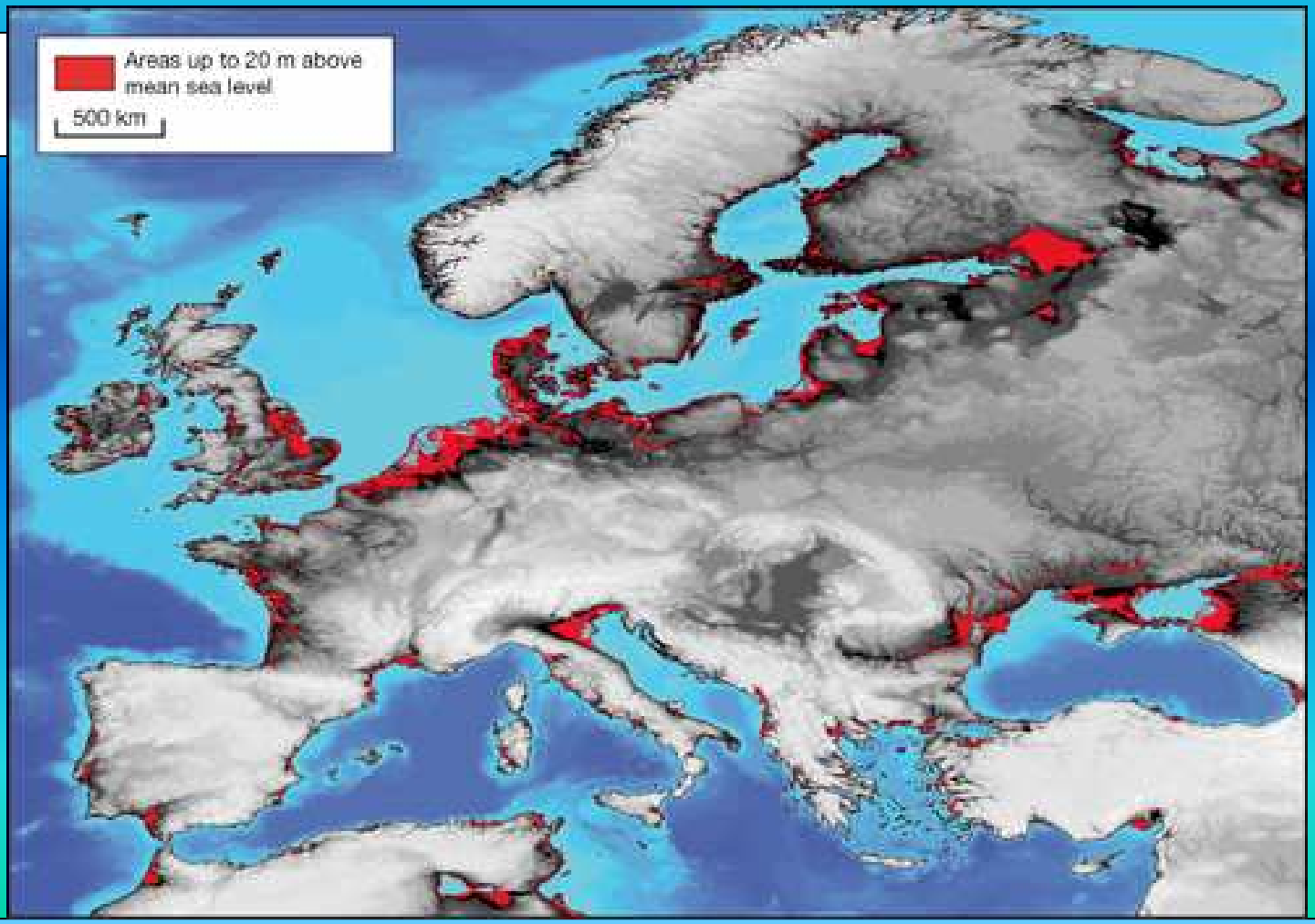
Flooding of coastal plains and valleys ?

Altitude < 20 m

Is sea-level rise of 20 m likely ?

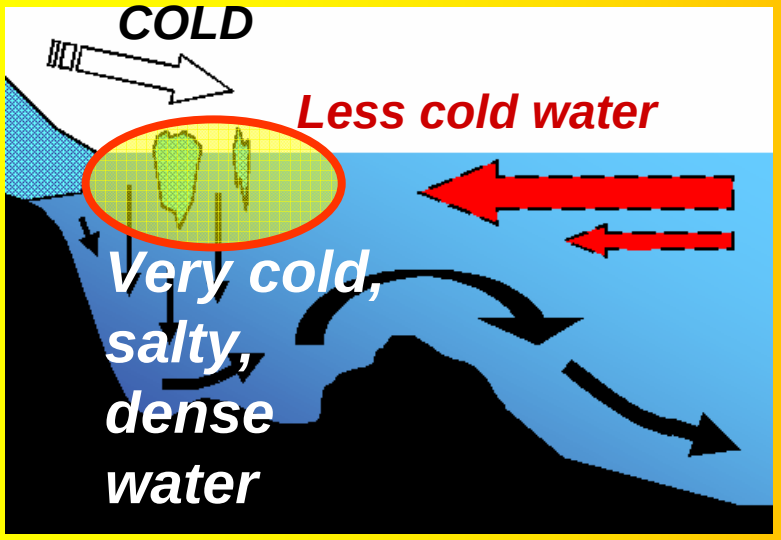
Surely not before 2100

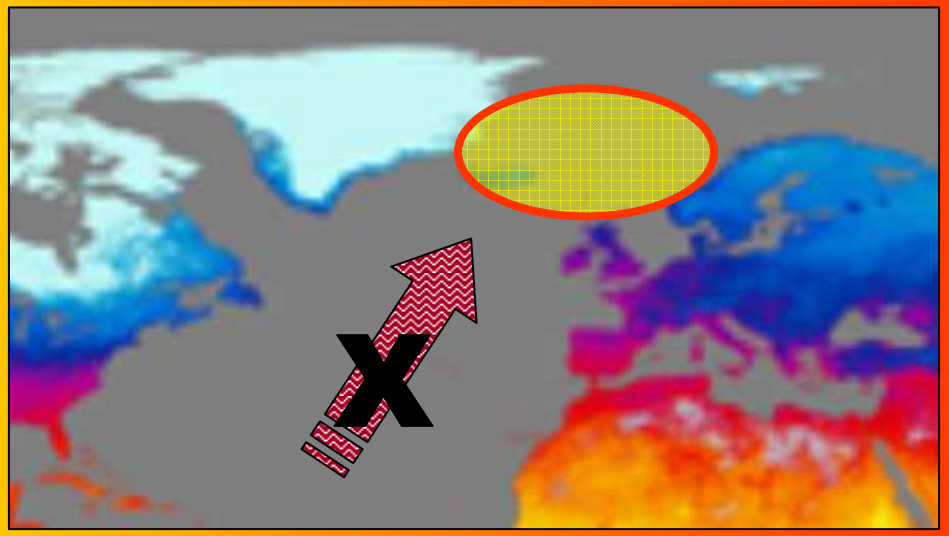
Possible before 2900?



Major Risk

Invasion of the Norwegian Sea by fresh water coming from increased precipitation as well as melting of Greenland ice.





Rapid blocking of the North Atlantic drift

Consequences :

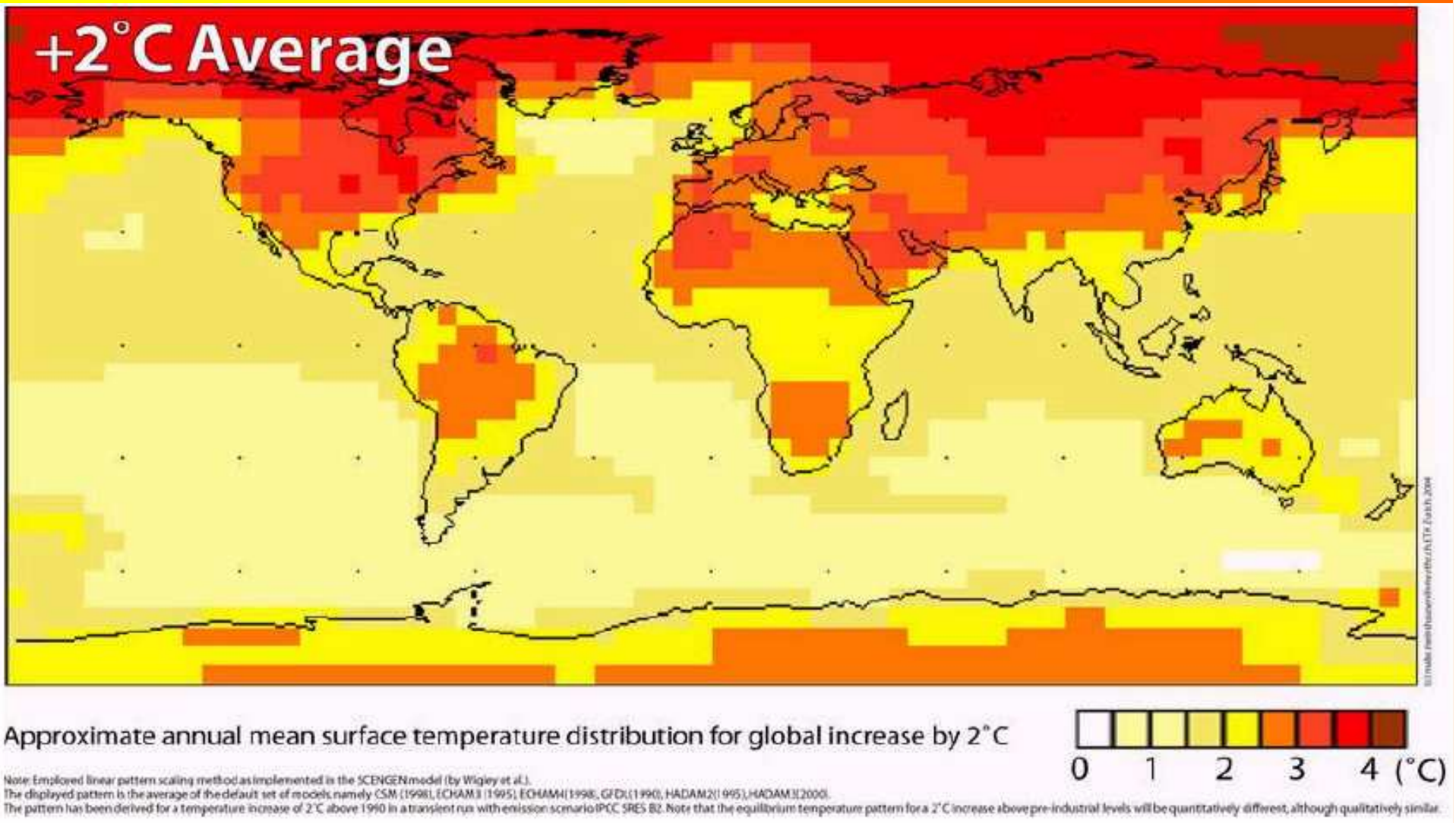
Extremely cold winters in Europe; and elsewhere ???

Extended drought in the mid-latitudes ???

Global Climate Change

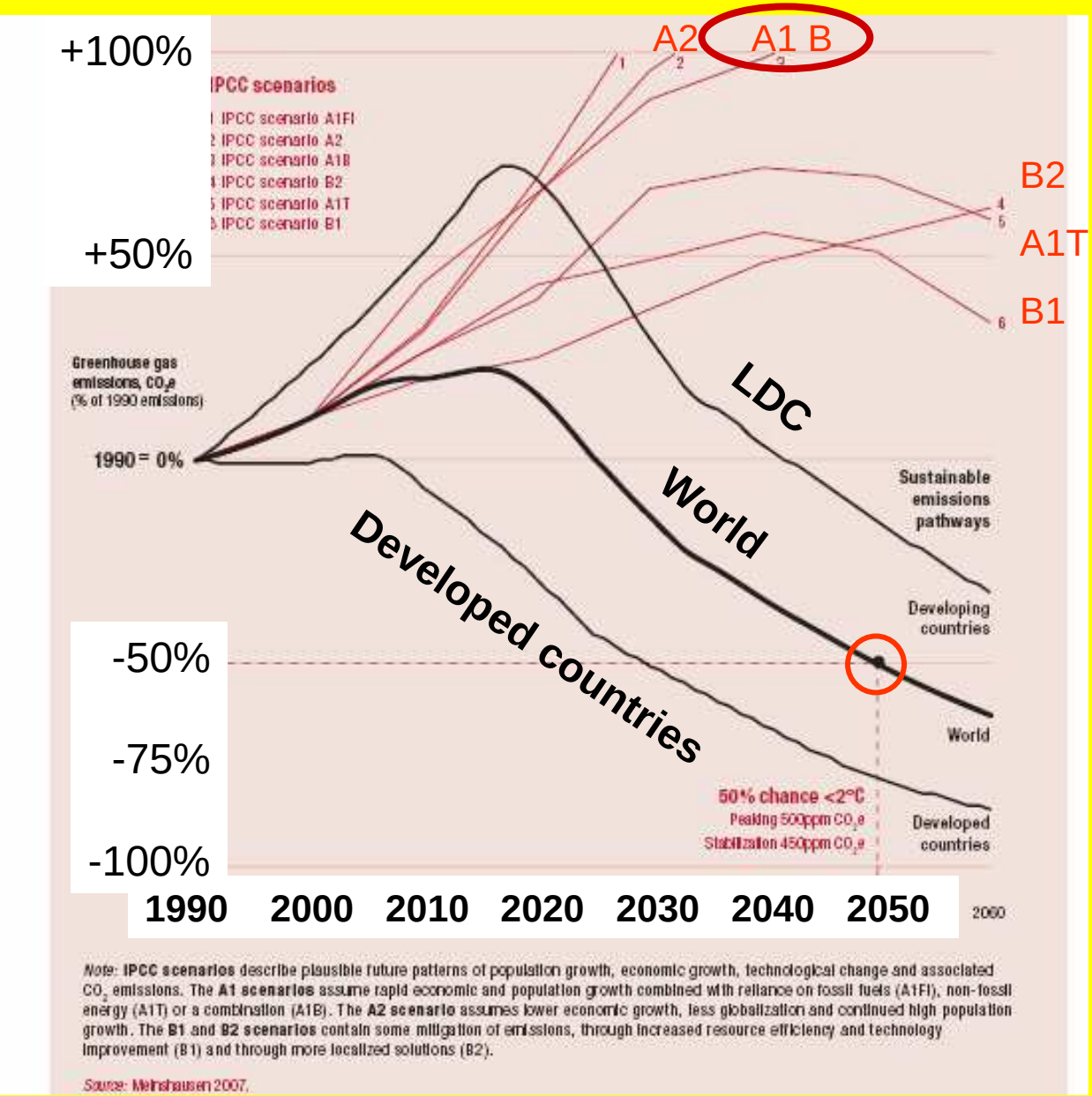
To slow the pace of climate change,
we *must move rapidly*
to modes of production
(a way of life ?)
compatible with a finite planet.

Global warming 2℃
Limit of the « danger zone » ?

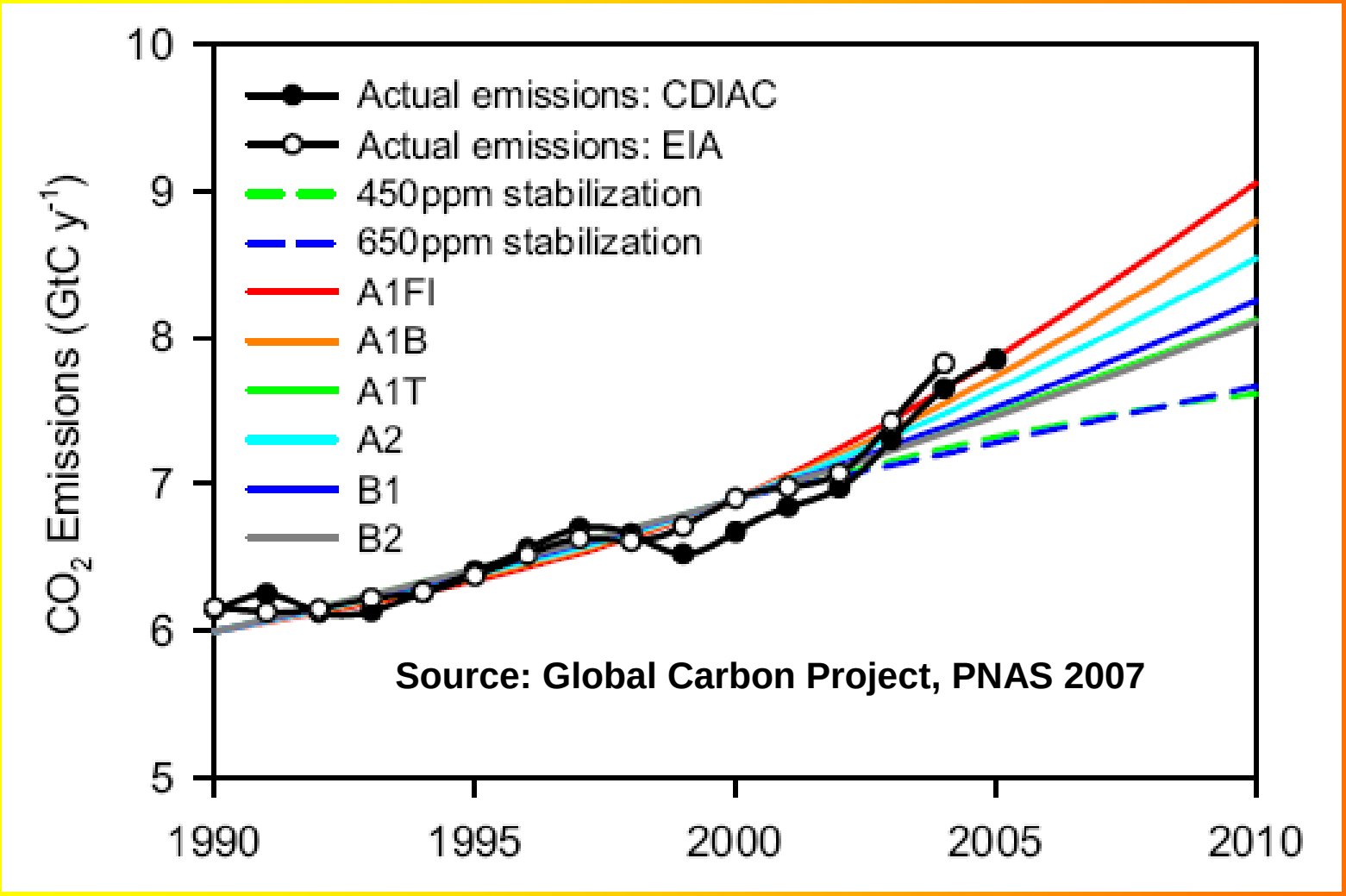


Emission Scenarios for 2000-2050

and what is needed to avoid the danger zone

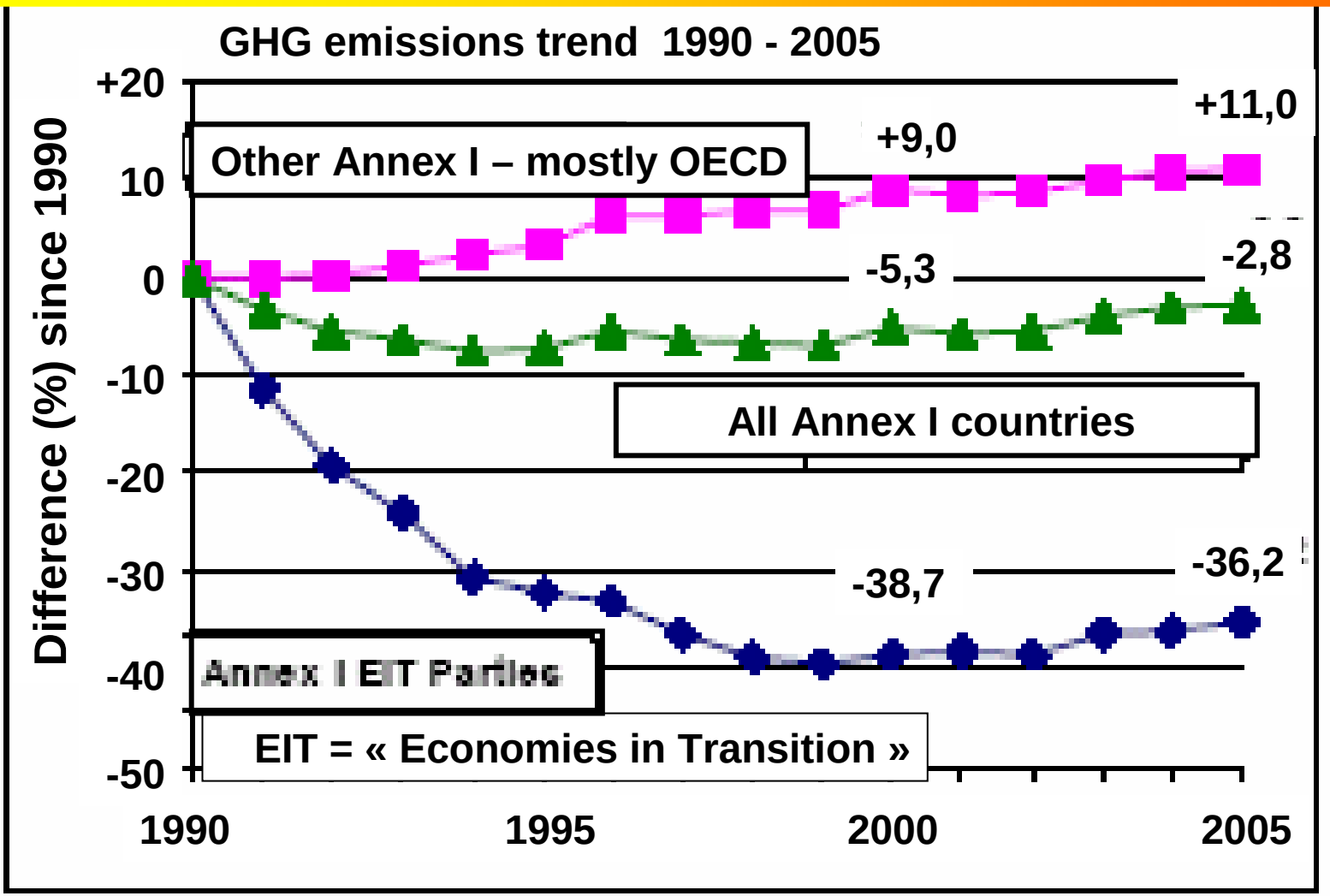


Reality (2007): Accelerated growth of CO_2 emissions

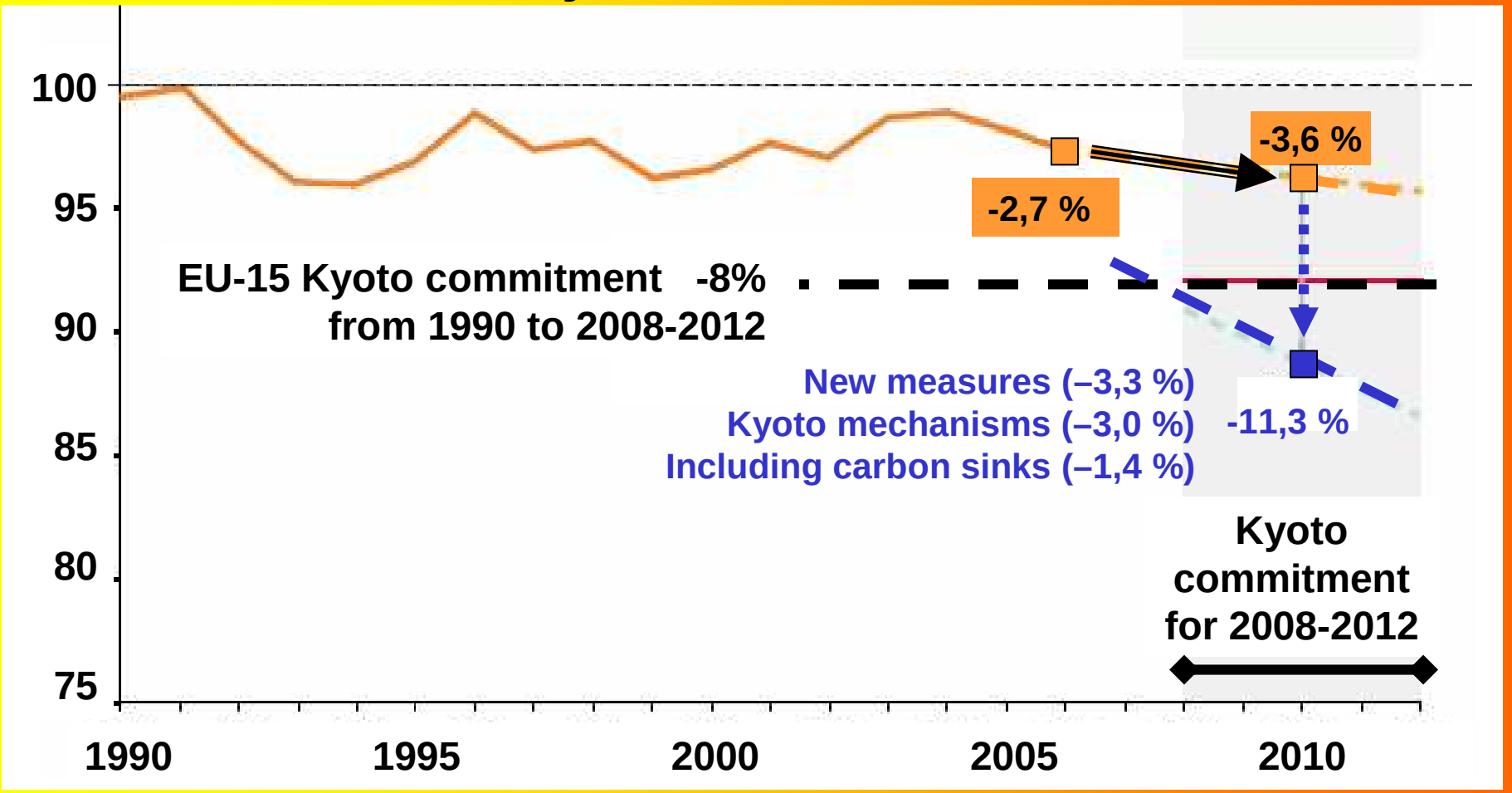


The Kyoto Protocol – a small first step

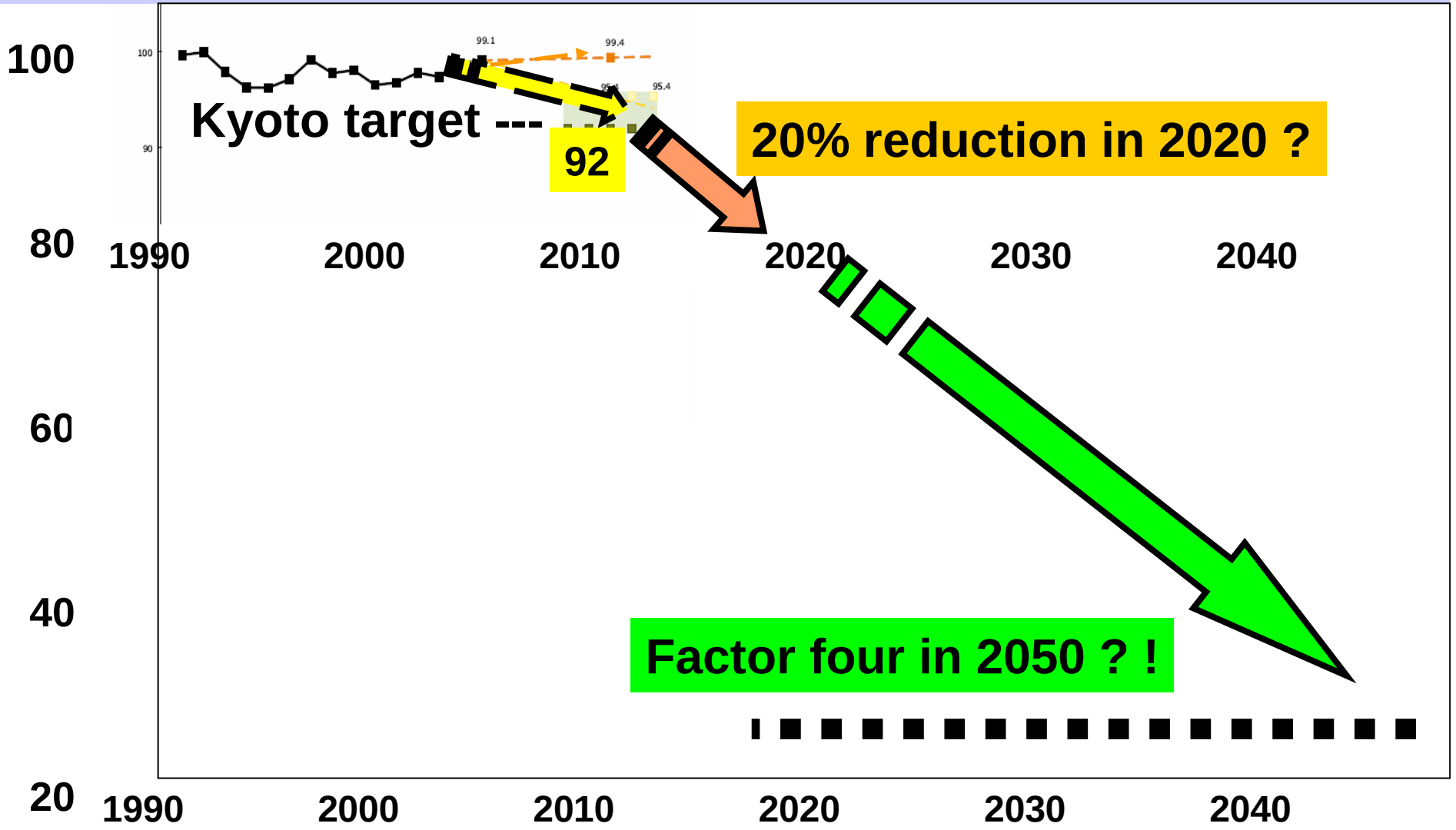
Inadequate commitments, not being met



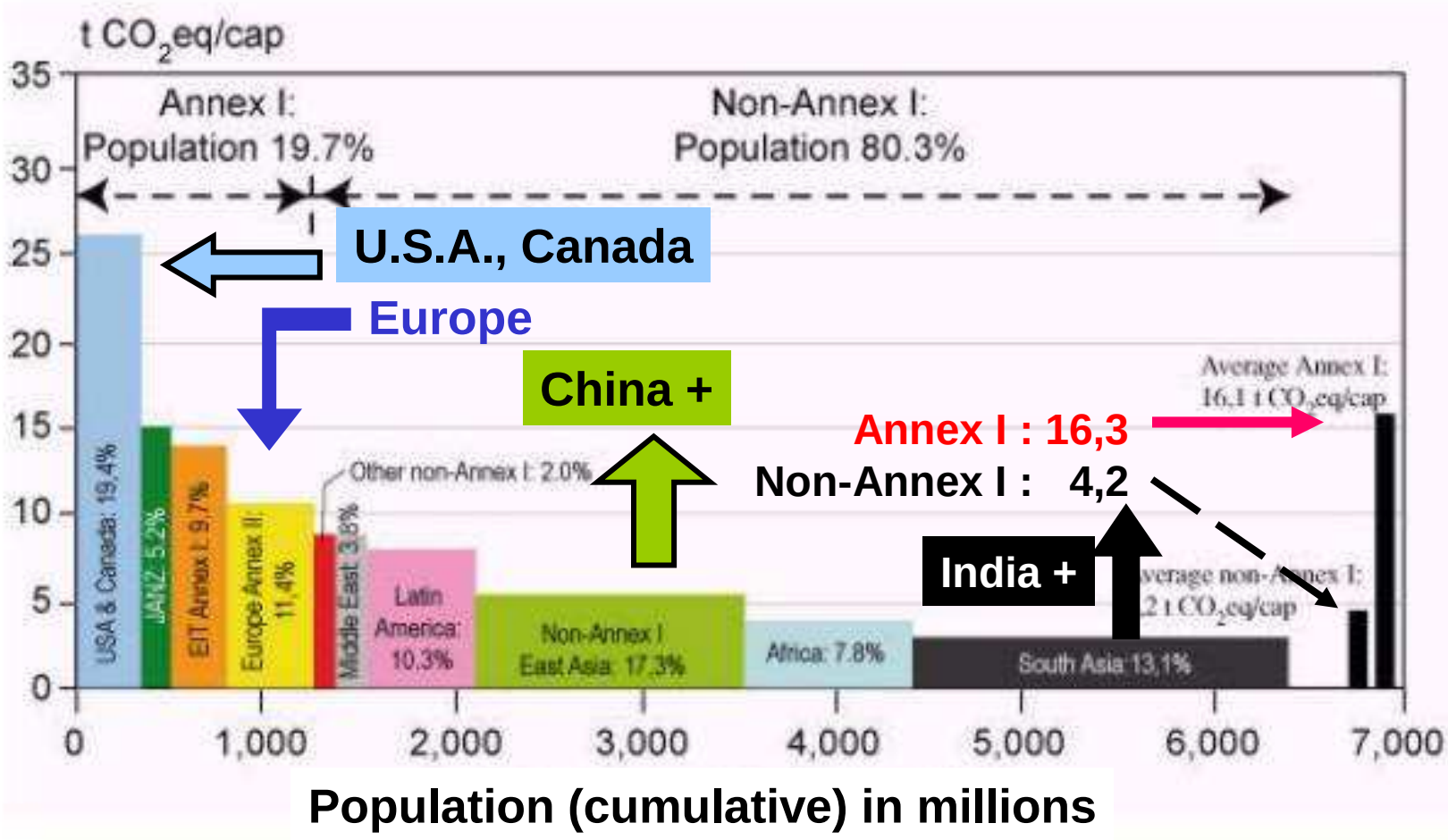
EU-15 : Kyoto commitment
Actual emissions vs. Projections for 2010



EU Targets for 2020 et 2050



GHG Emissions in 2004 (tons CO_2 equivalent per capita)



Gloom and doom ?

No ! ?

Growth (or its opposite) will depend more and more on innovation and finding solutions to the problems of :

1) **The imminent (?) end of cheap oil ;**
   but there still is (*too* much) coal.
2) **The absolute necessity of reducing greenhouse gas emissions.**
3) **The constraint of adaptation to *unavoidable climate change*.**

The crucial questions

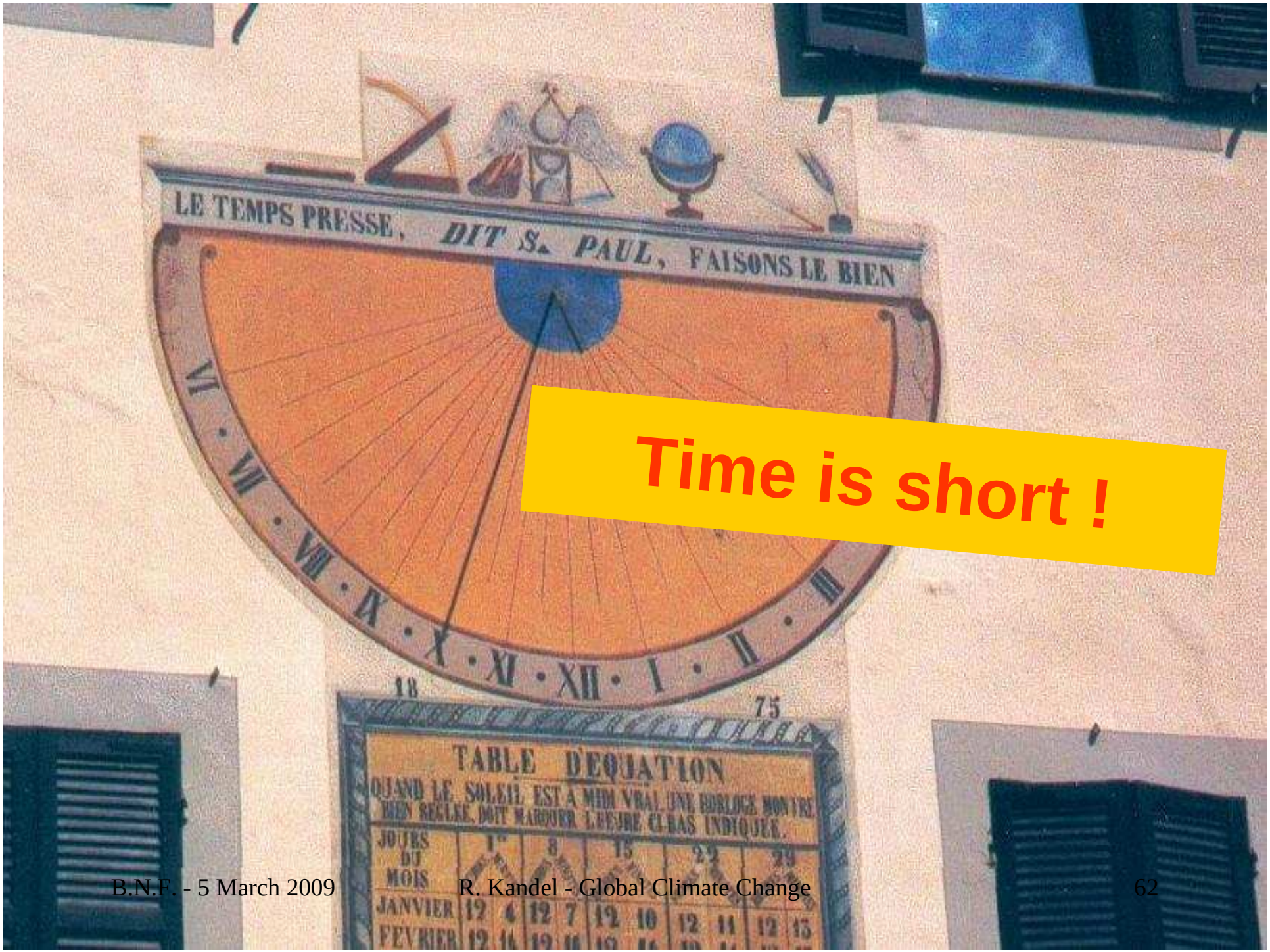
When, and at what level, will CO_2 concentrations be stabilized ?

Can global net GHG emissions be reduced by a factor 2 by 2050 ?

Can the technologically advanced countries reduce their GHG emissions by a factor 4 by 2050 ?

Can carbon intensity be reduced by a factor 10 (to 0.1 kg CO_2 per dollar wealth production) in this century ?


A planet worth some CARE
Prenons soin de notre planète



Time is short !

Thank you for your attention